Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2016
September 18-23, 2016, Kobe, Japan

ID5012

Dry Storage Ageing Project for Dual Purpose Casks in Switzerland

Frank Koch
Swiss Federal Nuclear Safety Inspectorate ENSI
Brugg, Switzerland

Abstract

For several years, many activities have been launched concerning ageing issues of dry storage casks for spent fuel as, for example, the joint working group of the transport and waste safety committees of the IAEA, TRANSSC and WASSC. As a result, TRANSSC intends to introduce ageing requirements in the upcoming revision of the transport regulations.

At the national level, several ENSI guidelines include ageing requirements based on different regulatory concepts. Specific ageing issues are already identified by the utilities and carried on to research projects. The announced prolongation of the final repository project in Switzerland gives an additional reason to deal with long time storage periods and ageing issues of dry storage casks.

As a result of these activities ENSI has identified the need for a comprehensive reassessment of the dry storage ageing issue resulting in a regulatory research project. The purpose of the project is to introduce a holistic approach covering all relevant technical ageing aspects and to identify necessary enhancements of Swiss regulatory framework and the need for additional research work.

The paper provides information concerning the initiation and the background of the project. This is followed by a brief description of the conduct of the work and the subjects addressed in particular within the project. More attention is spent on the results of the project: Further actions are identified in the fields of package components, spent fuel properties and final disposal procedures. The general aspects additionally identified in the project will be also discussed. The paper concludes with the summary of results, a description of the overall ageing management concept proposed by the project team for implementation and the path forward concerning ageing issues in Switzerland.

Introduction

For several years, many activities have been launched concerning ageing issues of dry storage casks for spent fuel. As a representative activity on the international level, Switzerland contributed to the joint working group of the transport and waste safety committees of the IAEA, TRANSSC and WASSC. The group has issued the TECDOC [1] and has provided recommendations for the attention of TRANSSC and WASSC to enhance IAEA standards and guides. In response, TRANSSC intends to introduce ageing requirements in the upcoming revision of the transport regulations SSR-6 [2].

At the national level, several ENSI guidelines include ageing requirements based on different regulatory concepts such as periodical safety review of nuclear power plants [3], licensing requirements for dual purpose casks (DPC) [4] or design and operation requirements with respect to spent fuel elements [5]. Specific ageing issues are already identified by the utilities and carried on to research projects.

As a result of the above mentioned activities ENSI has identified the need for a comprehensive reassessment of the dry storage ageing issue resulting in a regulatory research project. The purpose of the project is to introduce a rather holistic approach covering all relevant technical ageing aspects and to identify necessary enhancements of Swiss regulatory framework and the need for additional research work. The project involves all relevant technical competences such as in particular, mechanical, thermal, nuclear safety and material expertise as well as requirements developed within the final disposal project. For some specific aspects, ENSI has contracted independent external expertise.

Background

Spent fuel generated by nuclear power reactors needs to be cooled in the reactor pool at first directly after use. Reactor pools have capacities assuming reprocessing or disposal of spent fuel after a certain period of time. So, additional storage options have to be considered as extended wet storage capacities or dry storage in casks designed for storage and transport (DPC). All Swiss NPP have opted for the DPC as the final predisposal solution including those with extended wet storage capacities.

Because DPCs are designed for storage and transport, the Swiss nuclear regulations require package design approvals for transport as well as the acceptance of the DPC type for the dedicated storage facility. With respect to the package design approval according to the transport regulations [2], the repeated use as a transport package has to be assessed in a way, that several transport operations as loading, unloading and handling using different transport modes are considered. Due to limited transport approval periods, usually five years as a maximum, new design features can be easily introduced to improve safety, operation or fabrication. Old design features are often excluded in revised package design approvals to ensure fabrication with updated design features for new DPC. On the other hand, the use of a DPC is usually limited to one transport from the NPP to the storage facility and a second transport to the final repository after a long storage period.

Considering the acceptance for the use of the DPC in a dedicated storage facility, the safety demonstrations are usually based on a design lifetime of 40 years of storage for the DPC. In the case of Switzerland, the transport package design approval is a basic requirement at the time of storage acceptance [4]. The acceptance for storage is unlimited assuming a periodic safety assessment any ten years according to [3]. Recently, the process to find the final repository in Switzerland was facing slight delays: The start of operation has been prolonged for several years [6]. This put the spot on the questions how long spent fuel can be stored in dry conditions in DPCs and how safety margins for

storage periods more than 40 years can be quantified. Those questions have to address package components as well as the properties of the loaded spent fuel.

Set up of the project

The project is part of the regulatory research program of ENSI as the competent authority for issuing transport package design approvals and acceptances of DPC for storage facilities. Only experts within ENSI and experts contracted directly by ENSI are involved in the project. They represent the fields of package components (package and transport group), spent fuel (reactor core group) and final repository (geological deep repository group). In addition to the technical and operational aspects, regulatory and organisational issues addressed. The project had the objective to analyse the status of dry storage in DPCs in Switzerland also considering international activities and to identify necessary regulatory actions. The overall approach was the consideration of the full life cycle of DPC and, in particular spent fuel. This includes the following steps:

- reactor operation,
- cooling in the spent fuel pool,
- loading of spent fuel in the DPC,
- closing and drying of the cavity,
- transport of DPC to the interim storage facility,
- dry storage of more than 40 years,
- transport to the waste conditioning facility next to the final repository,
- retrieving the spent fuel and deploying it into containers designed for the final disposal,
- transfer and final disposal in the deep geological repository.

Alternatives to this general sequence referring to specialities of Swiss NPP have been also considered.

At first, each group of experts analysed the status in their own field of expertise. After this first step, several internal and external discussions have been launched to address interfaces of the different fields and to include national and international activities. The interface discussions have been mainly focused on the following aspects:

- boundary conditions for mechanical accident analyses,
- spent fuel transports,
- capability of thermal analyses,
- preparation for transport, in particular drying procedures,
- criticality analysis considering potential spent fuel release in the cavity,
- cladding criteria with respect to the spent fuel life time and irradiation history,
- handling of spent fuel in hot cells and
- spent fuel in the final repository including handling aspects.

The analyses of the expert fields and the interface discussions resulted in the clarification of assessment

interfaces and proposals for regulatory activities to follow the ageing issues [7]. These activities include technical, organisational and administrative aspects. Finally, the project has provided a plan for the prioritisation and the implementation of the identified activities.

Results

Package components

Concerning package components, all package designs used in Switzerland have been considered. The identified components have been compared with the results of international studies to identify the need for further activities focused on Swiss relevant package design features [8]. The following components were identified for further actions:

- metallic seals due to long term temperature effects,
- elastomeric seals due to difficult traceability of material properties,
- aluminum alloys due to weakening and copper due to creeping under long term temperature influence,
- special stainless steel alloys due to embrittlement forced by cooling and
- lid bolts due to loss of pre-load because of relaxation effects.

Spent fuel

Switzerland is faced with a wide variety of spent fuel assembly designs with respect to cladding material and fuel composition. Other aspects are the operational parameters as burn-up and cooling time, which vary also widely. Hence, mixed loadings are more and more preferred by the operators to exhaust the capability of DPC designs regarding shielding, thermal and nuclear safety.

Due to the mentioned design variety and the necessity to know more accurately the operational parameters, a detailed analysis of the spent fuel in each Swiss NPP was carried out resulting in a spent fuel database. This will be the basis for further activities and assessments focusing on phenomena as

- hydride reorientation,
- hydride layers and hydrogenated liners,
- radial hydrides after reactor operation,
- ductile/brittle transition
- delayed hydride cracking for high burn-up fuel

In addition, the project team has identified the need for potential complementary justifications such as

- evaluation of acceptable hoop stress,
- identification of temperature limits for the full life cycle of spent fuel,
- investigation of the overall influence of the drying process,
- accuracy of temperatures identified by thermal analysis,
- identification of structural loads introduced in spent fuel assemblies during accident scenarios,
- verification of cladding properties used in mechanical analysis.

Final disposal

In the most likely scenario, the transport of DPCs directly after the storage period without opening to the final repository, the operator of the surface facility of the deep geological repository will be the first to identify the final state of the spent fuel. He has to anticipate every fuel state, even the possibility of defect or damaged spent fuel rods due to preceding transport, storage or handling operations. Consequently, the responsible institution for the final repository in Switzerland, NAGRA, plans to install operational equipment for every potential state of spent fuel assemblies in received DPCs [9]. Clearly, the effort for conditioning operations will be significantly different depending on the fuel integrity or the state of fuel at all. Hence, the project team has identified questions related to this issue as

- ensuring cladding integrity,
- check of cladding integrity before opening the DPC,
- retrieval and handling of defect or damaged fuel and
- package design approvals (transport and storage) for damaged fuel.

General aspects

During various discussions within the project, also general aspects have been provided by the team and by external experts [10]: licensing management, quality assurance, ageing management, organizational measures, staff education, documentation.

As a result, ENSI has already started to issue own transport package design approvals for DPC according to [2] to get full access to ageing justifications. With respect to DPC acceptances for storage facilities, ENSI will add a mandatory requirement to these acceptances to introduce a 10-year periodical review for DPC aiming on maintaining transportability and storability including requirements for the final disposal [11].

In addition, quality assurance measures might be improved to consider ageing phenomena of DPCs [12]. This might include advanced material testing as well as complementary fabrication controls.

Ageing management will be the superior concept to organize ageing justifications for DPC and to ensure the safety of all future operations. Ageing management includes technical evolution, update of regulations and administrative requirements and, of course, assessment and control of ageing phenomena. An adequate inspection regime during the storage period and other measures such as the organization of documentation are integral parts of the ageing management system.

During the lifetime of the DPC, an institution or an organization has to be responsible for providing the necessary technical and financial resources including the availability of qualified personnel for all relevant operations. This has to be ensured even after the shutdown and decommissioning of the NPP. Related to this issue is the clarification of ownership of DPC. In Switzerland, this is implemented by the nuclear energy act in the way that every change of ownership has to be approved by the state.

If ageing management includes technical evolution, update of regulations and administrative requirements and ageing phenomena, educated staff must be available all the time during DPC lifetime. Considering the length of interim storage knowledge management should be introduced.

Within the project, the team has identified several parts of documentation stored at different places and assigned to different responsible institutions: the DPC fabrication documentation, the safety justifications and the assessment results and the spent fuel data loaded in the DPC. It might be useful for a comprehensive ageing management to centralize the documentation for a dedicated DPC at the place, where the DPC is stored: the interim storage facility.

Conclusions

The results mentioned above provide 30 regulatory actions. Some of the actions are dedicated to the regulator only, others require a statement of the operator or will be directly addressed to the operator as a requirement. The follow up of these actions will be included in the introduction of the comprehensive ageing management for DPC. This ageing management will be organized in three domains: technical, organizational and administrative issues (Figure 1).

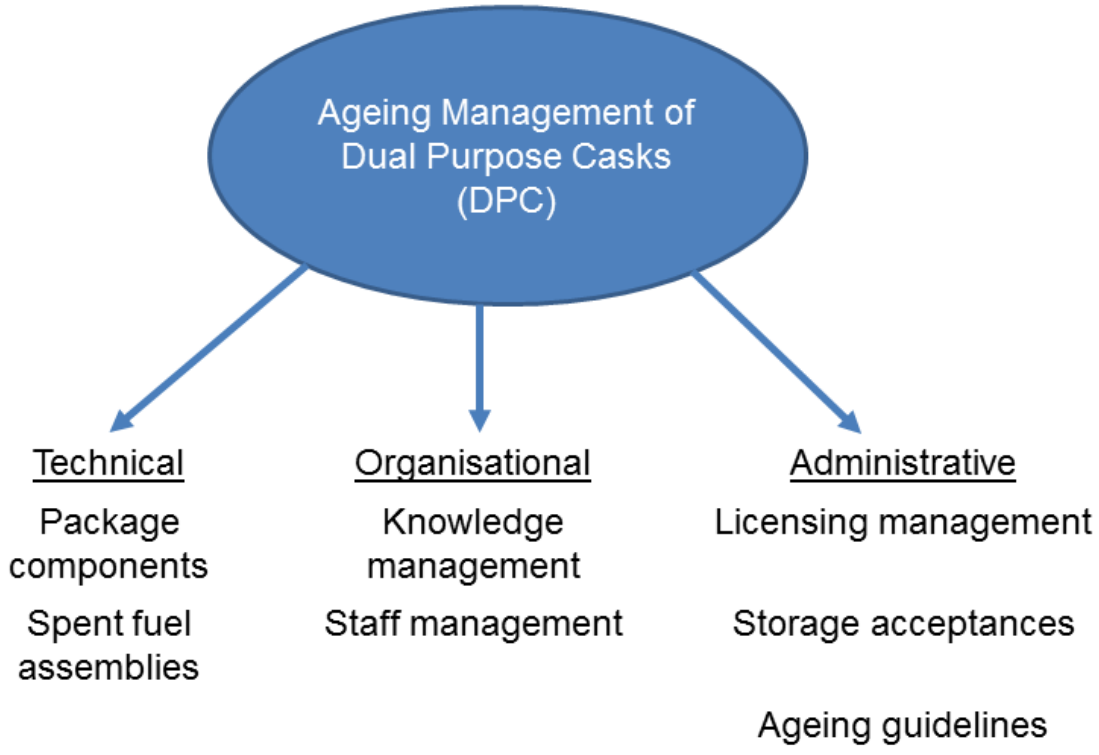

Figure 1: Ageing management domains

Currently, the regulatory framework is the periodical safety review for Swiss nuclear power plants [3]. Transportability and storability of DPC are addressed in this review. Due to the fact, that several NPPs use the same type of DPC, the safety review for these package types would be repeated within a few

years without a significant benefit. So, a review based on the DPC types would be more reasonable. Hence, the project team proposes the change from the NPP based to the DPC type based review system.

Revision of transport regulations [2] will probably require the consideration of ageing phenomena for the package design. There are already safety reports available and approved addressing this issue. To ensure a comprehensive ageing assessment and ageing management of DPC, ENSI will issue own package design approvals instead of pure validations of country of origin certificates for DPC.

With respect to the acceptance of DPC for storage, ENSI will issue similar certificates for this purpose including the requirement for the periodical safety review of the dedicated DPC type. This will implement the DPC type based review system. As a next step, the licensing periods and the content of the transport and storage certificate should be harmonized and, if necessary, also separated from each other in particular aspects. To combine the certificates into one is currently not planned because they address different fields of law: dangerous goods regulations and nuclear energy regulations. Based on this periodical safety review concept, all the measures and actions identified within the project will be addressed to the operators.

Ageing requirements should be clarified by ENSI guidelines addressing the design requirements of DPC for storage in Switzerland [4]. The project team proposes to implement ageing requirements at first in a rather general manner in guidelines, because the whole subject is quite new and there could be a need for updates in short time. In parallel, there may be developed a rather detailed supplementary guide to support applicants in providing ageing justifications and which could be changed more easily if needed. The supplementary guide will detail how to provide the justifications and will not discuss the necessity of the justifications at all. Positive experiences with supplementary guides already exist with the guideline for the manufacture and use of packaging of radioactive material [13].

Acknowledgments

I would like to thank all the supporters of the project and in particular, the members of the project team and the contracted external experts for their valuable contributions throughout the project.

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