Sealing Systems in German Spent Fuel Storage Facilities

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Abstract:

This paper describes the current issues related to sealing devices in the German on-site spent fuel dry storage facilities (SFSFs) related to the Germany's energy transition. Accordingly, there is a need of future investigations for improving techniques in order to achieve better radiation protection and occupational safety during safeguards verification of spent fuel casks stored in SFSFs.

In the context of phasing out nuclear energy production, the eight still operating reactors will be successively disconnected from the power grid by the end of 2022 at the latest. The nuclear material of all power reactors has to be removed prior to decommissioning of the reactor building. The defueling of reactors increases the handling operations at these sites especially by the temporary higher number of cask loadings. Accordingly, the number of transfers of these loaded casks (dual purpose: transport and storage casks) from the reactor to the SFSF will further increase as well. By end of 2027, it is foreseen that all spent fuel assemblies will have been loaded into casks. After their transfer to SFSFs, the SFSFs will have a static inventory of more than 1,000 casks, because no receipts or shipments are expected following the final reactor shut down. The spent fuel packed in casks will be stored in interim dry storages for several decades until a repository for heat generating high level waste is available. The casks may be difficult to be accessed; especially the seals attached at the protection plate on top of the approx. 6 meter high casks. A seal verification that involves the replacement of the seal will require more time and will lead to a higher radiation dose for both inspector and storage staff than easier in-situ verification or seal verification by Remote Data Transmission (RDT). Given this situation optimization of safeguards concepts and sealing systems devices applied is needed. Solutions are required to ease the verification of the casks and to minimize the exposure of the inspectors and storage staff.

Keywords: spent fuel management, spent fuel storage facilities, sealing systems

1. Introduction

Following the nuclear accident at Fukushima in March 2011, the German Government decided to immediately shut down eight of the 17 operating nuclear power plants (NPPs) and to completely phase out the use of nuclear energy for electricity production. The decisions have a significant impact on spent fuel management in Germany. After shut-down of another reactor in 2015, the eight remaining NPPs will be successively taken from the power grid by the end of 2022 at the latest. On 23 July 2013, The German Federal government entered an Act into force on the site selection process for a deep geological repository for high level radioactive waste, including spent fuel assemblies and vitrified waste [1]. This act does not specify a specific host rock type but it determines a selection of a final repository site until 2031. The repository site selection procedure should be transparent and science-based. Potentially suitable areas should be narrowed down, step by step, on the basis of scientific criteria for the best possible safety for a period of one million years. Furthermore, the selection procedure includes public participation. A commission was set up to prepare the site selection procedure and in July 2016, the commission submitted a final report including their recommendations for the German Federal Parliament (*Bundestag*). [2] The recommendations of the commissions were included in the Act on the further development of the site selection act, which entered into force on 16 May 2017 [3].

The site selection will be followed by the licensing procedure for the construction, operation and decommissioning of the repository. The decision of phasing out the production of nuclear energy provides some safeguards challenges in Germany. The defueling of reactors has a major impact on the time schedules and frequency of spent fuel handling operations in reactors, storage facilities and their associated safeguards activities. Due to the defueling of the reactors the amount of cask transfers dramatically increases. Therefore the need for long-term reliable unattended Safeguards (SG) measures must be put in place to preserve the Continuity of Knowledge (CoK).

This paper describes the current issues related to sealing devices in the German on-site dry spent fuel storage facilities. The Research Centre Jülich set up a project on this issue. The next step in this project is to investigate options for improving techniques in order to minimize the radiation exposure of the inspectors and storage staff as well as occupational safety for verification of spent fuel casks stored in SFSFs.

2. Spent Fuel Storage Facilities in Germany

Due to the defueling of reactors, the number of transfers of loaded casks (dual purpose: transport and storage casks) from the reactor to the SFSF are increasing. Accordingly the spent fuel cask inspections for safeguards are also rising.

By the end of 2027, all spent fuel assemblies are foreseen to be loaded into dual purpose casks. Once the transfer of all loaded casks to the SFSFs is complete, the SFSFs will have a static inventory of more than 1,000 casks because no receipts or shipments are expected following the final reactor shut down. Germany's former plan to store spent fuel in central dry storage facilities at Ahaus and Gorleben had to be abandoned due to the prohibition of spent fuel transports on public traffic routes. In this context, 12 new decentralized on-site interim dry storage facilities were constructed and licensed for the storage of spent fuel assemblies. The assemblies are loaded in dual purpose casks for transport and storage – CASTOR® V-casks.

Figure 1: Design of CASTOR Type V19 and V/52 (Copyright: GNS)

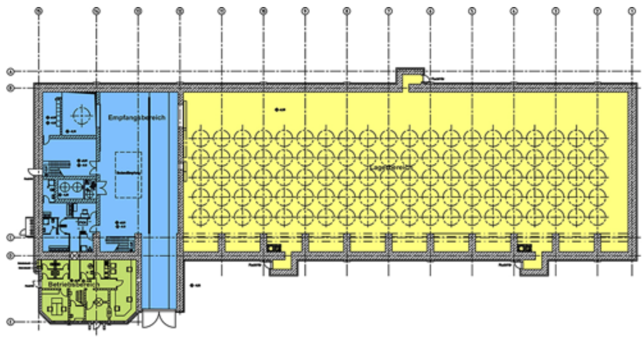
The licensed storage period of all German SFSFs is limited to 40 years beginning with the emplacement of the first spent fuel containing cask in the storage building. The licensed mass of heavy metal (HM) in the on-site dry SFSF varies between 450 Mg and 2,250 Mg and amounts to 3960 Mg (Ahaus) and 3800 Mg (Gorleben). The storage capacities of the on-site dry SFSFs range between 80 and 192 CASTOR® V-casks [7].

The construction of the 12 on-site dry SFSFs is based on three different concepts (acronyms will be detailed later): the STEAG, the WTI and the tunnel concept. They were constructed as storage halls from steel concrete (at the Neckarwestheim site in the form of storage tunnels). The STEAG concept has been applied at six North German sites at Brokdorf, Krümmel, Brunsbüttel, Grohnde, Lingen and Unterweser. The WTI concept has been applied at the five sites at Biblis, Philippsburg, Grafenrheinfeld, Isar and Gundremmingen located in the southern part of Germany. The tunnel concept at Neckarwestheim was developed as a special solution due to site-specific conditions [4].

In addition to the two central SFSFs and the twelve on-site dry storage facilities, two local interim dry storage facilities at Greifswald (ZLN) and Jülich are operated in Germany [4].

STEAG Design:

The design characteristics of the STEAG concept (designed by the company STEAG encotec GmbH) include a one-nave building with thick concrete structures (Figure 1). The wall thickness is about 1.2 m and the roof thickness is about 1.3 m. The distance between each cask is approximately 55 cm [4].



steag

Figure 2: SFSF built as STEAG Concept [4]

WTI Design:

The WTI concept (designed by the company of consulting engineers Wissenschaftlich-Technische Ingenieurberatung GmbH) is a two-nave building with two separate storage halls; the wall thickness is around 0.85 m, respectively, and the roof thickness about 55 cm (Figure 2). The distance between each cask is approximately 50 cm [4].

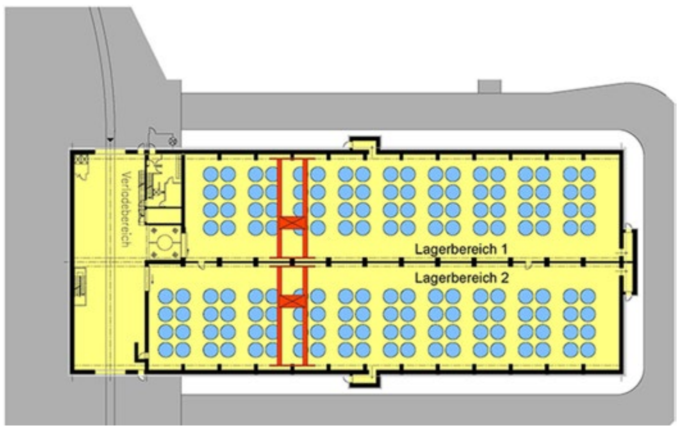


Figure 3: SFSF built as WTI Concept [4]

Tunnel Design:

The tunnel storage was designed to the specific on site geological conditions. The facility consists of an entrance building, which is arranged aboveground, two tunnel tubes running parallel in east-western direction, which are connected at their ends by a tunnel, and an exhaust air system and an escape construction (Figure 3). The distance between each cask is approximately 44 cm [4].

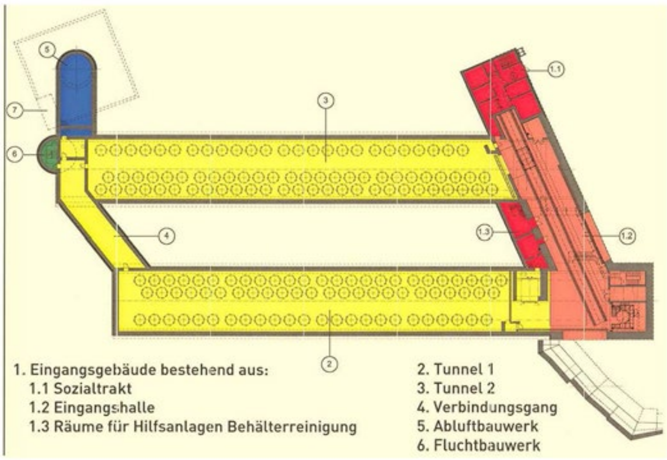


Figure 4: SFSF built as tunnel concept [4]

The dense packing of casks can be seen on the three layouts of the SFSFs. Due to this arrangement; casks cannot be moved between other casks. Movements of CASTOR® casks over other casks of this type with a height of approx. 6 m is technically not possible due to the maximum lifting height of the crane, which is 9 m from the ground. If a cask has to be transferred into the maintenance room (located inside the entrance area), all casks in the rows in front of this cask have to be transferred individually to a buffer area first in order to allow the movement of the selected cask.

3. Safeguards Implementation in German Spent Fuel Storage Facilities

The IAEA has drawn the 'broader conclusion' for Germany in March 2009 for the first time. The implementation of integrated safeguards started with in 2010. This was also the starting point for implementing integrated safeguards in the German SFSFs. Since the IAEA concluded on the absence of undeclared nuclear material and activities in Germany, the safeguards objectives changed. The requirements to timeliness for spent fuel verification and detection probability were lowered; the quarterly routine inspections were replaced by randomly performed inspections with a short notice of 24 h and a probability of occurrence of 20 percent in a given facility. The inspection-interval for physical inventory verification (PIV) continues to take place annually.

3.1 C/S of long term static dry storage casks

Regarding the long-term storage of spent fuel in SFSFs, any safeguards inspection plan for the dry interim storage should be ruled by two main aspects. First, CoK of the nuclear material flow by Containment & Surveillance (C/S) measures from the reactor to the storage facility and during the storage period should be maintained. Second, verifying the nuclear inventory of the casks by counting and identification should involve an evaluation of the C/S system and, as a back-up, non-destructive-analysis (NDA) measures on the CASTOR®-casks as appropriate in the hypothetical worst case, where all safeguards measures, seals and surveillance fail [5, 8]. In order to avoid this worst case, different sealing systems are applied for cask sealing in combination with camera surveillance.

For states under integrated safeguards, such as Germany, the IAEA requires maintaining CoK during transport of CASTOR® V-casks to their storage position and during their long term storage. Due to the inaccessibility of the nuclear material during interim dry storage, casks loaded with spent fuel should be under dual containment and surveillance (C/S). In order to meet this requirement, two independent sealing systems using different physical principles are applied by IAEA and EURATOM during long-term storage, mostly supplemented by surveillance. Three different types of sealing systems (see Table 1) are currently used at German SFSFs.

Code	Equipment name	Description/ Application
CAPS	Cap seal (metallic)	Passive seal, cable not monitored. After removal the verification of seals is only possible at IAEA or EURATOM Headquarters.
COBRA	Fibre optic general purpose seal	Passive seal, Multi Fibre optic seal; reflective particles incorporated in the seal body provide unique identifier; in situ verifiable
EOSS	Electronic Optical Sealing System	Active seal. Reusable seal consisting of a fibre optic loop and electronical seal. Light pulses monitor the loop, and every opening and closing of the seal is stored in the seal. A dedicated reader is used to verify the seal.

Table 1: Sealing Systems used in German SFSF [6]

3.2 C/S without inspector following loading of Castor casks

The loading and transfer of CASTOR® V-casks is not always as straight forward as desirable due to the drying process necessary before closing the cask and the seal can be applied. The residual moisture in the cask has to meet special criteria and the time needed to reach these criteria is difficult to predict. Practical experience shows a range from 10 to 200 hours. To avoid inspectors having to remain on-site or on-call while the cask is drying, the IAEA and EURATOM proposed an approach to delegate the task of applying the seals to the operator when the inspectors are not present. After the spent fuel has been loaded into the cask the operator seals the cask by using the COBRA seal, the electronic seal EOSS and the EOSS seal interface. The equipment needed for the sealing procedure is shown in figure 6.

Figure 5: Equipment needed by the operator for applying the COBRA and the EOSS seal [9]

Figure 6 shows the bolts, where the sealing wires are threaded. Two bolts each are used for the COBRA and the EOSS fiber-optic cables.

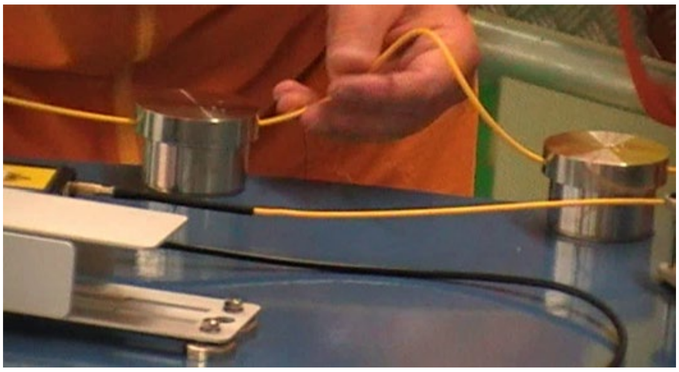


Figure 6: Threading the EOSS fiber-optic cable. Two additional bolts are used for COBRA sealing [9]

This procedure is recorded by installed safeguards video surveillance. The EOSS seal interface guides the operator through the sealing procedure and confirms its successful termination as a storable message. [7]. Casks that were sealed by the operator in the reactor and transported to the storage facility are there verified after finishing the loading campaign by the two inspectorates of EURATOM and IAEA; at the same time the EOSS seals are replaced by metal seals and/or COBRA seals. Some SFSFs use COBRA seals as group seals. In one SFSF individual CASTOR®-casks are sealed by COBRA seals and additionally groups of those casks are connected by a single EOSS seal as a group seal.

4. Discussion and Outlook

The verification of sealing systems currently used at German SFSFs is a very arduous and time consuming task due to the spatially limited storage configuration.

The obligation to replace a metal seal and a COBRA seal in regular intervals is difficult to fulfill in view of the small distance between casks, which excludes the possibility to transfer a cask between other casks into the maintenance room and requires the application of special climbing aids instead of elevating work platforms enabling a seal exchange at a height of approx. 6 m. Seal verification or seal renewing that involve the replacement of the seal on the top of the casks lead to a higher radiation dose for both inspector and storage staff than the easier in-situ verification or seal verification by RDT. Work safety rules do not allow unsecured movements between casks and thus enforce time consuming positioning of persons for each cask separately. Near the casks the radiation level is higher than elsewhere. The principle guideline for radiation protection „As Low As Reasonably Achievable“ (ALARA principle) calls for a reduction in the duration of stay in this environment as far as possible. Efforts should be made to minimize the dose rate for inspectorate and staff in this area for example by using RDT systems. According to the document of IAEA and EURATOM “Partnership Approach under Integrated Safeguards for Spent Fuel Storage Facilities” remote monitoring in SFSFs should be used to the extent possible in order to increase the effectiveness and efficiency of Safeguards implementation.

Given this situation, there is an urgent need to optimize the safeguards concept and to tailor the sealing devices to the specific conditions of an interim SFSF in a static operation. Solutions are required to ease the verification of the casks and to minimize the exposure of the inspectors and storage staff. This is the main goal of our current investigations. It requires reviewing suitable current and future sealing systems as well as complementary available technologies, such as laser based systems or neutron monitors, and evaluate pros and cons of their application to safeguarding spent fuel storage casks in the German SFSFs. This will be carried out in the next steps of this project.

5. Acknowledgements

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