Twenty Years of Dry Interim Storage of Spent Nuclear Fuel (SNF) in Germany History and Developments – 15575

Christoph Gastl and Julia Palmes
Federal Office of Radiation Protection

ABSTRACT

According to article 6 of the German Atomic Energy Act, storage of nuclear fuel requires a license granted by the competent authority in this field, which is the Federal Office of Radiation Protection.

In 1983 a license to store spent nuclear fuel (SNF) and later expanded for vitrified high level waste (HAW) for the interim storage facility in Gorleben was granted. Dry Interim storage at the NPP sites in its actual form started in 2002 in the interim storage facility next to the NPP Lingen. Since this time each NPP erected its own storage facility and three central storage facilities have been built. All of these facilities use dry storage in metallic casks. The actual storage licenses for SNF and the HAW (which is stored in Gorleben and Rubenow) are limited to 40 years starting with the first cask emplacement. As no opening of the cask is intended during the storage period the condition of the inventory and the cask before loading has to be known in detail. This requires for instance detailed knowledge of the history of the SNF loaded as well as supervision of the manufacturing process of the cask.

Within the last twenty years several mishaps influenced the regulatory point of view. During a loading campaign in a boiling water reactor traces of pool water remained in the gasket slot and during the drying procedure crystalline boron salts prevented the required tightness. After that event a long-term experiment was started and is still going on which studies the effects of water and minor damages to the gasket. As well changes in the loading procedure have been introduced.

The pressure switch used to monitor the pressure in the space between primary and secondary lid has a self surveillance function. This indicated a malfunction 23 times in the last twenty years. Examinations of all events indicated no systematic failure, but a weak point seems to be the plug-in connection. The manufacturer introduced some modifications to improve the system.

Introduction of FEM methods in safety analysis to amend the existing methods of testing allowed a new view on and in the cask safety analysis. Progress in this field is closely connected to the available computing capacity and stipulates experts to ongoing improvement.

After expiring of the storage license which will be the case for the first cask loaded in 1992 and stored in Ahaus 2032 an extension or a new license can only be granted if the at this time relevant requirements are met. This will require detailed knowledge about the happenings and accidents during the previous storage period. All experience of the periodic safety assessment (PSÜ) which started in 2013 and accompanying experiments conducted till now and during the licensed storage time will be needed.

INTRODUCTION

According to article six of the German Atomic Energy Act storage of nuclear material has to be licensed following by the competent authority in this field, which is the Federal Office of Radiation Protection (BfS). The legal basis for all licenses in this field is the atomic energy act in its latest version (15.11.2012). The competent authority is the Federal Office of Radiation Protection (§ 23) which is responsible for the licensing procedure. As the Federal Office of Radiation Protection cannot cover all relevant fields with its own experts, assignment of external experts (§ 20) is necessary to check whether the requirements for the license are given. If the applicant is able to show that all requirements are met, the license has to be granted. The supervision of the storage lies in the responsibility of the competent authority of the federal state in which the storage facility is located (§ 24). This authority can allow minor changes of the storage licence. In case of substantial changes the Federal Office of Radiation Protection has to be consulted and is responsible for the licensing procedure.

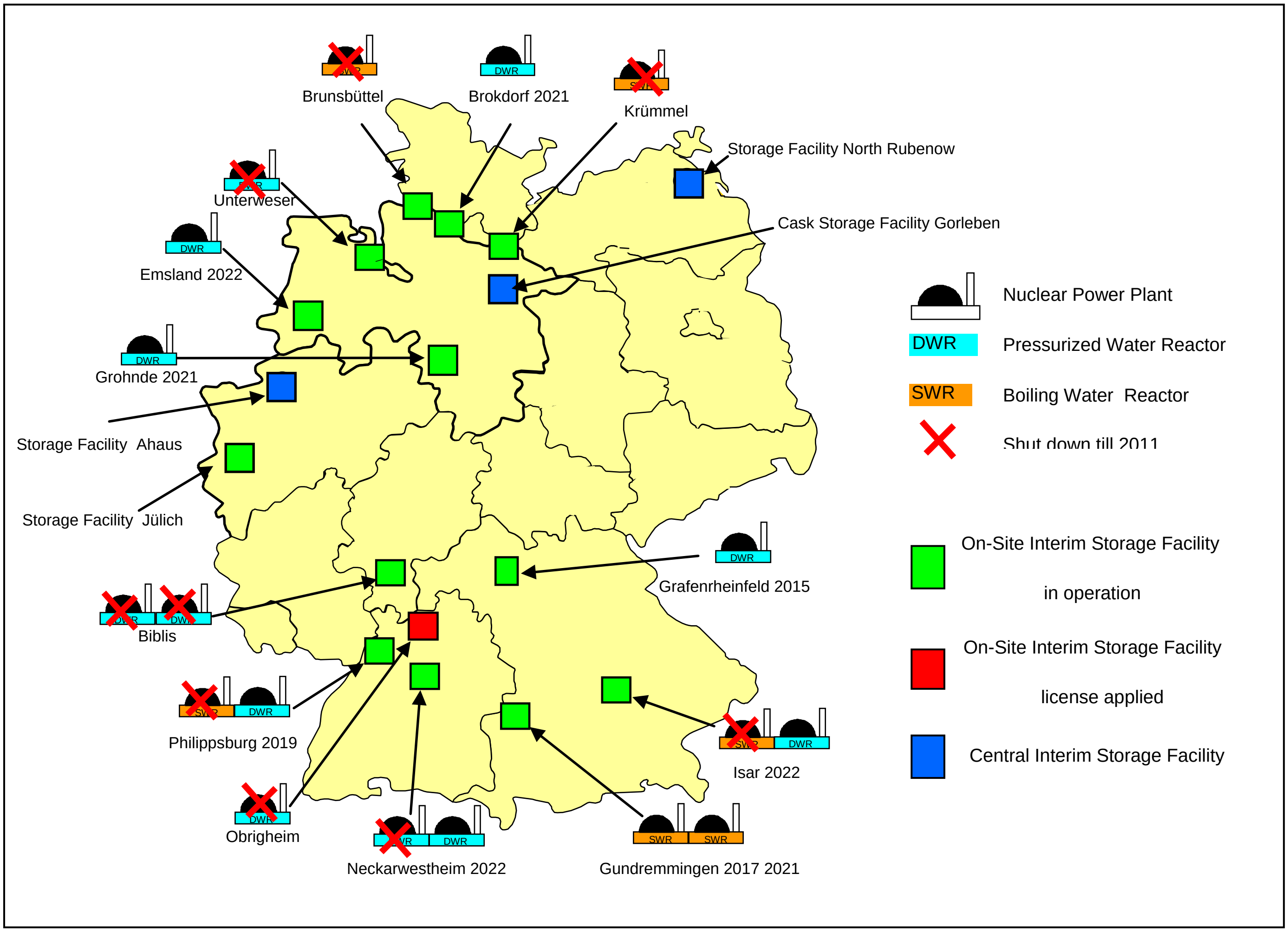

Fig. 1. NPP and storage sites in Germany

Description

The concept of dry interim storage of irradiated fuel in casks for transport and storage was developed in the late 1970s [2]. The first storage license in Germany according to this concept was granted in 1983 for storage of SNF in the storage facility in Gorleben. In june 1992, the first cask destined for dry interim storage was loaded (with spent fuel of the THTR-reactor for storage in Ahaus).

The actual storage licenses for SNF and HAW from reprocessing plants (which is stored in Gorleben and Rubenow) are limited to 40 years starting with the first cask emplacement. The first of these actually valid storage licenses is dated from 1995 (Gorleben). Additionally, the lifetime of each loaded cask is limited to 40 years on from closure after loading, as for this period safety of enclosure could be proven.

Interim storage of SNF in its actual form in storage facilities on the sites of the NPPs started in 2002 in the interim storage facility next to the NPP Lingen. Since 2005 delivering SNF for reprocessing is forbidden and direct disposal is the only allowed way of waste treatment in Germany. Because of this in the following years each NPP had to erect its own storage facility in addition to the three existing storage facilities (s. fig. 1).

In all of these facilities dry storage in metallic casks inside concrete buildings is used. A remarkable requirement for the storage license is the need for a valid package design approval during the whole storage period of 40 years. This enables the possibility to transport the cask at any time to a nuclear facility away from the storage facility. As usually the package design approval is only valid for three years, it has to be renewed quite often. For casks already in storage there is the possibility of granting the package design approval for ten years. In combination with a newly introduced monitoring program even longer periods should be possible.

All safety functions like subcriticality, safe enclosure, radiation shielding and decay heat dissipation are guaranteed by the cask. The storage building serves mainly as weather protection and additional radiation shielding. In Germany two cask concepts are licensed and in use: the CASTOR® design of the manufacturer GNS and TN design of the manufacturer TNI.
The CASTOR® design is based on a spheroidal graphite cast iron body with neutron moderator rods within. TNI uses a forged steal body surrounded by moderator compartments at the outside. Both designs use as required in ”Guidelines for dry cask storage of spent fuel and heat-generating waste” a double lid system with metallic gaskets which is constantly monitored.

As the last NPP in Germany is going to be out of commission in 2022, the number of casks to store can be calculated. In the year 2013, 332 different casks were in the storage sites at the NPPs. It is expected to have about 1046 different casks with SNF in the different storage sites after all SNF from the NPPs has been loaded into casks.
Totally, at the end of 2013 **1000** loaded casks were stored in all storage facilities in Germany. The HAW from reprocessing in France is stored in Gorleben in 108 casks, and five casks with HAW from the experimental reprocessing facility in Karlsruhe are stored in Rubenow. Research reactor fuel e.g. from the pebble bed reactors is stored in Jülich, Ahaus and Rubenow.

The actual storage licenses for spent nuclear fuel (SNF) and the vitrified high level waste (HAW) are limited to 40 years. As no opening of the cask is intended during the storage period the condition of the inventory and the cask before loading has to be known in detail. This requires for instance detailed knowledge of the history of the SNF loaded as well as supervision of the manufacturing process of all the cask components. Furthermore the loading and drying procedure of the cask is strictly regulated. This is necessary to ensure that no temperatures occur which might affect the behaviour of cask components or fuel rods during storage time.

Type of storage facilities

According to the safety philosophy in Germany the number of active systems at the storage facility is minimized. For instance cooling is ensured by natural convection. Among the storage facilities on the sites of the NPPS, there are two different storage site designs – the WTI concept and the STEAG concept with a two or one span hall. In case of the WTI design the building is expected to collapse in case of an aircraft crash, the STEAG design allows only damage of the building. Due to limitations in space the NPP Neckarwestheim decided to use two tunnels for storage instead of an extra building.

Supervision during storage

The only relevant active system is the monitoring system for the closure system which is continuously monitored and documented. At the beginning of storage an overpressure is adjusted between primary and the secondary lid. During storage the system continuously compares the pressure between the lids with the atmospheric pressure. Any change in pressure relation causes alarm. Sealing is realized by metallic gaskets in both lids. Since beginning of the interim storage in Germany no leakage or gasket failure was detected. There have been several alarms of the monitoring system but all of them indicated a malfunction of the pressure switch, which is a proof for working of the permanent self-monitoring. All of these incidents have been checked for any systematic failure, but till now none was detected. Anyhow there have been and there are still several minor changes in the construction in order to improve the system. At the moment the focus is on the insulating compound of the electric connection inside the switch towards the connector.

After the finding of crystalline boron salts in the gasket slot during a loading campaign additional experiments were started to gather further knowledge about the long term behaviour of these gaskets. Experiments with gaskets with premature damages and in the presence of corrosive media are running at the Federal Institute of Material Testing (BAM) under different conditions since 1999.

Repair

In case of a leakage the cask is transported into the maintenance station of the storage facility. First the leaktightness of the secondary lid is tested. If the tightness criteria is not fulfilled, the secondary lid is removed, the gasket is replaced and the lid assembled again. If the tightness criteria is fulfilled the conclusion is: a leakage has occurred at the primary lid. This one can’t be removed without release of radioactive material. All facilities have a special equipment to check if there is contamination in the space between the two lids. In this case the cask has to be transported to the neighbouring power plant. If this is not operating anymore it has to be transported to a nuclear facility which is equipped with a hot cell and able to repair the primary lid barrier. A transport in these cases is possible, as it requires only one valid lid barrier. Alternatively, a licensed possibility is the welding of an additional lid on top of the secondary lid and the installation of the monitoring device in the additional lid. The welding at this position requires highly qualified and continuously trained manpower which has to be ensured by the storage facility operator. Storage of such a repaired cask is licensed. As the cask cannot be transported with the additional lid it has to be removed before transport of the cask.

Developments

In the beginning of the dry interim storage in casks the number of SNF elements per cask was very limited (s. fig. 2 left). E.g. the CASTOR Ia was capable of four PWR fuel elements. The latest stage of development are the casks TN24E and CASTOR V19 with a capacity of 21 respectively 19 fuel elements including high burnup or MOXfuel.

Fig. 2. Development within 25 years

Introduction of FEM methods in safety analysis to amend the existing methods of testing allowed a new view on and in the cask safety analysis. Progress in this field is closely connected to the available computing capacity and stipulates experts to ongoing improvement. Drop tests are still an important tool to verify the calculations but today it is possible to calculate the impact on all parts of a cask. In the storage license proceeding first all possible drop orientations in the specific storage facility are considered. Then the ones with the most critical stresses are identified and for these cases detailed analysis and calculations are done. As far as possible results from the analysis required according to the international transport regulations are included.

CONCLUSION

After the storage period of 40 years provision is made for transporting the casks to a repository. The German committee defining the criteria for the repository search process has started its work in may 2014. The site for the repository is expected to be found 2031. This timescale is close to the expiring date for the interim storage facilities in Gorleben (31.12.2034) an in Ahaus (31.12.2036), so an extension has to be considered. Prior to the licensing procedure for an extension, the German Parliament has to decide about this option. Once the storage license has expired, an extension or a new license will only be granted if the at this time relevant requirements are met. This will require detailed knowledge about the happenings and accidents during the previous storage period as well as possible ageing mechanisms have to be respected. All experience of the periodic safety assessment (PSÜ) and accompanying experiments conducted till now and during the licensed storage time will be needed. In Germany the storage sites Gorleben and Lingen took part in a test run of the PSÜ and delivered reports. The outcome of these reports was used for improvement of the PSÜ procedure, which will be used on all other sites during 2014 and then every five years.

REFERENCES

1) S. Geupel, K. Hummelsheim and W. Mester, Entsorgung abgebrannter Brennelemente aus den Kernkraftwerken in der Bundesrepublik Deutschland, p. 17, (2013)
2) RSK-Empfehlung vom 19.09.1979 zur grundsätzlichen sicherheitstechnischen Realisierbarkeit (Konzept) der trockenen Zwischenlagerung bestrahlter Brennelemente in Transportbehältern