The management of spent fuel was based on two powerful columns until 30 June 2005, i.e. reprocessing and direct disposal. After this date any delivery of spent fuel to reprocessing plants was prohibited so that the direct disposal of unreprocessed spent fuel is the only available option in Germany today. The main steps of the current concept are:

(i) Intermediate storage of spent fuel, which is the only step in practice. After the first cooling period in spent fuel storage pools it continues into cask-receiving dry storage facilities. Identification of casks, “freezing” of inventories in terms of continuity of knowledge, monitoring the access to spent fuel, verifying nuclear material movements in terms of cask transfers and assurance against diversion of nuclear material belong to the fundamental safeguards goals which have been achieved in the intermediate storage facilities by containment and surveillance techniques in unattended mode.

(ii) Conditioning of spent fuel assemblies by separating the fuel rods from structural elements. Since the pilot conditioning facility in Gorleben has not yet come into operation, the underlying safeguards approach which focuses on safeguarding the key measurement points - the spent fuel related way in and out of the facility - has not been applied yet.

(iii) Disposal in deep geological formations, but no decision has been made so far neither regarding the location of a geological repository nor regarding the safeguards approach for the disposal concept of spent fuel. The situation was complicated by a moratorium which suspended the underground exploration of the Gorleben salt dome as potential geological repository for spent fuel. The moratorium expires in October 2010. Nevertheless, considerable progress has been made in the development of disposal concepts. According to the basic, so-called POLLUX®-concept spent fuel assemblies are to be conditioned after dry storage and reloaded into the POLLUX®-cask in the pilot conditioning facility. The conditioning mode was taken over for the subsequent BSK3 concept which varies in the canister for the fuel rods and the emplacement technology. To prove the principle feasibility of this concept aboveground demonstration tests have been performed by 2009. Investigations on a further concept intended for the direct disposal of spent fuel assemblies without conditioning have just begun. Conceptual differences may have an impact on the safeguards approach. With the end of the moratorium the political situation will change and further steps related to the final disposal of heat-generating waste could be decided.

German Approach to Spent Fuel Management

1. Introduction

The management of spent fuel (SF) was initially based on two powerful columns until 30 June 2005, i.e. reprocessing and direct disposal. By fixing this deadline for spent fuel deliveries to reprocessing plants the direct disposal of unreprocessed spent fuel is the only available option in Germany today. The prohibition of spent fuel transports to reprocessing is an integral part of an agreement made in 2001 between the German government comprised of Social Democrats and Greens and the nuclear operators. This agreement has been the legal basis for the revision of the German Atomic Energy Act which has been in force since 2002 with the aim of phasing out nuclear power in Germany. The key elements are:
- The operation of existing reactors which is limited to 32 calendar years
- No license for new nuclear power plants
- No spent fuel transport on public roads and railroads
- Termination of spent fuel transports to reprocessing since June 2005
- Storage of spent fuel in on-site dry storage facilities close to the reactor area
- Restriction of spent fuel management to direct geological disposal
- Interruption of salt dome exploration at Gorleben between 3 and 10 years

After the parliamentary election of a new conservative coalition in 2009 the phasing out approach appears to be on hold, because the new government aims at extending the operating lifetimes of reactors by 12 years on average. Moreover, the exploration of the salt dome at Gorleben is ready to be resumed. Concepts designed in the past decades have to be reassessed in view of these new plans e.g. the need for intermediate storage and disposal of a higher number of SF assemblies. Also, new challenges arise from the continuous trend to increasing burn-up of SF assemblies which affects the decay heat and storage requirements. In addition to that, the German operators are faced with the quite recent implementation of the Integrated Safeguards regime associated with a new inspection mode on random basis with short notice of 24 h.

2. Current Concept for Spent fuel Management in Germany

The purpose of the current concept for SF management in Germany is direct final disposal without prior reprocessing. The major steps of the current concept are

I. Intermediate storage of spent fuel
II. Conditioning of spent fuel and
III. Direct disposal in deep geological formations.

The German facilities for the long-term storage of SF are restricted to the centralized dry storage facilities in Ahaus and Gorleben [1-3], 12 on-site storage facilities close to the reactor [4], the local intermediate storage facilities at Greifswald (ZLN) and Jülich. Due to the outstanding license for the operation of a repository for spent fuel and heat generating high active waste the intermediate storage of spent fuel is the only step in practice up to now. Therefore, Safeguards for dry storage facilities have been successfully performed for many years as outlined in chapter 3.

Besides, a pilot conditioning plant (Pilotkonditionierungsanlage, PKA) now exists already for 10 years. According to the German reference concept SF assemblies are to be conditioned by separating fuel rods from the skeleton and loaded into self shielding casks designed for an emplacement in deep geological formations. The remaining structural parts will be compacted and thus space-sparringly disposed of. To prove the conditioning technology the PKA was constructed for an operational capacity of 35 t HM per year and completely erected at Gorleben till 2000. At present, the operation of the PKA is restricted to the repair of damaged casks loaded with spent fuel from nuclear power plants or high active waste returned from abroad. The approval process of the PKA has been finished but the pilot conditioning operation with SF assemblies can only be started provided that the siting process for a repository has been completed, a definite repository site has been selected and the conditioning process has been qualified. Therefore the underlying safeguards approach has not been applied yet. The conditioning procedure involves a transfer of CASTOR® casks into an unloading hot cell, where the casks are discharged, a transfer of SF assemblies to the disassembling cell where head pieces are removed from fuel assemblies, spent fuel rods are pulled out and loaded into cans which are finally loaded into the special disposal POLLUX® cask in the loading cell [5]. Due to the conditioning procedure the original identity of the spent fuel assembly as an item is lost. However, the loading of spent fuel rods into a can creates a new item which is suitable for verification by means of non-destructive measurement methods such as camera surveillance [6]. When loaded into the POLLUX® cask the new items can only be identified indirectly by verifying the POLLUX® cask. Due to the lack of screwing bolts another sealing procedure based on the verification of unique surface and material structures of the cask as a short welding seam is to be applied [7]. Altogether, the Safeguards approach focuses on the key measurement points – the spent fuel related way in and out of the PKA.

Since the implementation of a deep geological repository in Germany still lies ahead the construction of such a repository is based on conceptual considerations [8]. The German reference concept represents the first practical approach for the direct final disposal of spent fuel and vitrified high level active waste (HLW). The basis was to develop a comprehensive technology in order to demonstrate the transport of both spent fuel and vitrified HLW to underground and the emplacement in a disposal drift of the repository mine. The transport, handling and emplacement equipment of the POLLUX® cask reference concept was proved
under simulated conditions at full-scale in an aboveground test station. The backfilling of the void of rock salt around the cask was tested at a former rock salt mine. In 1990s evidence of reliability for the handling technology in particular the feasibility to hoist about 85 t payload resulting from transport cart and POLLUX® cask from the surface to underground was provided by means of about 2,000 transport cycles including the loading and unloading of the cask from the shaft.

In view of flexibility and unification of handling technologies alternative disposal concepts were considered. According to the BSK3-concept the fuel assemblies are similarly conditioned and transferred in a shaft to underground as in case of the POLLUX® cask reference concept but the consolidated spent fuel is loaded into a non-shielding BSK3-canister which is inserted into a reusable transfer cask for transport and disposal to ensure protection from gamma and neutron radiation. In contrast to the POLLUX® cask reference concept involving storage in horizontal drifts the BSK3 canister is to be stored in a vertical borehole. Corresponding tests in full scale to demonstrate the functionality and reliability of the new emplacement technology in principal were successfully finished in 2009. Since the diameter and the geometry of the BSK3 canister correspond to those of the vitrified high level waste canisters already produced in high numbers and also destined for direct final disposal the BSK3 concept has the advantage of enabling the application of the same emplacement technology for BSK3 and vitrified high level waste canisters. Moreover, the beneficial thermal conditions of the smaller BSK3-canisters compared to the POLLUX®cask may lead to an earlier emplacement of the BSK3-canisters in salt rock boreholes.

Irrespective of the emplacement procedure a retrievability of spent fuel or HLW is not intended due to the backfilling of all boreholes, shafts and drifts. Whether a handling of disposed canisters after 500 years should be feasible in particular situations is currently under discussion. Under those boundary conditions geological disposal is a suitable option for long-term management of spent fuel or HAW that in contrast to intermediate storage does not depend on continuous care and maintenance. During operation design information verification may be the major Safeguards measure aiming at verifying the “as built” information on the basis of the declared design information. Moreover, the access shafts may be subject to camera surveillance. Upon closure of the repository the Safeguards measures may be focused on Satellite imagery.

The underground exploration of the salt dome at Gorleben as potential repository for spent fuel and heat generating waste had to be suspended due to a moratorium which expires in October 2010. The exploration of the salt dome at Gorleben will be resumed from October onwards.

3. Safeguarding of intermediate storage of spent fuel

Germany had initially planned to accumulate all spent fuel in the two central dry storage facilities at Ahaus and at Gorleben. With the prohibition of spent fuel transports on public traffic ways this concept of central storage of spent fuel in two far-away centralized facilities had to be abandoned. Instead, 12 decentralized on-site storage facilities close to the reactor were constructed and taken into operation stepwise, the first facility in December 2002 and the latest one in April 2007. The permitted storage period of all German spent fuel dry storage facilities is limited to 40 years beginning with the emplacement of the first SF containing cask in the storage building, respectively. The storage capacities between 80 and 192 CASTOR® V-casks were targeted to the current reactor lifetime of 32 years and the SF assemblies accumulated until the shut down of the reactor. This aspect will have to be taken into account in view of the planned reactor life time extension by 12 years on average.

3.1 Traditional Safeguarding according to the previous Safeguards regime based on INFCIRC/193 and Additional Protocol

After the first cooling period in the spent fuel storage pool located in the reactor containment SF assemblies are loaded into dual purpose casks for transport and storage as the CASTOR® V-cask which is characterized by a thick-walled monolithic cask body made of ductile cast iron and a double lid system with monitored tightness control. As soon as enclosed by the cask the SF assemblies defy a direct control. Therefore the SF assemblies are said to be “difficult to assess items”, which require the verification prior to being transferred into casks and the application of a dual C/S system consisting of cask sealing and optical surveillance. The seal system provides for freezing the spent fuel content of a cask at the time of the last verification thus maintaining the continuity of knowledge without re-measurement [9]. Therewith, the casks are regarded as items which identification and integrity are ensured by verifying the installed seal system. Several seal types as metal cap seal, COBRA fibre optic seal and the VACOSS electronic seal which is currently gradually replaced by the follow-up EOSS-seal are available. The selection of the appropriate seal has not
only to take into account the respective device specification as for example reliability, data capture or evaluation effort and costs of purchase etc. but rather the conditions during transport and storage. The seal resistance to vibration, shock, air humidity, radiation, decay heat if the seal operates in cask vicinity play an essential role in the selection process as recently described in [10, 11]. The Safeguards approach mostly involves a sealing of the secondary lid and the protective plate of each cask as well as a group seal that interconnects several casks by a common sealing wire. The seal on the secondary lid is only accessible after removal of the protective plate. It serves as a back-up solution in case that the other seal systems as well as the optical surveillance fail. In contrast, the seals at the protective plate are always accessible and normally used to check the identity and integrity of casks during interim storage of spent fuel. The purpose of the group seal is the immobilization of casks so that it will be impossible to remove or lift a cask of this group without affecting the group seal system. Thus the group seal serves as a back-up solution for the camera surveillance which has the disadvantage of depending on appropriate lighting conditions in the storage hall. Since the video camera systems are used to register all cask movements it enables the tracking of each cask from the arrival at the reception area via the transfer to the separate maintenance area - where the preparatory handling of the received cask occurs including seal exchange on the secondary lid, mounting of the pressure sensor, screwing of the protective plate on the secondary lid - to the transfer to the storage position in the storage hall. Until 2010 a total of 6482 fuel assemblies were loaded into 268 casks of the type CASTOR® V which are accumulated in the dry spent fuel storage facilities as shown in Fig. 1.

![Status: 31th December 2009](image)

**Fig. 1.** 12 on-site dry storage facilities with 1440 storing positions

The effort for safeguarding the two centralized storage facilities which are regarding spent fuel storage in a static phase is less compared to the 12 on-site storage facilities where the number of casks increases steadily associated with a higher number of loading activities and cask movements. Due to the increasing occupation of the on-site storages with LWR spent fuel containing casks the reduction of the stay period in the storage hall for inspectors and facility staff gains more and more importance in the field of radiation protection. Therefore the implementation of electronic seals which can be interrogated remotely without entering the storage hall would counteract the radiation exposure effectively.

### 3.2 Dry storage facilities under Integrated Safeguards

The positive evaluation of the whole state by the Agency, the broader conclusion for Germany, was the basis for the implementation of Integrated Safeguards in Germany which went into force on 1st January 2010. The safeguards approach may vary from state to state e.g. if no reprocessing plant exists in the state as in Germany the assumption that spent fuel could be reprocessed within the state clandestinely has not to be considered any longer. After IAEA had gained credible assurance on the absence of undeclared nuclear
material and activities in Germany the level of safeguards parameters for spent fuel as timeliness, detection probability were lowered. The timeliness changed from 3 months to 1 year and the quarterly routine inspections were replaced by randomly performed inspections with a short notice of 24 h leading to a reduced inspection frequency.

Irrespective of whether a traditional or Integrated Safeguards regime is in force the highest inspection effort will be needed for the transfer activities from the reactor to the on-site dry storage facility. According to the Agency considerable effort reduction would be achieved if the cask sealing after loading could be delegated to the operator. Taking over this task in the absence of an inspector would mean that the operator would be responsible for the correct performance of the sealing procedure. This is very problematic and therefore not acceptable in particular if the operator has no confirmation of the correctness of his seal handling. The identification of the cask and its loaded status is a primary safeguards activity that has to be done by the inspectorates.

4. Closing remarks

Based on the timeliness change for spent fuel to one year it is logical to assume that the yearly performed physical inventory inspection would be sufficient in all intermediate dry storage facilities as a stand-alone inspection without the need for further randomly performed inspections. In view of the increasing amount of SF to be placed into an intermediate storage in particular as a consequence of the reactor life time extension the radiation exposure to operator and inspector during seal verification may become an issue that supports the implementation of remotely interrogatable electronic seals. In order to allow adaptations to changing situations in due time, future developments have to considered and initiated well in advance.

The disposal of non-dismantled SF assemblies without the time-consuming and technical demanding conditioning procedure would simplify the back-end fuel cycle to a high degree. In parallel the lack of spent fuel transfer from the CASTOR® V cask to the disposal canister would imply the preservation of items associated with a saving of safeguards measures.

The current political decision of resuming the repository relevant activities sets the course for the implementation of geological disposal.

References