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TRANSPORT AND STORAGE OF SPENT FUEL IN GERMANY - POSSIBILITIES FOR MORE SAFETY

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1. Introduction

The safe transport of spent fuel from nuclear power plants in Germany is ensured by compliance with the dangerous goods transport regulations of class 7 which are fully consistent with the IAEA Transport Regulations and in parallel with the regulations of the German Atomic Energy Act. The purpose of this paper is to give an overview of this legal basis and the appropriate regulations applicable to spent fuel transport in Germany. Some aspects of the status and the future development of spent fuel shipments are described including experiences since resumption of those shipments in 2001. Furthermore, the status of licensing of on-site interim storage, assessments of an terrorist attack as well as consequences resulting from changes in energy policy are given.

2. Legal Basis

The transport of spent fuel in Germany is regulated by two legal areas:

- the area of the dangerous goods transport law and the dangerous goods transport regulations for which the Federal Ministry of Transport, Building and Housing (BMVBW) is responsible for, and
- the area of the German Atomic Energy Act for which the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has the responsibility.

There is a link between these two areas in so far as the transport provisions of the German Atomic Energy Act contain the requirement that the transport must comply with the dangerous goods transport regulations. In addition to this they contain other requirements regarding the reliability of transport organisations and persons, the qualification and training of persons involved in transport, the nuclear liability insurance, the physical protection and the public interest.

The IAEA Regulations for the Safe Transport of Radioactive Material TS-R-1 (ST-1 Revised) [1] have to be applied in Germany through the implementation of the dangerous goods transport regulations for class 7 of the International Modal Organisations. Therefore, for spent fuel shipments from nuclear power plants taking place by road and rail, the dangerous goods transport regulations for class 7 of the international modal regulations ADR (European Agreement Concerning the International Carriage of Dangerous Goods by Road) and RID (Agreement for the International Carriage of Dangerous Goods by Rail) have to be applied in Germany. They have been implemented for the two modes of transport by the following German Regulation: GGVSE, Gefahrgutverordnung Straße und Eisenbahn.

There are the following responsibilities according to these dangerous goods transport regulations:

- The Federal Office for Radiation Protection (BfS) is the competent authority for package design approvals for spent fuel casks and, if applicable, also for shipment approvals,
- The Federal States are responsible for the inspection of spent fuel shipments by road, and
- The Federal Railway Office (Eisenbahnbundesamt) is the competent authority for the inspection of spent fuel shipments by rail.

The shipment of spent fuel has to be approved according to section 4 of the German Atomic Energy Act [2]. The BfS is the competent authority for such shipment approvals. An approval for spent fuel shipment from a nuclear power plant will be granted if the applicant can demonstrate the fulfilment of approval requirements according to section 4 of the German Atomic Energy Act comprising mainly [3]:

- Reliability of companies and persons involved in transport,
- Qualification and training of persons involved in transport,
- Compliance with dangerous goods transport regulations,
- Nuclear liability insurance,
- Physical protection measures,
- Public interest, and
- On-site interim storage capabilities for spent fuel.

3. Spent Fuel Transportation

3.1 Actual Status

The spent fuel shipments are subject to the approval requirements of section 4 of the German Atomic Energy Act. These shipments as well as the shipments of vitrified high level radioactive waste from France to Germany were stopped in May 1998 by the BMU when it became known that contamination limits had massively been exceeded. The main requirement for the resumption of these shipments to be demonstrated by the applicant was that the limits for non-fixed surface contamination can be met. This demonstration is in particular necessary to fulfil the approval requirement of section 4 of the German Atomic Energy Act regarding the compliance with the dangerous goods transport regulations. Only when such a demonstration was available and accepted and all the other approval requirements according to section 4 of the German Atomic Energy Act were fulfilled, a shipment approval could be granted by BfS to resume these shipments.

Based on the criteria catalogue of the BMU and on intensive and comprehensive studies and expertises by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Köln, and Öko-Institut, Darmstadt, many measures were taken to meet the requirements for non-fixed surface contamination. They contain detailed procedures for the loading, handling, transport, transfer and unloading of casks to prevent contamination, to improve decontamination methods as well as contamination detection and contamination measurements, to get complete and uniform documentations and to ensure the duty of notification if contamination limits are exceeded. Those measures are laid down in the shipment approval issued by BfS depending on the concrete shipment application.

Experience has shown up to now that these measures are effective. The resumption of transport of vitrified high-level radioactive waste from France to Germany took place at the end of March 2001 with full compliance with the contamination requirements. The first shipment of spent nuclear fuel to France (COGEMA) was performed on April 10, 2001 and to the UK (BNFL) on April 24, 2001. Since then 269 casks with spent fuel or vitrified waste were shipped in Germany up to the end of 2003. In all cases non-fixed surface contamination was clearly below the permissible limits.

3.2 Prospects

Concerning the future development of spent fuel shipments within Germany and to the reprocessing facilities in France and the UK there is a new concept on the basis of the agreement between the German government and the utilities (dated June 11, 2001) to limit the future use of the nuclear power plants in Germany. This agreement has been legally implemented by the latest amendment of the German Atomic Energy Act which came into force on April 27, 2002. The essential requirements affecting transport are:

- The transport of spent nuclear fuel to foreign reprocessing facilities will end on July 1, 2005.
- Interim storage of spent nuclear fuel shall be performed at the nuclear power plant sites (decentralized storage) and the spent nuclear fuel shall be stored on-site or near-site until a repository will be available by the year 2030.
- The transport of spent fuel from a nuclear power plant to a centralised storage facility is subject to the demonstration that on-site interim storage capabilities are not available.

By this concept the number of shipments of spent nuclear fuel will be minimized in the future.

4. On-site interim storage of spent fuel

Prior to the agreement between the Federal Government and the utilities and to the April 27, 2002 amendment of the German Atomic Energy Act, spent nuclear fuel is either shipped to the COGEMA and BNFL reprocessing facilities, stored on-site at the nuclear power plant or at centralized off-site interim storage facilities.

The revised German radioactive waste management concept provides, among other things, the establishment of decentralized on-site interim storage facilities for spent fuel elements. Thus, as pointed out, the number of spent fuel shipments to the central interim storage facilities in Gorleben and Ahaus as well as to the reprocessing plants at La Hague in France and Sellafield in Great Britain will be reduced to the indispensible quantity. In addition, the period of time until the start of operation of a geological repository to host all types of radioactive waste (including spent fuel) will be bridged. Decentralised on-site facilities may either be interim storage facilities (operational lifetime: 40 years) or interim storage areas (operational lifetime: 5 years). The latter are necessary for nuclear power plants with limited fuel element pool capacity in order to bridge the time gap until the proper on-site storage facilities will become operable.

The construction and operation of such decentralized facilities require a license for the interim storage of nuclear material according to the German Atomic Energy Act and a construction license for the erection of the storage building according to the respective Federal State building regulations. The license according to nuclear law is issued by the Bundesamt für Strahlenschutz (BfS), the construction license by the respective local building authority.

4.1 Status of licensing procedures

Starting end 1998 until February 2002 the utilities filed 18 applications for dry on-site interim storage of spent fuel in decentralized facilities to BfS:

- 5 applications for interim storage areas;
- 13 applications for interim storage facilities (the application for the Stade facility was withdrawn in August 2001 due to the final shut down of the Stade nuclear power plant in autumn 2003).

As to the interim storage areas the mass of heavy metal applied for varies between 120 Mg and 200 Mg and the activity between $7.6 \cdot 10^{18}$ Bq and $2.8 \cdot 10^{19}$ Bq. The respective figures for the interim storage facilities are 450 Mg to 2,250 Mg and $4.4 \cdot 10^{19}$ Bq to $2.7 \cdot 10^{20}$ Bq. The number of casks varies between 12 and 28 for on-site storage areas and between 80 and 192 for interim storage facilities.

When filing the applications the applicants ask for a stepwise licensing of parts of an application in order to expedite the issuing of a license. The excluded parts of the applications remain to be pursued later on. Thus, subsequent to a thorough examination of the fulfilment of the licensing prerequisites, BfS issued the licenses for the interim storage areas from April 2001 to June 2003 in the first licensing step. With respect to the storage areas Neckarwestheim, Philippsburg and Biblis the second licensing step was finished by the end of 2002 and in 2003, respectively, by issuing supplementary licenses. A decision on the Brunsbüttel interim storage area was not pursued in 2003.

The applied storage of spent fuel in the on-site facilities at Lingen, Grohnde, Grafenrheinfeld, Biblis, Isar, Neckarwestheim, Unterweser, Brokdorf, Brunsbüttel, Philippsburg, Krümmel and Gundremmingen was licensed by BfS in the period of time from November 2002 to December 2003. Thus, the first licensing step for all interim storage facilities was successfully completed.

With respect to construction all license applications for the erection of interim storage areas as well as of interim storage facilities were filed to the competent building authorities. With the exception of the Brunsbüttel interim storage area and the Gundremmingen interim storage facility the required construction licenses for all decentralized interim stores were issued. Nevertheless, same of the licenses comprise additinal requirements imposed by the licensing authority the fulfilment of which is an essential prerequisite to start construction work.

According to the licenses issued the erection of the Grafenrheinfeld, Brunsbüttel, Neckarwestheim, Biblis and Brokdorf interim storage facilities started in the period of time September 2003 to April 2004. The Neckarwestheim, Philippsburg, Biblis and Krümmel interim storage areas already started operation; the Lingen interim storage facility is operated since December 10, 2002.

4.2 Forced airplane crash

Having the September 11, 2001 terrorist attacks using large airplanes in the USA in mind, it cannot be excluded any more that German nuclear installation such as interim storage facilities may become the target of such on attack. That is the reason why BfS being the competent German licensing authority by law, has decided to include the analysis of a terrorist attack with an airplane within the licensing procedures. The legal basis for such examination is given by section 6 (2) no. 4 of the German Atomic Energy Act.

For the analyses of forced airplane crashes onto an interim storage facility different sizes and types of modern airplanes have been considered up to the Boeing 747-400 and the Airbus 340-600. The investigations include, among other things, maximum take-off weights as well as maximum fuel volumes. Thus, a wide range of possible mechanical and thermal impacts is covered.

For the different types of airplanes considered the time dependent mechanical impact to a heavily steel-reinforced concrete wall was calculated. The mechanical momentum of fuselage, wings and engines on a solid target was analyzed in order to determine whether an interim storage building can withstand direct airplane crashes. If not, the remaining momentum of penetrating airplane debris and the momentum of accelerated concrete wall and roof pieces were analyzed.

With respect to thermal impacts it was considered which amount of aviation fuel would enter the interim storage building and contribute to a thermal impact onto a spent fuel cask. Besides aviation fuel the combustible parts of an airplane were taken into account. Thus, an aviation fuel fire of about 15 min with temperatures of maximum of up to 1,100°C was determined. For other combustible materials a temperature of about 700°C and a fire duration of about 25 min was calculated. The most important result of the analyses is that the thermal impact onto spent fuel casks does not cause any relevant decrease of the leak tightness (from $\leq$ 10 (exp-8) Pa · m^3/s to 10 (exp-4) Pa · m^3/s at maximum).

Using the detailed information on the consequences of mechanical and thermal impacts possible releases of radioactivity and subsequent radiological consequences were calculated. The results clearly demonstrate that a forced airplane crash onto an interim storage facility does not lead to any risk of health or life due to radioactivity releases. Respective dose limits are not exceeded; on the contrary, the radiological effects remain well below the protection goal of 100 mSv per person:

- << 1 mSv due to events beyond the design basis (accidental crash of a military jet),
- < 10 mSv due to terroristic attacks (forced airplane crash).

Thus, it could be demonstrated that a forced airplane crash leads to a maximum dose which is by factor 10 lower than the required dose limit.

4.3 Future activities

Subsequent to the issue of the licenses until December 2003 current activities of BfS are focussed on a continuation of the licensing procedure (second licensing step) dealing in particular with

- average surface dose rate of 0.5 mSv/h at maximum,
- thermal output of 50 kW at maximum,
- additional spent fuel inventories (e.g., spent fuel elements with defect fuel rods),
- additional casks (e.g., TN 244 and CASTOR V/a), and
- alternative method for the determination of residual moisture.

5. Conclusions

The transport of radioactive material in Germany is regulated by the dangerous goods transport regulations of class 7 in compliance with the IAEA Transport Regulations and in parallel to these regulations by the regulations of the German Atomic Energy Act .
Based on the demonstration of compliance with the dangerous goods transport regulations and the shipment approval requirements of the German Atomic Energy Act shipments of spent nuclear fuel could be resumed in March 2001. Experience with all shipments up to the end of 2003 has shown that the measures taken to meet the requirements for non-fixed surface contamination are effective so that in all cases the measured contamination levels were clearly below the permissible limits.

The agreement between the German government and the utilities to phase out the use of nuclear power was legally implemented by the latest amendment a of the German Atomic Energy Act, which came into force on April 27, 2002. In particular, the requirements to end the shipments of spent nuclear fuel to reprocessing facilities on July 1, 2005 and to build decentralized interim storage facilities at the nuclear power plant sites will result in a minimization of the future number of shipments of spent nuclear fuel in Germany.

6. References

[1] Regulations for the Safe Transport of Radioactive Material, IAEA Safety Standards Series No. TS-R-1 (ST-1, Revised), 1996 Edition (Revised), Vienna

[2] Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren (Atomgesetz) in der Fassung der Bekanntmachung vom 15. Juli 1985 (BGBl. I S. 1565), zuletzt geändert durch Gesetz vom 22. April 2002 (BGBl. I S. 1351)

[3] Nitsche, F., Fasten, Ch., Transport Regulations for radioactive material in Germany, International Journal of Radioactive Material Transport -RAMTRANS-, Vol. 13, No. 1, pp. 19-22 (2002)