Interim and Final Storage Casks

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Abstract

The disposal of radioactive waste is a huge social challenge in Germany and all over the world. As is well known the search for a site for a final repository for high-level waste in Germany is not complete. Therefore, interim storage facilities for radioactive waste were built at plant sites in Germany. The waste is stored in these storage facilities in appropriate storage and transport casks until the transport in a final repository can be carried out. Licensing of the storage and transport casks aimed for use in the public space is done according to the traffic laws and for handling in the storage facility according to nuclear law. Taking into account the activity of the waste to be stored, different containers are in use, so that experience is available from the licensing and operation in interim storage facilities. The large volume of radioactive waste to be disposed of after the shut-down of power generation in nuclear power stations makes it necessary for large quantities of licensed storage and transport casks to be provided soon.

1 Introduction / Motivation

The storage of nuclear fuel, the recycling of radioactive residues and the disposal of radioactive waste is regulated in articles 6 and 9a of the German Atomic Act, AtG [1]. Permission is required, if nuclear fuel is to be stored outside of State administration. Approval is granted if there is a need for storage, there are no concerns about the reliability of the applicant and the responsible people having the necessary expertise according to the state of science and technology and necessary precautions against damage by storing the nuclear fuel are taken, if the required provision for the statutory compensation obligations is fulfilled, and if the necessary protection against disruptive or other actions of third parties is guaranteed. This also applies to the temporary storage of spent fuel, i.e. the so-called interim storage. In Germany irradiated nuclear fuel must be stored on site until the date of delivery to a repository site.

The federal states are responsible for the temporary storage of radioactive waste and need to set up regional collecting centres. The Federal Government is responsible for the collecting and the final disposal of radioactive waste and must set up appropriate sites.

The Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) has been consulted since 2008 in matters of nuclear waste by the Nuclear Waste Management Commission (Entsorgungskommission, ESK). This includes the aspects of conditioning, storage and transport of radioactive materials and waste, also the closure and the decommissioning of nuclear installations and disposal in deep geological formations.

Radioactive waste is currently distinguished primarily into two groups [2]:

(1) Waste with negligible heat generation and

(2) Heat developing radioactive waste and irradiated fuel.

Interim storage sites for radioactive waste with negligible heat generation (formerly called "weak and medium active wastes") are usually approved and supervised according to § 7 of the radiation protection code by the competent regulatory and supervisory authorities of the Federal states.

Interim storage facilities for heat generating radioactive waste and irradiated fuel elements are approved by the Federal Office for Radiation Protection according to art. 6 of the Atomic law and supervised by the competent supervisory authorities of the Federal states. Waste with negligible heat generation will be stored in the future in the approved site Konrad. There is still no permanent storage site for the other waste group. As we all know the long favored location Gorleben has been called into question. A new act to be adopted in the near future may help to find the right location.

Appropriate containers for radioactive waste and spent fuel are needed for intermediate and final disposal, which is to be identified in a certification procedure. Because the containers in

most cases must be transported on public traffic areas, the certification process is divided into a traffic law part and a nuclear law part.

An overview of current situation of storage and transport casks in Germany is given in this paper.

2 Waste and interim storage sites

2.1 Waste with negligible heat generation

Radioactive waste from the operation and decommissioning of nuclear power plants is stored in interim facilities up to their removal to a final repository. According to the “polluter pays principle” the utility has to build and operate the interim storage site. Currently beside the interim storage on site, interim storage facilities are available in the External Storage Unterweser, the decentralized interim storage of Biblis, the waste storage Gorleben (ALG), for Bavarian utilities and the Bavarian state the interim storage facility in Mitterteich, for the Nuclear Cargo Service GmbH (NCS) company in Hanau, the interim storage facility Nord (ZLN) at Greifswald, as well as the interim storage facility for the Department of decontamination (HDB) of the research centre Karlsruhe. Radioactive waste from the reprocessing of German fuel from abroad can be stored in the central storage depot in Ahaus and Gorleben (vitrified highly radioactive waste). Radioactive waste from the research centres (Karlsruhe, Jülich, Geesthacht) are usually conditioned on site and stored temporarily.

Radioactive wastes from research, industry, and medicine can be given to the eleven collecting centres of the Federal states. Also private companies exist that pick up radioactive residues, condition and store them temporarily.

Waste from the nuclear industry, for example from the former operation and decommissioning of the fuel element production facilities in Hanau are usually conditioned storage-friendly on the site and stored in this example in the storage of NCS in Hanau, Germany.

The approved storage capacity of the storage depot is used as a measure for the amount of waste. However, the unit of measure of the permits is not uniform. The storage capacity will be given in becquerels Bq, in cubic metres m^3, number of containers or in area m^2 [2]. Gorleben waste storage, the interim storage facility Nord (ZLN) in Rubenow (Mecklenburg-Vorpommern), the Department of decontamination in Karlsruhe and the collection centre of the Bavarian utilities and of the state of Bavaria in Mitterteich, have the largest storage capacities, see **Table 1**.

2.2 Heat generating waste and fuel elements

In recent years on the sites of operating nuclear power plants, interim storage facilities were built and put into operation for the storage of irradiated fuel elements during operation. They are called decentralized or on site interim storage facilities. The containers should be stored there for 40 years. Central interim storage facilities are located in Ahaus (Transportbehälterlager Ahaus) for irradiated fuel from power generating reactors, prototype reactors and research reactors and in Gorleben (Transportbehälterlager Gorleben, TBLG) for irradiated fuel elements from nuclear power plants and vitrified highly radioactive waste from the reprocessing of irradiated fuel from German nuclear power plants in France and the United Kingdom.

Irradiated fuel elements from the decommissioned nuclear test reactor (AVR) Jülich are kept on the site of Jülich. The interim storage facility Nord (ZLN) at the site of Greifswald is for the storage of irradiated fuel elements from the nuclear power stations of Greifswald and Rheinsberg in the former German Democratic Republic.

All interim storage facilities are designed as dry storage, where the transport and storage containers with irradiated fuel or vitrified highly radioactive waste are stored. Different design variants of the temporary storage facilities are approved. They differ mainly in the arrange-

ment of the storage areas and in the building wall thickness; for example, the interim facility in Neckarwestheim is built in a tunnel. All concepts meet the requirements of the nuclear law on safe storage. So, the interim storage facility with a passive natural draught cooling have been designed which dissipates the heat of the container regardless of active technical systems.

The entire intermediate storage capacity amounts to approx. 22400 Mg (tonnes), where until end of 2010 were stored about 3300 Mg, of which 2600 Mg were on site and 700 Mg were in external intermediate stores.

3 Casks

There are different containers in the form of barrels, cylindrical and rectangular-shaped containers from concrete or steel or cast iron containers for radioactive waste. Rectangular-shaped containers are often called a “container” in Germany. The containers are usually also transported and therefore they become a shipping unit, i.e. packaging with radioactive contents. The transport of radioactive material is subject to strict national and international regulations, to ensure the protection of individuals, of property and of the environment through the concept of "safe shipping unit".

For each type of shipping unit for the transportation of radioactive substances, it is necessary to demonstrate conformity with the applicable national and international regulations. There is a distinction between accredited and non-accredited components. The procedure for the authorisation of containers in Germany is given in the guideline R 003 of the Federal Ministry of Transport, Building and Urban Development [3]. The Technical Guide “Package Design Safety Reports for the Transport of Radioactive Material” of the European Union [4] provides more information, including information and assistance in the creation of documentary evidence for the compliance with the provisions for non-accredited components. This technical guidance document was developed by the authorities responsible for the transport of radioactive material from Belgium, France, Germany, Spain and the United Kingdom and their supporting organizations and the world nuclear transport Institute (WNTI) and Areva as industrialists and translated by the Federal Office for Radiation Protection. The technical guide follows the recommendations of the IAEA [5]. There [5] the designations of the different shipping units are also defined.

The concept of "safe shipping unit" to meet the protection objectives (persons, property, environment) includes various types of packages:

• optional items (such as for clinical reagents)

• Industrial shipping units of the type IP-1, type IP-2 and type IP-3 (such as for radioactive waste)

• Type A items (e.g. for radiopharmaceutical products)

• Type B items (e.g. for spent fuel and highly radioactive sources)

• Type C items (for the transport of radioactive materials by air beyond a specific activity)

• Items for fissile materials (e.g. for not irradiated fuel elements)

There are different safety requirements depending on the type and quantity (hazard potential) of the radioactive substance to be transported for the items. These range from general requirements for items with limited content (optional items) up to "accident-proof" packages with radioactive sources of high activity (type B and type C). For containers with fissile radioactive materials additional requirements exist to ensure the security against criticality (that is the exclusion of the emergence of a nuclear chain reaction) during transport.

Applications on approval of a shipping unit or for recognition of a foreign approval are sent to the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS). Currently BfS has approved 35 containers and recognized 19 foreign approvals.

Above all the big containers of the type CASTOR for irradiated fuel elements or vitrified waste are known in public. CASTOR is an acronym for "cask for storage and transport of radioactive material" and is a protected trademark of the Gesellschaft für Nuklear-Service (GNS). Other manufacturers are Transnuclear International (TNI) within the AREVA group (formerly COGEMA Logisitics) or Excellox from the United Kingdom, see table 3.

4 Final repository sites

4.1 Waste with negligible heat generation

In the past, the two sites Morsleben (Saxony-Anhalt), and ASSE II (Lower Saxony) served as a final repository for waste with negligible heat generation (formerly low and medium radioactive waste).

Waste from the former East Germany (German Democratic Republic), and from the old Federal States with a total of 37 000 m³ are stored in Morsleben. Since 1998, no additional storage took place. During the closure, the plant was to be filled with 4 million cubic metres of concrete of salt [7].

In the site ASSE II containers have been stored until 1978 with a total activity of about $2{,}9 \cdot 10^{15}$ Bq. About 124 500 containers with low radioactive waste and around 1300 barrels of medium radioactive waste have been stored [7]. After a comparison of different options, the return of the waste is currently considered best option for further dealing with the radioactive waste there.

The repository Schacht Konrad is approved as a new final repository for waste with negligible heat generation. The site is currently accordingly converted. From today's perspective the storage of intermediary waste in 2019 may be started.

The BfS has created disposal conditions for the site Schacht Konrad on the basis of results of a site-specific security analysis [8]. They include general requirements for package units such as specific requirements for waste products and waste containers, as well as activity limits for individual radionuclides and mass limits for non radioactive harmful substances.

Many demands are subjected on the containers to be stored. Basic types of containers were defined, see table 3. This ensures that the containers comply with the dimensions and volumes, and are manageable and stackable. Steel containers must have corrosion protection and during delivery the containers must be of course free from mechanical and corrosive damage, which may affect the tightness or integrity during handling and stacking. The container may differ with regard to the specified tightness.

The containers are divided into two waste container classes, depending on the impact/drop behaviour and fire behaviour. A further subdivision of the containers is carried out in "Non-accident proof" and "accident proof".

The design and testing of containers and packaging for the permanent storage site Schacht Konrad is described in [9]. The audit includes among other things static load tests, drop tests with different heights, thermal tests and leak tests and the detailed documentation.

4.2 Heat generating waste and fuel elements

A repository for heat generating waste (irradiated fuel) does not currently exist. The long-term favorite site Gorleben is in discussion. A new act “Act for Search of a Final Repository” to be adopted even 2012 shall help to find a new location. Thus, other locations can be included.

The BMU has defined the requirements to the heat generating radioactive waste disposal in [10]. The already mentioned Waste Management Commission has now developed guidelines on this basis for the treatment of human intrusion, for the classification of the scenarios for the long-term safety proof, for definition of effective ground for inclusion of and for safe oper-

ation. The demand for returnability of high-level radioactive waste from a repository represents a new challenge to the concept of a repository [11].

5 Summary and conclusion

In Germany, there exist sites for interim storage for some hundred thousand cubic metres of non-heat-generating waste and of over 20 000 tonnes for heat generating waste. There are multiple repository locations for non-heat-generating waste. No sites are available in Germany for final repository of heat-generating waste.

The waste in containers must be transported from the interim storage facilities to a final repository. This needs numerous containers, which are used only once. The work of the producers and authorities for the approval of the containers for transport and storage are under way. The phase-out of the peaceful use of nuclear energy by the year 2022 increases pressure on the parties as regards provision of approved containers.

As a final repository in Germany has not yet been found, it is obvious that long intermediate storage is necessary. This results in new tasks and issues, for example with regard to transport after a very long intermediate storage.

References

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Table 1: Interim sites for storage of non heat generating waste [2]

site purpose		capacity
TBLG Gorleben (Fasslager), Niedersachsen	Storage of low and medium radioactive waste from nuclear power, medicine, research and industry	200-l-, 400-l-casks, containers of concrete Type III, cast containers Type I-II, containers Type I-IV with total activity of $5x10^{18}$ Bq
Zwischenlager Nord (ZLN) Rubenow, Mecklenburg-Vorpommern	Intermediate storage of operating and decommissioning waste of the Greifswald and Rheinsberg nuclear power plants and intermediate storage of depleted large components	200.000 m^3
Hauptabteilung Dekontaminationsbetriebe, Karlsruhe (WAK GmbH) and Landessammelstelle Baden-Württemberg	Waste from research centre Karlsruhe and from Baden-Württemberg	Approx. 78.000 m^3 (storage volume)
Sammelstelle der EVU and Landessammelstelle Mitterteich, Bayern	Waste from Bavarian nuclear power plants and Bavarian medicine, research and industry	50.000 package units (200-l-, 400-l-casks or cast containers)
Zwischenlager der NCS, Hanau	conditioned and operation waste from the nuclear industry	Approx. 13.000 m^3
Landessammelstellen Berlin, Hessen, Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz, Saarland, Sachsen	Waste from medicine, research and industry	Approx. 7700 m^3
Landessammelstelle der vier norddeutschen Küstenländer, Geesthacht	Waste from medicine, research and industry	68 m^2 area
Landessammelstelle Mecklenburg-Vorpommern, Rubenow/Greifswald	Waste from medicine, research and industry	80 pieces 70-l-casks
Abfalllager Esenshamm, Niedersachsen	Storage of waste from NPP Unterweser and Stade	200-l- und 400-l-casks, containers made from concrete, steel sheets, steel cast up to around $1{,}85x10^{15}$ Bq
Zwischenlager Ahaus, Nordrhein-Westfalen	Intermediate storage of operating and decommissioning waste from nuclear power plants	requested

Table 2: Approved interim storage sites according art. 6 AtG for fuel elements [2]

site capacit	**y**		**stored (End 2010)**	
	Container /pieces	metal / Mg	Container /pieces	metal / Mg
Biblis	135	1400	46	468
Brokdorf	100	1000	13	134
Brunsbüttel	80	450	6	51
Grafenrheinfeld	88	800	13	133
Grohnde	100	1000	13	135
Gundremmingen	192	1850	25	227
Isar	152	1500	22	213
Krümmel	80	775	19	175
Lingen/Emsland	125	1250	32	327
Neckarwestheim	151	1600	36	333
Obrigheim	15		15	
Philippsburg	152	1600	36	357
Unterweser	80	800	7	72
Gorleben	420	3800	102	37
Ahaus	420	3960	56	64
ZLN Greifswald	80	585	69	585
Behälterlager Jülich	158	0,225	152	0,075
sum		**22370**		**3311**

Table 3: Examples for containers for heat generating radioactive waste

designation producer		**contens**
CASTOR V/19	GNS	Fuel elements from PWR
CASTOR V/52	GNS	Fuel elements from BWR
CASTOR HAW28M	GNS	vitrified highly radioactive waste from the reprocessing
Excellox	Excellox	vitrified highly radioactive waste from the reprocessing
TN13/2	TNI/AREVA	Fuel elements from PWR
TN85	TNI/AREVA	vitrified highly radioactive waste from the reprocessing

Table 4: Basic types for containers for site Schacht Konrad

designation	**Length or diameter**	**width**	**heigt**	**volume**
Dimension	mm	mm	mm	m^3
Concrete container Typ I	1060	-	1370	1,2
Concrete container Typ II	1060	-	1510	1,3
cast container Typ I	900	-	1150	0,7
cast container Typ II	1060	-	1500	1,3
cast container Typ III	1000	-	1240	1,0
Container Typ I	1600	1700	1450	3,9
Container Typ II	1600	1700	1700	4,6
Container Typ III	3000	1700	1700	8,7
Container Typ IV	3000	1700	1450	7,4
Container Typ V	3200	2000	1700	10,9
Container Typ VI	1600	2000	1700	5,4