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Interview with Massimo Garribba

Practical Response to a Dirty Bomb

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Return transport of vitrified high-level radioactive waste from reprocessing of German fuel elements in Sellafield in November 2020 (Courtesy of GNS Gesellschaft für Nuklear Service mbH).

First Repatriation of Vitrified Reprocessing Waste from Sellafield

Managing challenges with transport organization and radiation protection

Marco Wilmsmeier and Michael Köbl

Repatriation from the United Kingdom Reprocessing contracts which the operators of German nuclear power plants (EVU) had concluded with the Nuclear Decommissioning Authority (NDA, former BNFL) formed the basis for the transport of spent fuel elements to the reprocessing plant at Sellafield, where they were reprocessed. Until 1994, the reprocessing of irradiated fuel elements from nuclear power plant operation was mandatory in Germany pursuant to § 9 AtG (Atomic Energy Act). Since a national reprocessing concept was dispensed with in 1989, the waste had to be transported abroad for reprocessing. From 1994 onwards, an amendment to the Atomic Energy Act made it possible to also transport nuclear waste directly to a repository in parallel with reprocessing as a waste management concept. As of July 1, 2005, the transfer of irradiated fuel elements to a reprocessing plant is banned. There is an obligation to take back the amount of heavy metals produced during reprocessing in accordance with national agreements and the corresponding exchange of notes between Germany and the UK. International law states that an amount equivalent to the mass of 768 t of heavy metal delivered to Sellafield must be returned to Germany.

Fig. 1.
HLW canister.

The mass to be returned equates to 560 HLW canisters, whose return and packaging is in turn contractually agreed between the EVU and the NDA. The HLW canister is a waste product from the reprocessing and takes the form of a sealed stainless steel cylinder which is filled with a glass matrix in which dissolved high-level radioactive fission products are embedded.

Preparations for the first transport from Sellafield

In preparation for the return of the stream of high-level radioactive waste from Sellafield, the design and statutory approval of the CASTOR® HAW28M transport and storage cask, and the loading planning, were undertaken on the basis of the specification of the Sellafield canister and the inventory specification in compliance with international and national regulations.

Furthermore, the return of the HLW canisters from the UK required the infrastructure for the transport, loading, and dispatch to be created, a process which was successfully verified by carrying out a cold trial of the cask loading and handling operation for the CASTOR® HAW28M cask in Sellafield in 2013.

The first six of a total of 20 empty casks of the design CASTOR® HAW28M which were needed – each capable of holding 28 canisters – were transported by rail and ship from the GNS production plant in Mülheim to Sellafield in June 2018. In Sellafield, each was loaded with a total of 28 HLW canisters in the loading facility of Sellafield Limited between December 2018 and November 2019. The first return transport from Sellafield to Germany and the storage facility of BGZ Gesellschaft für Zwischenlagerung mbH at the nuclear power plant site in Biblis (BZB) took place in November 2020.

Challenges with the transport organization

The companies and organizations involved in the return transport have many years of experience in the transport of radioactive materials and waste. The means of transport employed and the equipment used have already been successfully utilized several times in comparable projects. Until 2011, casks of the type CASTOR® HAW28M were already being transported by rail from La Hague to Gorleben. The same type of cask was also used in 2016 to transport vitrified waste from Sellafield to the ZWILAG in Switzerland.

Nevertheless, several firsts at the same time presented special challenges: The transport from Sellafield to Biblis was the first repatriation from the UK to Germany. For the first time in nine years, loaded CASTOR® HAW28M casks were transported within Germany, and for the first time ever, their destination was not the central interim storage facility in Gorleben, but an interim storage facility of a nuclear power plant.

Fig. 2.
Cask of the type CASTOR® HAW28M (shown in cross section, without shock absorbers).

Coronavirus pandemic

Whereas the logistical challenges were largely foreseeable, manageable, and plannable, the coronavirus pandemic brought completely new types of complications: The transport was originally planned for spring 2020 and all necessary preparations had been completed on time. On February 27, 2020, the GNS issued the so-called "Clearance for Shipment".

But on March 12, 2020, less than a week before loading was scheduled to commence in Sellafield, the Federal Police regional headquarters in Hanover, which was

Previous repatriations from France

Until 2005, spent fuel elements from the operation of German nuclear power plants were transported to the United Kingdom and France for reprocessing. The radioactive waste produced during reprocessing has to be returned to Germany. The GNS Gesellschaft für Nuklear-Service mbH has been commissioned by the German nuclear power plant operators to prepare and undertake the return of this waste to German interim storage facilities. Between 1996 and 2011, GNS already undertook twelve transports to the central interim storage facility in Gorleben, Lower Saxony; these transports involved a total of 108 large casks filled with vitrified high-level radioactive waste from the reprocessing of German fuel elements in the French reprocessing plant in La Hague. The sometimes sizeable protests against the transports, extensive discussions on the political level and within society, and days of media coverage, resulted in these transports, which were generally known as "Castor transports", becoming a symbol of the resistance against nuclear energy.

responsible for the security of the transport, gave notification that the security measures were not justifiable given the spread of coronavirus at that time, and hence the planning and realization of the transport was suspended with immediate effect.

In the months that followed, extensive coordination with all stakeholders, and the police forces involved in particular, was necessary to draw up a new transport schedule – but still with the proviso that the coronavirus risks were manageable, and under much more difficult conditions. The pandemic situation led to a new transport schedule being agreed in July 2020 for late fall. It was thus possible to avoid additional complications resulting from the completion of BREXIT at the end of the year, and repeat tests which would otherwise have had to be carried out in Sellafield on the casks which were already loaded, and the shock absorbers which were already mounted.

In addition to the extensive preparations which had already been undertaken for the transport in spring 2020, the pandemic brought completely new types of problems: A continuous, unbroken hygiene concept had to be compiled for the whole transport route from Sellafield to the port of Barrow-in-Furness, the sea crossing to Nordenham, and the subsequent rail transport to Biblis, and agreed with the authorities in both countries. In addition to the hygiene measures themselves, which have meanwhile become established, the contact between all those involved had especially to be kept to a minimum. One consequence was therefore that German representatives were not allowed to be present at the operations in the UK, for example. We had to fall back on local experts instead. And the pandemic meant that the police forces in particular also had to overcome considerable challenges posed by the operational planning along the transport route.

Transport schedule

On October 2, 2020, GNS was again able to issue the "Clearance for Shipment" and this time it was final. Shortly after 6 a.m. GMT on October 26, 2020, the first three casks left the Sellafield plant heading for the port of Barrow-in-Furness. On October 26 and 27, 2020, the casks were transferred from the railroad car and onto the transport ship, the MV Pacific Grebe. After a sea crossing lasting several days, the Pacific Grebe arrived in the port of Nordenham on November 2, 2020, under tight security. On the very same day, November 2, and the following day,

Fig. 3.
Transferring a CASTOR® HAW28M from the MV Pacific Grebe onto a railroad car at the Port of Nordenham.

November 3, the six casks were again loaded onto railroad cars for the last stage of their journey to Biblis. The train with its special cars left Nordenham on the evening of November 3 and arrived in Biblis without any major incidents on the morning of November 4.

While the transport was in progress, comprehensive measurements and tests were carried out to verify the proofs which had been provided in advance to obtain the authorizations.

Temperature measurements during the transport

A condition for the German Federal Institute for Materials Research and Testing (BAM) agreeing to the use of the transport ship, the MV Pacific Grebe, was proof that heat could be safely removed from the closed holds. The verification was therefore undertaken by continuously recording the surface temperatures of the casks during the several days they were at sea. A thermal imaging camera was used to verify that the maximum temperature on the container surface was 41 °C, and the exhaust air temperature was a maximum of 19 °C during the whole 170 hours of the measurement.

The safe removal of heat from the holds of the MV Pacific Grebe was therefore guaranteed at all times. The maximum temperature on the package was below the

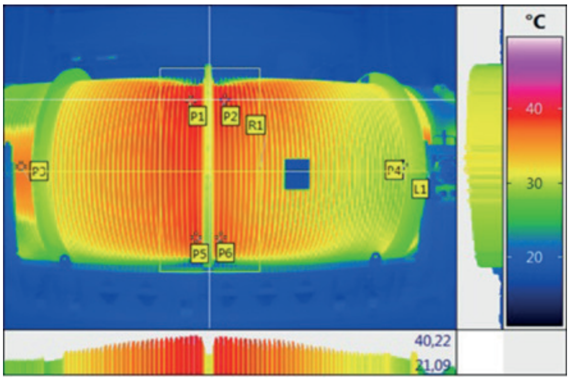

Fig. 4.
Thermographic image of a CASTOR® HAW28M in the hold of the MV Pacific Grebe.

value calculated in advance and thus significantly below the maximum permissible surface temperature of 96 °C.

Acceleration measurements during the various transport stages

A further measurement requirement originates from the 9th amended storage license of Spent Fuel Interim Storage Biblis (BZB) regarding the storage of the casks with the canisters from Sellafield. To ensure that the leak tightness of the sealing barrier for the primary lid complied with the specification, it was necessary to verify that the routine transport conditions (RBB) were complied with. To this end, the acceleration values for each individual cask on each stage of the transport were recorded by means of data loggers (Moni Log).

Here as well, it was possible to verify that all stages of the transport complied with the RBB, since the acceleration of the casks during the transport did not exceed the maximum permissible value of 2g in each spatial direction. The highest acceleration value on all transport stages was 0.85 g.

Radiological Tests

By far the most comprehensive measuring program involved the radiological tests before and during the transport. In Sellafield, the ports of Barrow-in-Furness and Nordenham, and in Biblis, too, comprehensive radiological tests were carried out during the complete transport cycle of the six transport and storage casks to verify compliance with the requirements of transport legislation and storage legislation.

To safeguard the protection of humans and, as far as the long-term protection of human health is concerned, the environment against the harmful effects of ionizing radiation during the transport and storage of the loaded CASTOR® HAW28M, compliance with the relevant limit values for the dose rate and surface contamination is also checked. The limit values originate from the ADR, RID [1, 2] regulations, and the IMDG Code [3]. The specifications of § 58 StrlSchV [4] apply to the relocation of equipment from nuclear facilities in Germany (controlled area), i.e. the (surface) contamination is < 0.04 Bq/cm^2 for α-emitters and < 0.4 Bq/cm^2 for β/γ-emitters. The limit values under storage legislation are specified in the technical acceptance conditions of the accepting interim storage facility of a nuclear power plant. The appropriate limit values which have to be applied to the cask or the package (cask with shock absorbers), the particular means of transport, and the handling equipment, are laid down in the GNS test specifications.

Execution of the radiological tests

To document all handling and test steps while the empty casks are being transported from Mülheim to Sellafield, while they are being loaded and dispatched in Sellafield, and also while the loaded casks are being transported from Sellafield to Biblis, cask-specific sequence plans including test and measurement logs which have to be signed were used.

Prior to carrying out the radiological tests, the calibration certificates for the measuring equipment which had already been submitted were checked to make sure they had not expired. At the start of each radiological test, care was taken that the measuring range of the equipment used to measure the dose rate was set correctly, and the contamination measuring devices were functioning correctly. The tests were carried out by qualified radiation protection staff.

Contamination tests:

All contamination tests were carried out in compliance with the limit values specified under transport legislation. Protocols which identify representative measuring points, and which were laid down on the basis of experience gained during the cold trails or previous use of the equipment, were used for the measurements.

The contamination tests performed while the empty casks were being transported, and for relocating equipment out of the controlled area, served to verify they were contamination free according to the limit values under transport legislation of < 0.04 Bq/cm^2 for α-emitters or < 0.4 Bq/cm^2 for β/γ-emitters.

Further contamination tests were carried out on the loaded cask and equipment while the cask was being loaded and dispatched, and while it was being transported, to verify it was contamination free according to the limit values under transport legislation of < 0.4 Bq/cm^2 for α-emitters or < 4 Bq/cm^2 for β/γ-emitters.

While the empty CASTOR® HAW28M casks were being transported from the GNS production plant in Mülheim to Sellafield, while they were being loaded and dispatched in Sellafield, and during the return transport to Biblis until the handover to the BZB, the first test method used was the wipe test for non-fixed surface contamination. A preliminary screening test, if provided for, served as an indicative test on the railroad car, for example, to prevent contaminated surfaces from being

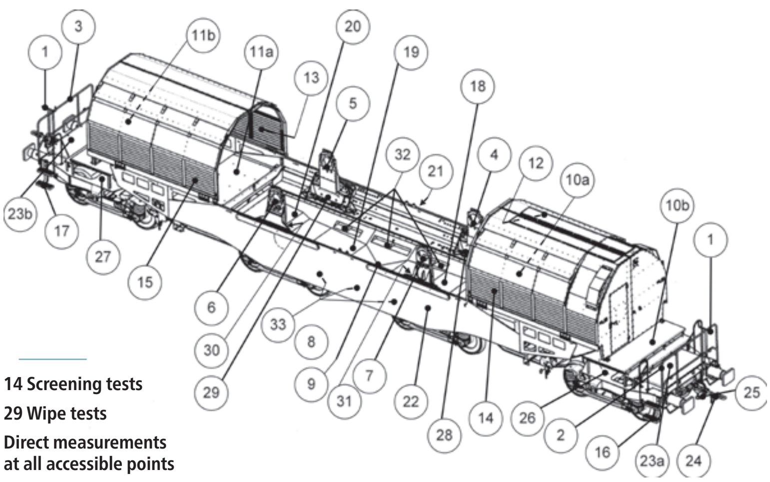

Fig. 5.
Plan of the measuring points for contamination measurements on the railroad car before loading/after unloading.

overlooked. Afterward, at each operational site, the equipment coming into direct or indirect contact with the cask, such as crane traverses, transport and storage racks, as well as railroad cars and the decks of the ship, were subjected to a direct measurement at all accessible points prior to use and checked for fixed contamination.

While the casks were being loaded and dispatched in Sellafield, and during the return transport to Biblis until the handover to the BZB, wipe tests were carried out on the particular package as well to check for non-fixed contamination.

A total of 270 wipe tests were conducted on the casks alone and the contamination measurements were assessed.

Dose rate measurements

After loading each cask, the γ and neutron dose rate was measured on the vertical cask at twelve predefined measuring points which are highlighted in color and spread over the outer surface of the cask. Afterward, the average dose rates were calculated taking into account the limit values for neutrons of ≤ 250 µSv/h and γ+neutrons of ≤ 350 µSv/h stipulated in the storage legislation.

After the cask had been transferred onto a means of transport, dose rate measurements were carried out on the package as a contact measurement on the basis of a predefined plan of the measuring points with 13 measuring points, and the maximum value was determined. The limit value under transport legislation for γ+-neutrons of ≤ 2 µSv/h had to be verified here.

After the particular cask had been transferred within the site from the loading facility to a store to prepare it for transport in Sellafield, the γ and neutron dose rate was measured at ten measuring points on the outer surface of the package at a distance of one meter to determine the transport index. The transport index is required to rate the package category, for the hazardous goods labeling among other things.

Before the loaded casks were transported from the dispatching facility in Sellafield in October 2020, further dose rate measurements were carried out on at least four measuring points in each case at a distance of two meters from the outer surface of the transport vehicle after they had been transferred onto a means of transport, and after changing the mode of transport in Nordenham, to verify compliance with the limit value of 100 µSv/h under transport legislation.

While the casks were being loaded and transported, 540 dose rate measurements (contact, 1 m and 2 m) were carried out and assessed.

Assessment of the measurements

As expected, the contamination values measured while the empty casks were being transported were below the limit values under transport legislation, so that this transport could be dealt with as a conventional transport.

The contamination values measured for relocating equipment were also below the limit values under transport legislation, so that the equipment could be returned to its conventional use.

The contamination measurements on casks and equipment during loading, dispatch, return transport until the handover to the BZB, showed that the measured values were less than 10% of the limit values specified under transport legislation of < 0.4 Bq/cm^2 for α-emitters or < 4 Bq/cm^2 for β/γ-emitters.

The average γ and neutron dose rate was determined from the results of the measurement on the loaded casks

Fig. 6.
Dosage measurement at a distance of 2 m from the transport vehicle in Nordenham.

Requirement / result	Package CASTOR® HAW28M- 01	02	03	04	05	06	Proportion of limit value (in relation to max. value) in %
Dose rate on surface of cask in acc. with storage legislation requirements Limit value: γ+neutrons < 0.35 µSv/h	0.098	0.099	0.102	0.112	0.108	0.109	32.0
Dose rate on surface of package in acc. with transport legislation requirements Limit value: γ+neutrons < 2 µSv/h	0.384	0.275	0.342	0.318	0.299	0.383	19.2
Dose rate at distance of 2 m from outside of vehicle in acc. with transport legislation Limit value: γ+neutrons < 0.1 µSv/h	0.023	0.029	0.025	0.026	0.026	0.028	29.0
Total activity of cask content in 10^{15} Bq Maximum permissible: 1,270 × 10^{15} Bq	309	325	309	316	324	379	29.8

Tab. 1.
Dose rates and activities of the casks for the transport from Sellafield to Biblis.

required by storage legislation, and recorded. During the subsequent check of the calculated dose rates, it was confirmed in the presence of experts and GNS that all the casks complied with the requirements under storage legislation. It was ascertained that the values did not exceed 35 % of the maximum permissible limit values.

The dose rate measurements as a contact measurement on the packages showed that the maximum value was approx. 20 % of the limit value for γ+neutrons of $\leq 2\ \mu Sv/h$ under transport legislation.

The verification of the limit values for the dose rate measurements under transport legislation was conducted at a distance of two meters from the packages in both Sellafield and Nordenham. It was ascertained that the maximum value was approx. 30 % of the limit value of $\leq 100\ \mu Sv/h$ under transport legislation.

The fact that the values were only a fraction of the limit values under transport legislation and storage legislation corresponds with the total activity of the HLW canister inventory in the respective CASTOR® HAW28M casks which were loaded in Sellafield. This is also due to the design of the cask shielding and an optimized loading plan.

Fig. 7.
Arrival of the MV Pacific Grebe at the Port of Nordenham. Transferring a CASTOR® HAW28M from the MV Pacific Grebe onto a railroad car.

Conclusion and outlook

All radiological tests carried out while the empty casks were being transported, while the casks were being loaded and dispatched in Sellafield, and also while the loaded casks were being transported from Sellafield to Biblis until the handover to the BZB, prove with the aid of the test results determined that during the first HLW return transport from the UK to Germany, the limit values under transport and storage legislation were safely complied with or nowhere near reached, at all locations. The measurements of the temperature and the acceleration of the casks, which were conducted in addition, likewise verified the reliable compliance with all specifications. Although the pandemic meant that the measures required were much more complex, it was possible to conduct the whole transport safely, reliably, and on schedule. The experience and insights gained while transporting the casks to Biblis form an optimum basis for the two still outstanding return transports, both of which involve transporting seven federal casks of the type CASTOR® HAW28M from Sellafield to the interim storage facilities at the Isar and Brokdorf nuclear power plants.

References

[1] ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road (Accord relatif au transport international des marchandises Dangereuses par Route), in the version valid as of January 1, 2021

[2] RID: Regulation concerning the International Carriage of Dangerous Goods by Rail (Règlement concernant le transport International ferroviaire des marchandises Dangereuses), in the version valid as of January 1, 2021

[3] IMDG Code: International Maritime Code for Dangerous Goods, 2020 edition including Amendment 40-20

[4] § 58 StSchV – Radiation Protection Act (Verordnung zum Schutz vor der schädlichen Wirkung ionisierender Strahlung – Strahlenschutzverordnung): Verlassen von und Herausbringen aus Strahlenschutzbereichen, Artikel 1 V. v. 29.11.2018 BGBl. I S. 2034, 2036 (Nr. 41); zuletzt geändert durch Artikel 6 G. v. 20.05.2021 BGBl. I S. 1194

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Marco Wilmsmeier studied bilaterally at the Gelsenkirchen University of Applied Sciences and Sheffield Hallam University, UK, waste management technology and environmental engineering. He graduated from Prof. Malcom Denman in Sheffield in 2000. Until mid-2001 he was employed as technical operations manager at SCA Packaging in Hövelhof before he started as Project Manager for loading service and reprocessing transports at GNS. In 2004 he changed to the department of recycling of reprocessing waste within the GNS and since then has been responsible as Project Manager for HAW recycling from the UK.

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