TRANSPORT OF LARGE COMPONENTS IN GERMANY – SOME EXPERIENCES AND REGULATORY ASPECTS

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ABSTRACT

After decommissioning of nuclear facilities it is very often necessary to transport large components such as steam generators or reactor pressure vessels in public areas.
In Germany, such shipments were carried out in 2007 and 2008 as follows:

- steam generators from the Nuclear Power Plant (NPP) Stade to Studsvik/Sweden by road and sea
- reactor pressure vessel from NPP Rheinsberg to the interim storage facility near Greifswald by railway and
- steam generators from the NPP Obrigheim to Greifswald as well by road and inland waterway.

The paper describes the experiences with these shipments including radiation dose assessments to transport workers as well as the main aspects of the applied regulatory procedure by special arrangement, for which the Federal Office for Radiation Protection (BfS) is the competent authority in Germany. A high level of safety could be achieved for all involved modes of transport (road, rail, sea and inland waterways).
Based on these experiences some regulatory aspects will be discussed finally which include classification issues of large components within the current IAEA Transport Regulations, the safety concept and the use of special arrangements for such shipments and options for the further development of the IAEA Transport Regulations to achieve more specific and internationally harmonized conditions or requirements for shipments of large components.

INTRODUCTION

The transport of large components from nuclear facilities is necessary in conjunction with replacement or decommissioning activities. There is no clear definition of large components due to their wide spectra in size, shape, mass, radioactivity composition and distribution according to different origin and design of nuclear facilities. Such components are e.g. reactor pressure vessels, reactor vessel heads, pressurizers, steam generators and other various kinds of components which are all quite large in dimensions and heavy in mass.
This paper is focusing on steam generators and a reactor pressure vessel as large components resulting from decommissioning of nuclear reactor facilities in Germany as presented in Fig. 1 and 2. Experiences with shipments of these components by various modes of transport will be presented as well as some regulatory aspects discussed to approve and perform such shipments under special arrangement.

EXPERIENCES WITH STEAM GENERATOR AND REACTOR PRESSSURE VESSEL SHIPMENTS

The following shipments of large components (steam generators and reactor pressure vessel) were carried out in Germany so far:

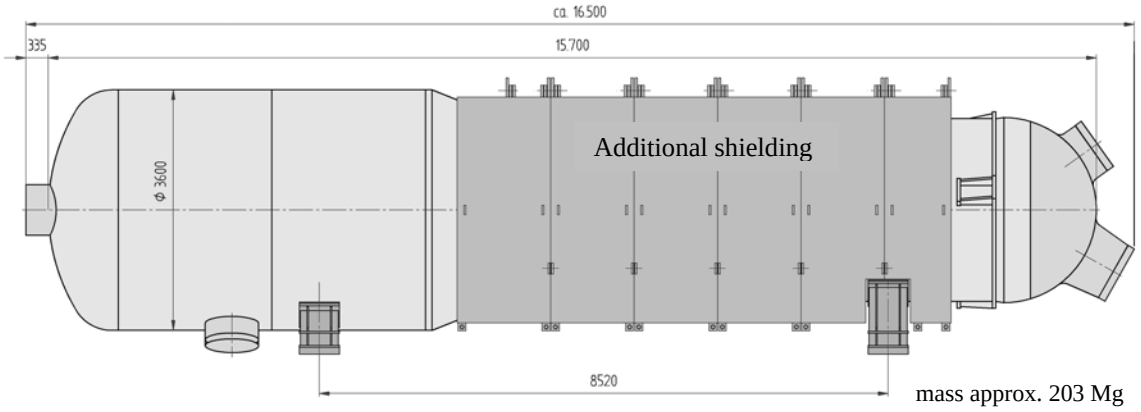

Figure 1. Steam Generator Obrigheim in transport position

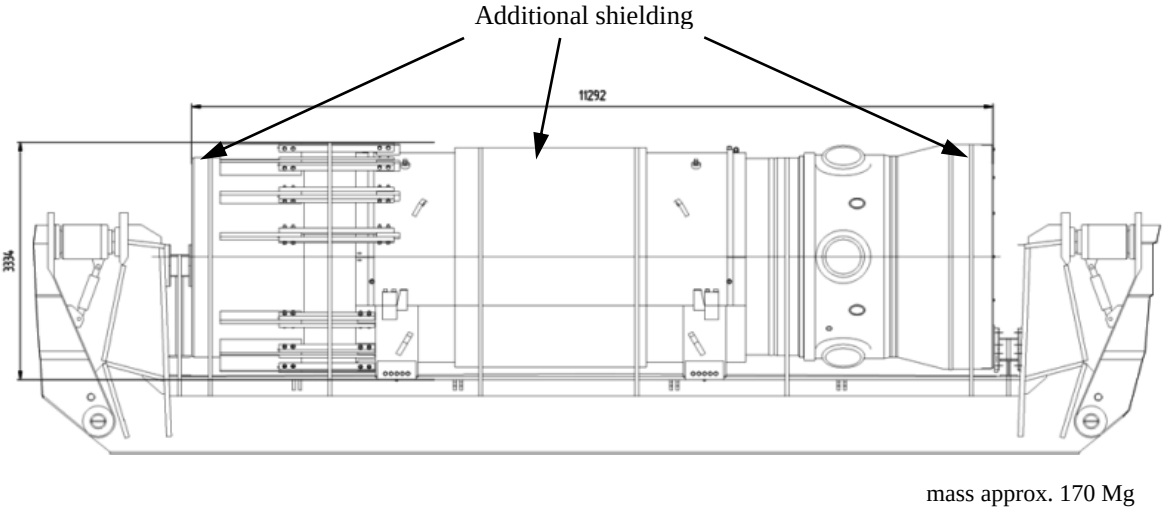

Figure 2. Reactor Pressure Vessel Rheinsberg in transport position

- the transport of four steam generators from the Nuclear Power Plant (NPP) Stade (Germany) to Studsvik(Sweden) from 19 – 23 September 2007 by road and sea,
- the transport of the reactor pressure vessel from the NPP Rheinsberg to the interim storage facility Lubmin near Greifswald from 30 - 31 October 2007 by railway, and
- the transport of two steam generators from the NPP Obrigheim to Lubmin from 23 September - 8 October 2008 by road and inland waterway.

The steam generator shipments were international transports, in which Poland was involved as transit country in one case and in the other case the consignee of the shipment was situated in Sweden. According to the international transport regulations for dangerous goods, it is required to receive approval by the responsible authorities of the countries which are affected by the transport (multilateral approval) based on a special agreement. Thereby, it is common practice that the transport approval is firstly issued in the country where the transport starts. Accordingly, the approval issuance in Poland and Sweden was carried out after the issuance of the approval certificates by BfS as the competent authority in Germany.

With respect to the transport of the 4 steam generators from the nuclear power plant in Stade to Sweden close consultations between BfS and the Swedish competent authority where already undertaken during the approval procedure due to the usage of the Swedish special ship MS “Sigyn”, especially regarding the coordination of the radiation protection programme for this ship. The international cooperation during the approval procedure turned out to be very useful and additionally enhanced the harmonisation of regulatory practice in different countries.

Specific considerations were given to radiation protection issues. Therefore, before transport as part of the radiation protection programme dose assessments for all involved persons and all transport operations (including loading and unloading) were requested. In addition, the shipment approvals for the steam generators determined that an individual monitoring of the relevant transport personnel must be conducted during transport. In the following the comparison between the estimated and measured individual doses is presented:

Transport Stade – Studsvik:
Estimated max. dose: 1,44 mSv (stowage personnel on the seagoing vessel)
Measured max. dose: 0,058 mSv

Transport Obrigheim – Lubmin:
Estimated max. dose: 1,44 mSv (Personnel on the road vehicle)
Measured max. dose: 0,08 mSv
Estimated max. dose: 0,29 mSv (Personnel on the inland waterway)
Measured max. dose: 0 mSv (below detection limit)

Transport Rheinsberg – Lubmin:
Estimated max. dose: 0,03 mSv (Personnel on the train)
Based on this estimation no individual monitoring was conducted

Comparing the estimated and measured doses it is evident, that the assessments were very conservative and led to dose overestimations. The measured doses confirmed the application of an appropriate radiation protection programme during transport.
Overall experiences have shown that the procedure of special arrangement approval has been applied very successfully to these types of shipments. The implementation of all requirements and conditions of the BfS special arrangement approval certificate ensured a high level of safety involving all useable modes of transport (road, rail, sea and inland waterways).

REGULATORY ASPECTS OF SPECIAL ARRANGEMENT PROCEDURE

Due to size, mass and construction of activated and/or contaminated large components from the decommissioning they are not easily classified into one of the package types as defined in the IAEA Transport Regulations [1]. In particular, an outer packaging in the usual sense is not feasible as can be seen from Fig.1 and Fig. 2. Such large components are therefore treated as special cases, for which the concept of transport under special arrangement in the Transport Regulations is applicable.

Classification issues for large components

The main focus of the safety demonstrations for large components is to verify, that the safety of the package is at least as high as it would be in compliance with all applicable requirements of the transport regulations. Thereby the problem may arise that it cannot be proved that the radioactive contents fully matches the radioactive material classifications and/or no packaging can be used that is in full compliance with the transport regulations. Regarding the classifications of the radioactive material, the conditions for the steam generators from Stade and Obrigheim differ from the reactor pressure vessel from Rheinsberg.

For the steam generator, the radioactive contents can be classified as surface contaminated object of the category SCO-II (see [1],para. 412) which requires a package of Type IP-2 according to the transport regulations. For the safety demonstration it needs to be shown that the contamination of the steam generator heat exchanger tubes does not exceed the defined limits of SCO-II and that the outer shell of the steam generator satisfies the requirements of an IP-2 packaging. The essential criterion for the steam generator as IP-2 package is the verification that the integrity of the packaging sustains a 0.3 m drop test on an unyielding target, to ensure that no radioactive contents is being lost or dispersed and that the increase in the maximum dose rate at any external surface of the package is restricted to 20 percent (see [1], para. 622).

For the reactor pressure vessel it must be taken into account that the radioactive contents exists as surface contamination as well as activation of parts of the large component. Accordingly, the contents needs to fulfil both the classification requirements of SCO-II and LSA-II (low specific activity material, see [1], para. 408). Regarding the assessment of the reactor pressure vessel as IP-2 packaging the same considerations apply as for the steam generator.

In addition for both types of large components the classification requirements regarding the conveyance activity limits according to para. 520 as well as the dose rate limitation of 10 mSv/h at 3 m distance from the unshielded radioactive contents according to para. 516 of TS-R-1 [1] have to be considered.

Very often it is not possible to demonstrate full compliance with all of these classification criteria so that such shipments of large components have to be classified as shipment under special arrangement assigned to the appropriate UN numbers UN 2919 or UN 3331.

Approval conditions and procedure

The conditions and requirements for a special arrangement are defined in TS-R-1, paras. 238, 310, 824-826 and 831 from which the essentials are as follows:

a) Special arrangement shall mean those provisions, approved by the competent authority, under which consignments of radioactive material which do not satisfy all the applicable requirements of these regulations may be transported.

b) Provided the competent authority is satisfied that conformity with the other provisions of these Regulations is impracticable and that the requisite standards of safety established by these Regulations have been demonstrated through alternative means the competent authority may

approve special arrangement transport operations for single or a planned series of multiple consignments. The overall level of safety in transport shall be at least equivalent to that which would be provided if all the applicable requirements had been met.

c) An application for approval of shipment under special arrangement shall include all the information necessary to satisfy the competent authority that the overall level of safety in transport is at least equivalent to that which would be provided if all the applicable requirements of these Regulations had been met. The application should also include:
   - a statement of the respects in which, and of the reasons why, the shipment cannot be made in full accordance with the applicable requirements ; and
   - a statement of any special precautions or special administrative or operational controls which are to be employed during transport to compensate for the failure to meet the applicable requirements.

Based on these conditions an application for approval of shipments under special arrangement shall include the following main information:

- period of time, related to the shipment, for which the approval is sought,
- modes of transport, the types of conveyances, and the transport route,
- specification of the actual radioactive contents,
- description of the packaging and the dose rate field around the package,
- statement of the respects in which, and of the reasons why, the shipment cannot be made in full accordance with the applicable requirements,
- technical and administrative measures to ensure that the overall level of safety in transport is at least equivalent to that which would be provided if all the applicable requirements had been met in conjunction with appropriate risk assessment considerations,
- statement of any special precautions or special administrative / operational controls which are to be employed during carriage to compensate for the failure to meet the applicable requirements,
- Radiation Protection Programme (RPP) which must take into account all steps and activities of transport and all relevant transport workers and members of the public,
- emergency response procedures.

The application documents have to be submitted to BfS as the competent authority. The assessment of the application documents with respect to the mechanical integrity of the packaging, the tie-down as well as the quality assurance aspects is conducted by the Federal Institute for Materials Research and Testing (BAM) after an assignment by BfS. All other assessments of the application documents, especially regarding radiation protection, are conducted by BfS. They comprise primarily the specification of the radioactive contents, the safety demonstration of the shielding, the radiation protection programme, emergency response requirements, risk evaluations and the handling of the package during the preparation and the whole procedure of transport. The approval procedure can only be completed with a positive statement of the expert's report by BAM and a positive result of the examinations by BfS. The approval certificate will then be issued by BfS and sent to the applicant.

<u>Specific aspects to demonstrate equivalent level of safety</u>

As described above the equivalent level of safety must be demonstrated in comparison with all applicable classification requirements for SCO-II in case of steam generators and for SCO-II and LSA-II material in case of reactor pressure vessel. The main criteria in this regard are

- the SCO-II contamination limits inside the heat exchanger tubes of the steam generator,

- the LSA-II specific activity limits of the reactor pressure vessel material,
- the IP-2 package integrity level requirements of para. 622 [1] which apply to the steam generator shell as well as to the reactor pressure vessel as outer packagings,
- the dose rate limit of the unshielded radioactive contents according to para. 516 [1], and
- the conveyance activity limits for SCO of 10 A_2 for inland waterway transport (para. 520).

The assessments showed that the compliance with the SCO-II contamination limits for the inner heat exchanger tubes of the steam generators could not be proven free of doubt and that for all large components the complete demonstration of the fulfilment of all requirements as IP-2 package could not be provided. All other criteria were fulfilled.

The BAM assessment regarding the IP-2 integrity provisions showed, that for the steam generators the required mechanical stability under the 0.3m drop test could not be shown free of doubt for certain drop positions. Therefore specific fixation and handling conditions were determined by the BfS approval certificate to assure that such drop position could not occur during transport. Similarly, the compliance with the required safety level for the transport of the reactor pressure vessel was assured through a secure fixation of the large component, specific tie-down requirements and handling restrictions.

Based on the assessment of the shielding and the radiation protection analyses by BfS further conditions and measures were stated to decrease the individual doses to persons and to assure compliance with applicable dose rate limits at the large components and conveyances.

In the approval certificates these technical measures were completed by some administrative/operational conditions like e.g.:

- notification of the involved authorities before and during the shipment,
- limitation of the velocity of the vehicle (rail and road transport),
- restrictions on the ambient temperature conditions (for reactor pressure vessel)
- emergency response requirements, and
- operational controls for preparation, loading, shipment and unloading

Due to all these measures and conditions it was guaranteed, that the overall level of safety in transport was at least equivalent to that which would be provided if all the applicable requirements had been met.

FUTURE DEVELOPMENTS

There will be an increasing need to transport large components from nuclear facilities in the future. The described experiences in Germany have shown that the procedure of special arrangement approval can be applied very successfully to these types of shipment for all modes of transport. Similar positive experiences are also available in other countries. Therefore this topic has also been discussed during the current IAEA revision process of the Transport Regulations TS-R-1 [1] and the corresponding Advisory Material TS-G-1.1 [2] with the aim to develop more specific and internationally harmonized regulatory conditions for such shipments of large components. The latest IAEA Technical Meeting within this revision process was held in Vienna in January 2010. It recommended to develop guidance material for the transport of large components under special arrangements and drafted appropriate text for TS-G-1.1 as an input to the ongoing revision process. This advisory text has been supported by the Transport Safety Standards Committee (TRANSSC) at its last meeting at IAEA in Vienna in June 2010 to be sent out for Member States comments. This advisory text is intended to be a standardized guidance for competent authorities to be used as reference for large component special arrangement preparation and approval as well as for the industry for its preparation and application activities.

This guidance material is focusing on large objects which are generated from light water reactors facilities and which are mainly surface contaminated objects with a mass of a few 10 tons to a few 100 tons.

Basic safety criteria

Steam generators as discussed in this paper belong to this category of large objects as contained in the draft TS-G-1.1 and therefore some additional generic considerations will be derived in the following from the described experiences as a basis for further guidance for special arrangement procedures.

Despite administrative and operational special arrangement conditions the main basic safety requirements for the transport of steam generators as large components can be summarized as follows:

a) The large component itself must meet the SCO-II and IP-2 package requirements as far as possible. If additional shielding is needed it must be considered as part of the IP-2 package. The most important criteria to be demonstrated are the required package integrity level under 0.3 m drop test conditions and the limitation of radiation level increase after drop test to not more than 20 %,
b) If the requested package integrity level under drop test conditions can not be fully demonstrated for certain drop positions technical measures must be applied to avoid that such drop positions can occur during transport,
c) The dose rate at 3 m distance from the unshielded contents of the large component must not exceed 10 mSv/h and the conveyance limits of 10 A_2 for inland waterway transport and 100 A_2 for all other modes of transport must be complied with, and
d) The limitation of the total radioactive contents inside the large component must be such that under accident conditions of transport an equivalent level of safety will be achieved as for IP-2 or Type A packages.

Based on this the total radioactive contents inside the steam generator is limited by c) and d).
The unshielded dose rate limit of 10 mSv/h according to c) restricts the permissible activity level of gamma emitters. A model calculation of the dose rate field around a typical bundle of heat exchanger tubes shows that for Co-60 as a strong gamma emitter the permissible total activity is restricted to 2.8 TBq which is equivalent to 7 A_2. For this calculation the bundle of heat exchanger tubes was modeled as a homogenized bundle (diameter 240 cm, height 787 cm, density 0.78 g/cm^3) with the Co-60 activity distributed throughout.
Under accident conditions of transport various exposure routes must be considered as outlined in the Q-System [2]. The potential exposure due to external gamma radiation is already limited by the 10 mSv/h dose rate criterion according to c) in compliance with the Q-system. Besides this external dose due to gamma radiation the potential inhalation dose is considered to be the main exposure route under accident conditions. Regarding this inhalation dose some conservative assessments have been performed by Lange [3] to estimate the potential inhalation dose of a person in the vicinity of a damaged steam generator following a severe accident with a mechanical impact equivalent to the 9 m drop test for Type B packages. The results show that under such conditions the intake by inhalation is not more than 10^{-5} of the released activity from the damaged steam generator. If this activity release does not exceed 10^{-1} A_2 the resulting intake by inhalation is not more than 10^{-6} A_2 which is consistent with the Q-System to demonstrate that the inhalation dose to a person exposed in the vicinity of a transport package following an accident should not exceed 50 mSv. According to

the Q-System a release fraction in the range of 10^{-3} to 10^{-2} can be assumed for an IP-2 package because its required integrity level is comparable with that of a Type A package for solid radioactive material. The application of this release fraction range to the steam generator would result in a maximum permissible radioactive contents in the range of 10 A_2 to 100 A_2. The adopted release fraction range from 10^{-3} to 10^{-2} represents very conservative values for a steam generator because this release fraction range was used for the purpose of the Q-System which is based on quite different package types. A more realistic and much lower release fraction of 10^{-5} for the steam generator has been derived by Lange [3] which takes into account the large size and volume of the steam generator as well as the kind and properties of the radioactive contents (mainly contamination inside the closed heat exchanger tubes) and the various release barriers and mechanisms on the release path of this radioactive contents from inside the heat exchanger tubes to the outer shell of the steam generator.
In summary if both exposure routes due to external gamma radiation and due to inhalation are taken into account it can be concluded that for a total radioactive contents of the steam generator in the range of 5 A_2 to 10 A_2 an adequate level of safety also under accident conditions of transport is provided. Based on more specific assessments even higher levels of the total activity contents could be justified.

CONCLUSIONS

Within the framework of the decommissioning of nuclear power plants transports of large components are necessary. In the years 2007 and 2008 transports of 6 steam generators and of a reactor pressure vessel were carried out in Germany involving all useable modes of transport (road, rail, sea and inland waterways).
Overall experiences have shown that the procedure of special arrangement approval could be applied very successfully to these types of shipments. The implementation of all requirements and conditions of the BfS special arrangement approval certificate ensured an adequate level of safety in compliance with the transport regulations.
Also in the future such transports will be necessary. Experiences should also be used to develop the provisions for special arrangement within the IAEA transport regulations and their supporting documents further to achieve more specific and internationally harmonized guidance for such shipments of large components. This subject is among others on the agenda of the current revision process of the IAEA transport regulations focusing on the development of specific advisory material. Some contributions to such an advisory material can be derived from this paper. All interested parties in this field should be encouraged to contribute to this IAEA revision process with their experiences and should provide their input to develop appropriate guidance within due time.

REFERENCES

[1] Regulations for the Safe Transport of Radioactive Material, 2009 Edition, Safety Requirements No. TS-R-1, International Atomic Energy Agency (IAEA), Vienna 2009
[2] Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No. TS-G-1.1 (Rev.1), International Atomic Energy Agency (IAEA), Vienna 2008
[3] F. Lange, Estimation of potential exposure from a severe accident during transport of a steam generator as SCO-II, 2010-09-05, private communication