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TRANSPORT OF TWO STEAM GENERATORS FROM THE NUCLEAR POWER STATION KWO TO THE INTERIM STORAGE SITE OF EWN

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ABSTRACT

The paper presents the project to move two steam generators from the nuclear power station KWO to the interim storage site of EWN GmbH in Greifswald, Germany. The steam generators have a diameter of 3.6 m and a length of 16.6 m. The total mass is approx. 177 to. One of the steam generators must be equipped with additional shielding which adds another 25 to.

The first issue to be solved was the categorization of the steam generators with respect to the Regulations. Due to the design of the inner surfaces which are not accessible it could not be proved with certainty that the steam generators comply with SCO-II. Therefore the transport has to be carried out under special arrangement. However, the steam generators fulfill the requirements towards an industrial package of type IP-2.

Second, the transport route had to be evaluated. The only feasible mode of transport is by barge on inland waterways. The itinerary will start at the reactor site of KWO which has direct access to the river Neckar and lead through inland waterways and channels to the Baltic Sea. After a short trip through the coastal waters the site of EWN will then be reached. At KWO and EWN a short road transport is necessary to reach the barge and the new storage site, respectively.

The third problem to be solved was the tie-down of the large parts to the heavy cargo trailers used for the road transport and to the barge. NCS devised a solution which provides adequate safety, reduces radiation exposure of the personnel and is economically favorable for EWN.

INTRODUCTION

In 1983 two steam generators were dismounted in the nuclear power station Obrigheim (KWO), Germany and replaced by new ones. They were stored in an interim storage on-site for a limited period of time. The intention was to scrap the steam generators after the storage period. As no installation for scrapping such heavy components is available on-site and the interim storage is required for waste accruing from dismantling the reactor the steam generators have to be moved to the site of EWN GmbH in Greifswald, Germany. Fig. 1, which shows a typical steam generator, gives an impression of the task at hand.

Figure 1. Typical steam generator

The paper will present an overview of the design, dimensions and mass of the steam generators as well as of the IP-2 proof and the additional shielding measures. Then the logistics will be discussed and the tie-down measures shown. Remarks concerning licensing will conclude the paper.

DESIGN, DIMENSIONS AND MASS

The design of the steam generators is shown in Fig. 2. They consist of a thick shell of boiler plate which is closed at the bottom (primary) side with a spherical calotte and on the top (secondary) side with a dished end. At the primary side there are 3 welded nozzles with primary inlet/outlet and a manhole. At the top side there is the steam outlet in central position. At the cylindrical shell there are manholes and handholes. Inside the steam generators there is the primary tube bundle attached to the tube bottom and secondary side installations. Main data of the steam generators are given in Tab. 1

Table 1. Main data of the steam generators

Characteristic	unit	
Total length	mm	16 580
Diameter	mm	3 600
Mass	kg	177 000

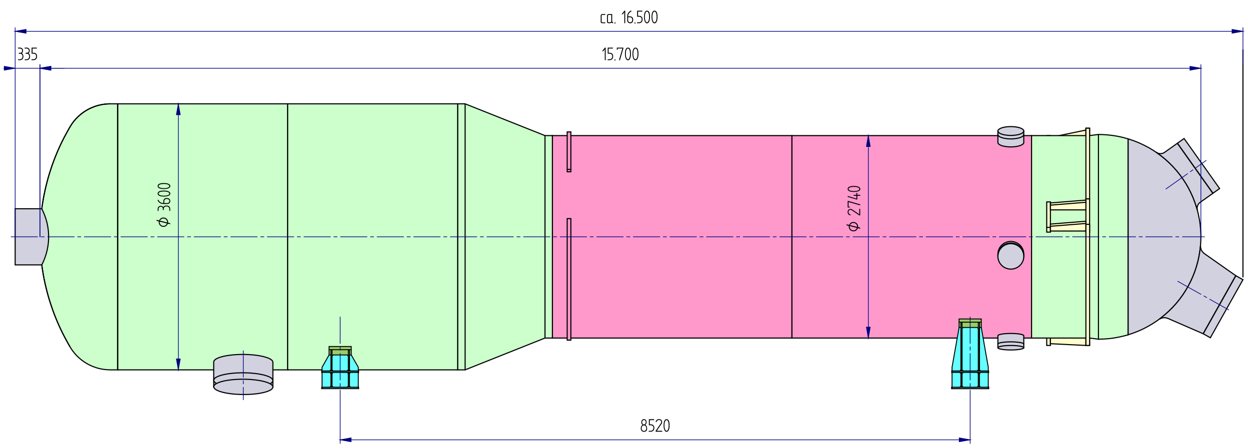

Figure 2. Outer dimensions of the steam generators

RADIOLOGICAL PROPERTIES OF THE STEAM GENERATORS

Contamination

For the categorization of the steam generators as SCO-II the fixed and non-fixed contamination of the accessible and inaccessible surfaces must be assessed. The relevant limits are given in Tab. 2. The contamination has to be in all cases averaged over a surface of 300 cm^2.

For the outer surface of the package the general contamination limits apply:

- beta and gamma emitters and low toxicity alpha emitters: 4 Bq/cm^2
- all other alpha emitters: 0,4 Bq/cm^2

Table 2. Contamination limits for SCO-II

Accessible / inaccesible	Fixed / non-fixed	Contamination type	Bq/cm^2
Accessible	non-fixed	beta + gamma + alpha[1]	400
		alpha	40
	fixed	beta + gamma + alpha[1]	8×10^5
		alpha	8×10^4
Inaccessible	non-fixed + fixed	beta + gamma + alpha[1]	8×10^5
		alpha	8×10^4

1) low toxicity alpha emitters

First, samples of the contamination of the accessible surfaces taken during the decontamination of the steam generators some years ago were analyzed. The main radionuclides in the analysis were Co-60, Ni-63 and Fe-55 with a small amount of alpha contamination. Then, taking into account Co-60 contamination, dose rate calculations were carried out and compared with dose rate measurements on the steam generators. From the Co-60 contamination which resulted in the same dose rates as measured and based on the composition of the samples the contamination contribution of other radionuclides was derived.

The average contamination derived with the procedure described above was less than 20% of the contamination limit for SCO-II. The same procedure applied to local hot spots near the manhole in the primary part of the steam generators resulted in contamination values which exceeded the limit by a factor of 2 - 4.

Radioactivity

The total activity of the contamination was derived from the above calculations and measurements. Conservative assumptions resulted in a total activity of less than 10 A_2.

Dose rate

The dose rate limits if transported under exclusive use are:

surface of the package:	≤ 10 mSv/h
surface of the vehicle:	≤ 2 mSv/h
2 m distance from the surface of the road vehicle:	≤ 0,1 mSv/h

On one of the steam generators the dose rates measured in two meter distance from the steam generator (equivalent to 2 m distance from the road vehicle) exceeded the limit of 100 µSv/h. All other dose rates measured were within the limits of the transport regulations.

IP-2 PROOF

According to TS-R-1 para. 622 a package to be qualified as IP-2 shall be designed to meet the requirements for IP-1 and, in addition, if it were subjected to the tests specified in paras 722 and 723, it would prevent:

(a) loss or dispersal of the radioactive contents; and
(b) a more than 20% increase in the maximum radiation level at any external surface of the package.

The general requirements for all packagings and packages as specified in TS-R-1 paras 606-616 are certainly fulfilled and the requirement of para. 634 (smallest dimension more than 10 cm) is obviously fulfilled as well. So the steam generators meet the requirements for IP-1.

The stacking test TS-R-1 para. 723 is not applicable because the shape of the steam generators prevents stacking and stacking of objects of this size during transport is not a realistic or even feasible option.

What remains is the free drop test according to TS-R-1 para. 722 and according to TS-R-1 Tab. 13 the drop height must be 0.3 m. The proof was carried out analytically by using Finite Element calculations with the 3D code LS-DYNA[1]. For the calculation model of the steam generators only the outer shell, bottom, head and the tube plate were considered. The primary inlet/outlet and the manhole in the primary chamber wall as well as the hand hole in the impact area were explicitly modeled. The total mass of the inner components and the mass of the additional shielding were considered, too.

The drop orientation complied with the transport configuration. The result of the calculations was that the global stresses in the shell of the steam generators are far below the yield strength of the material. Locally, at the primary inlet, the manhole and the handhole there are large plastic strains which are, however, smaller than the breaking elongation. It can th us be concluded that

- based on the negligible remaining deformations no increase of the maximum dose rate need to be assumed
- a release of radioactivity is not possible beca use the integrity of the steam generators is preserved

With this it was proved that the steam generators fulfill the requirements for a type IP -2 package.

SHIELDING

The shielding around the primary part of the st eam generator is shown in Fig. 3 . It consists of a 40 mm thick mild steel encapsulation. Local shielding measures with lead reduce the dose rates at the hotspots at the bottom nozzles.

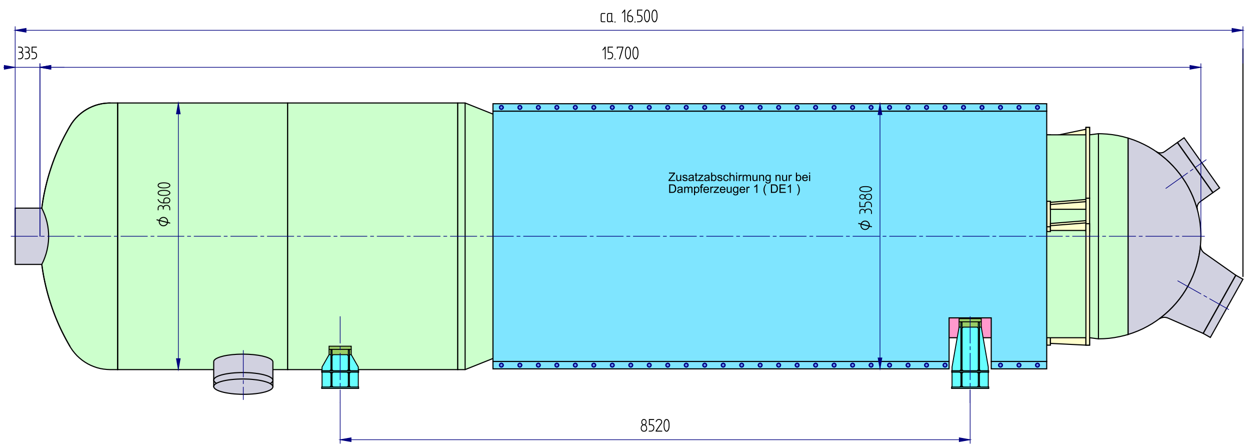

Figure 3. Shielding around the primary part

LOGISTICS

The nuclear power station KWO is located in the southern part of Germany adjacent to the river Neckar which flows into the river Rhine. The interim storage of EWN is located in the very northern part of Germany at the Baltic Sea. The road distance is approx. 900 km.

Neither road nor rail transport was proved to be a feasible way because of the size and mass of the steam generators. It was hence decided to transport them by barge with short road transports at the start and end of the journey. In detail the route is as follows:

- Road transport from the nuclear po wer station KWO to a nearby port at the river Neckar
- Transfer onto a barge RO/RO
- Transport from the River Neckar via several inland waterways (rivers and channels) and the German coastal waters of the Baltic Sea to the harbor of Lubmin
- Transfer to road tra nsport vehicles with cranes (no RO/RO harbor)
- Road transport to the interim storage of EWN

TIE-DOWN MEASURES

Fig. 4 shows the tie-down measures. During transport the steam generators rest on two supports which are attached to a base plate. Steel wedges welded to the supports at both sides prevent lateral movement of the steam generators. Large supports, which are fixed to a base plate, prevent movements in axial directions. All connections of the different parts of the tie -down system are furnished with anti-sliding mats and are bolted to the heavy load road vehicle.

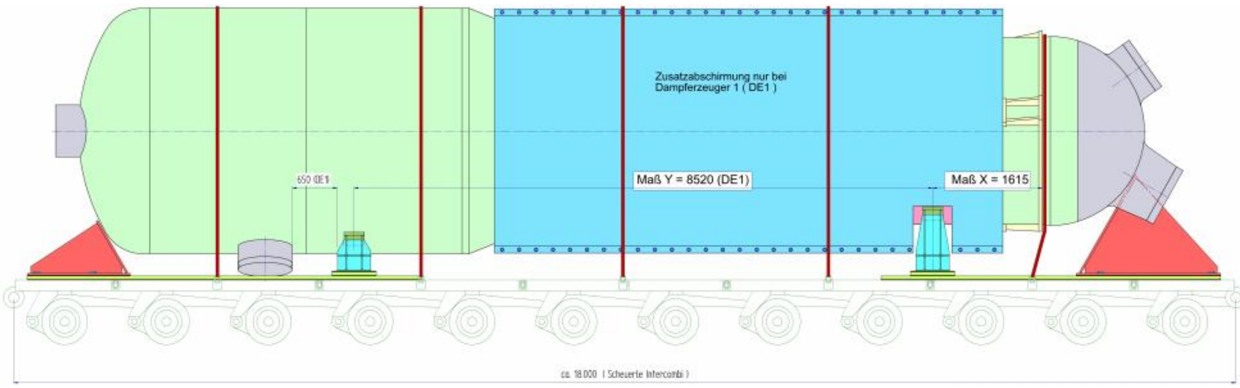

Figure 4. Tie-down

On the barge, chains are used for additional tie -down.

LICENSING

The transport of the steam generators must be licensed by the German and the Polish Competent Authority. The application for the transport permit must contain following details:

- Carrier
- Transport route
- Transport means
- Description of transfer operations / change of transport means
- Number and kind of transports
- Consigner, consignee
- Description of the radioactive material
- Description of the packaging
- In case of special arrangement: reason and compensating measures
- Radiation protection programme

The application for the transport permit was filed in March 2007.

EXPERIENCE WITH SIMILAR TRANSPORT

In September 2007 NCS carried out the transport of steam generators from the nuclear power station in Stade to Studsvik Nuclear in Sweden. Fig. 5 shows the transfer of the steam generators from the road transport vehicle to the vessel by floating crane. Fig. 6 shows the ste am generator in the load compartment of the vessel.

Figure 5. Transfer of the steam generators by floating crane

CONCLUSIONS

The transport of large and heavy radioactive objects is challenging in the planning phase as well as in the transport phase. In the planning phase the radiological properties of the object must be assessed in a conservative manner acceptable to the competent authority. For the design of shielding measures the dose exposure of workers during installation has to be considered carefully. The tie-down is a more routine task as NCS has a long term experience in the transport of large and heavy objects up to a mass of 450 to.

The transport itself is under the supervision of the competent authority. The transport schedule must be adhered to at all times. Unplanned delays must be reported immediately to the involved authorities and in the transport involved partners. For the transport qualified equipment must be used to ensure always the safety of the operation.

NCS is experienced in the transport of radioactive material and of heavy cargo. With its high qualified personnel and own equipment all steps of the planning and realization of such a transport are safely carried out.

Figure 6. Positioning of the steam generator in the vessel

REFERENCES

[1] LS-DYNA, A Program for Nonlinear Dynamic Analysis of Structures in Three Dimensions, Version: 971s, Revision: 7600.398, Livermore Software Technology Corporation, 17.08.2006