

**Decommissioning of the reactor pressure vessel and its peripheral facilities
of the Nuclear Power Plant in Stade, Germany – 11100**

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ABSTRACT:

The modern Dismantling of reactor pressure vessels (RPV) is based on a systematic and safe project execution without any aerosol migration or carry over of contamination.

In March 2009 E.ON Kernkraft Company, Germany signed a contract with the consortium Siempelkamp NIS Ingenieurgesellschaft mbH (NIS) as leader and E.ON Anlagenservice GmbH (EAS) for concept development, the delivery of all necessary equipment and for dismantling and packaging of the reactor pressure vessel with its peripheral facilities of the nuclear power plant Stade.

The high contaminated and activated RPV was segmented in 2010 by means of remote controlled cutting tools utilizing a special manipulator system, a high performance thermal cutting system and angle grinder as cutting tools.

The engineered equipment was developed in a 18 months R&D program and then approved in a short two months testing phase.

It was qualified to cut through steel walls of more than 500 mm thickness.

The RPV as well as its peripheral facilities had to be segmented into such size, that the segments could afterwards be packed into shielded waste containers each with a volume of roughly 1m³.

Segmentation of the RPV and its peripheral facilities, like coolant loop tubes and shielding chambers was performed within 12 month.

INTRODUCTION:

The Nuclear Power Plant KKS in Stade was a light water pressurized reactor. It went critical for the first time in January 1972. The reactor had an electrical output of 630 MW. After 31 years of successful operation, the Nuclear Power Plant went off line in November 2003.

After the disposal of the fuel elements, the Nuclear Power Plant has been running in site-mode operation since September 2005.

The Nuclear Power Plant deconstruction is divided into 5 phases, which shall be completed until 2015.

- Phase 1: Deconstruction of machinery and parts, which are not required for "residual" operation. Preparation of further decommissioning steps and necessary infrastructure
- Phase 2: Deconstruction of large components in the containment building
- Phase 3: Deconstruction of the reactor pressure vessel with internals
Deconstruction of the biological shield
- Phase 4: Deconstruction of the remaining contaminated parts. Proof of absence of contamination, Release of remaining structures from governmental nuclear supervision
- Phase 5: Destruction of conventional structures

Phases 1 and 2 have already been finished. Phase 3 is currently being performed. The consortium Siempelkamp NIS Ingenieurgesellschaft mbH and E.ON Anlagenservice mbH was assigned with the subproject of phase 3 „Disassembling, dismantling and packaging of the reactor pressure vessel”.

The dismantling concept for the reactor pressure vessel and its peripheral facilities comprises the following main steps:

- Step 3.1: Removal and packaging of the shield compartments
- Step 3.2: Dismantling of the eight coolant pipes of the RPV and packaging in repository casks
- Step 3.3: Dismantling and packing of the RPV insulation with its sheet metal covering
- Step 3.4: Dismantling and packing of the flood container of the RPV
- Step 3.5: Disassembling and dismantling of the RPV as well as packing into waste containers

Project Target

The aim of the project was the dismantling of the RPV and the dismantling and packaging of the reactor pressure vessel (RPV) with its peripheral facilities.

The project was operated by the following objectives:

- execution by safety objectives:
 - Minimizing of radiation exposure to the staff
 - Keeping the activity within the control area
- safety and risk minimized technical execution
- cost transparency and cost optimizing
- minimizing of project execution time
- waste minimizing and using licensed waste containers and disposal routes in an optimal way
- packaging concept with respect to intermediate storage as well as to the national “KONRAD” final repository requirements

The KKS reactor pressure vessel was manufactured with high strength steel and a chromium nickel steel plating inside the vessel.

The RPV has the following dimensions:

- | | |
|--|-----------|
| • external diameter | 4700 mm |
| • height | 7941,5 mm |
| • max. wall thickness (flange) | 478 mm |
| • wall thickness (cylindrical part) | 199 mm |
| • thickness of the plating | 7 mm |
| • total mass with 8 pcs. Coolant-pipes (3000 mm) | 209 Mg |

Radiological Initial Condition

Already before segmentation of the RPV internals, the RPV and the primary system had been chemically decontaminated. During the dismantling phase of the RPV activation of the RPV and its additional parts e.g. the insulation and the flood container were therefore the main radiation source.

Activation of the reactor assembly group were mainly based upon:

- neutron flux density surrounding the core during the former power operation
- characteristics of the reactor during its power operation
- material properties
- decay time between the end of the last operation cycle and the beginning of dismantling

For the characterisation of the radiological status, a calculation was made according to the above mentioned factors for the radial and axial neutron flux density allocation. To get serious and actual data, a comprehensive probing and measuring program was performed.

For the packaging of the activated parts, the Co-60 inventory was essential. Table 1 shows are the parameters for the specific Co-60 activity of the RPV based upon the results of the measuring and probing program.

Table I. Specific Co-60-activity of the activated areas of the RPV after the measuring and probing program

Assembly group		specific Co-60 activity [Bq/g]
Reactor Pressure Vessel		
RPV- flange		
	base body	9,9E2 – 4,38E3
	plating	2,02E3 – 9,12E3
RPV core		
	base body	1,43E5 – 2,09E5
	plating	4,74E5 – 6,15E5
RPV calotte (bottom)		
	base body	4,96E1 – 1,36E2
	plating	1,21E1 – 1,19E2
contamination, Bq/cm ²		1,22E2
RPV-flood container		1,37E5
RPV-insulation (liner)		2,2E5

Technical Resources

For dismantling of the RPV on site available systems as well as new systems were used:

Existing equipment:

- polar crane
- radiation protection instrumentation
- main ventilation
- lifting accessories
- shielding material
- weighing equipment for waste containers
- water supply and disposal system

New equipment:

- 5-Mg- gantry crane for transportation of the segments to the packaging station
- 6-axis-manipulators with own elevator platforms for the remote controlled segmentation of the RPV
- propane and oxygene gas supply
- sealed housing above the spent fuel element pool incl. a ventilation system to exhaust and filter the combustion gas and to prevent contamination leakage from the housing
- ventilation system with 8.000 m³/h to exhaust and filter the combustion gas
- high performance thermal cutting and mechanic cutting tools
- modular packaging station for contamination-free handling and loading of MOSAIK and KONRAD containers
- turntable with redundant drives as mounting construction for the RPV
- shielding plate with suction hood placed on top of the RPV during segmentation

Terms of Radiation Protection

Due to health physics requirements the expected collective dose had to be calculated and agreed by the licensing authorities. For the ongoing work in the different radiation areas a total dose of 180 mSv was calculated and accepted by the authorities. The main work activities were:

- Installation of the necessary equipment
- Removal of the shield compartments and the eight cooling pipes
- Transportation of the RPV out of the reactor pool into the spent fuel pool
- Dismantling and packaging of the RPV insulation, and flood container
- Dismantling and packaging of the RPV
- Handling of the waste containers

The dismantling of the RPV itself was mainly operated and surveyed by remote controlled systems. This was the main measure to keep the collective dose below 180 mSv.

Planning of Segmentation and Packaging

The segmentation of the RPV and its peripheral facilities was based on a very detailed cutting and packaging planning. On one hand technical demands had to be respected and on the other hand radiological requirements and the demands of the interim store of NPP Stade as well as the requirements of the final storage in KONRAD had to be concerned.

Finally the segmentation plan in figure 1 included 172 single segments. Each of these had to be characterized radiologically.

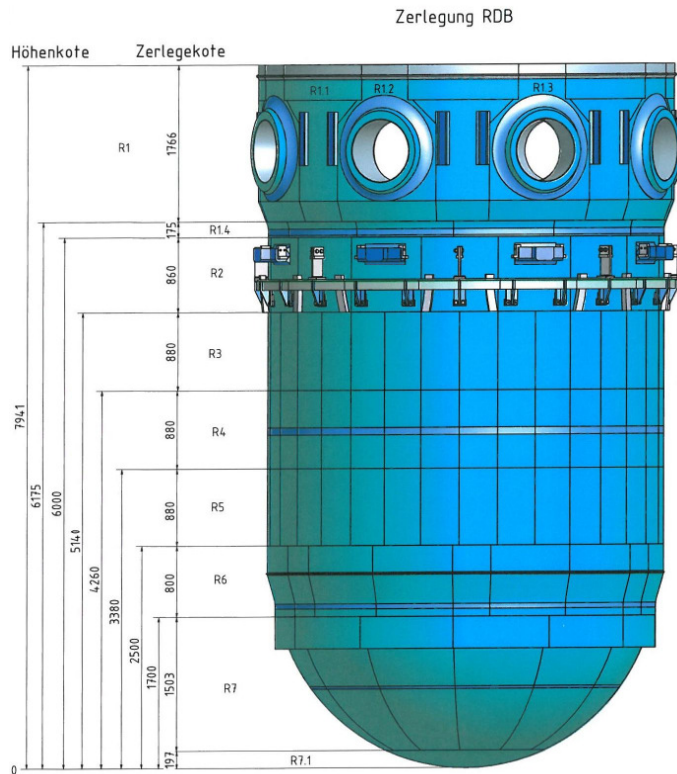


Fig. 1. Cutting plan of the RPV in single segments

The segments from the core zone of the RPV were packed into cast iron containers (MOSAIK), all other segments into steel containers with additional concrete shielding (KONRAD).

Main Procedure

At the project start the RPV was located in the reactor cavern. The internals were removed. The barium sulfate filling behind the shield compartments of the biological shield was removed as well.

The dismantling of the Reactor Pressure Vessel was done basically with thermal cutting tools. Mechanical cutting tools were only used for some special tasks. Only approved dismantling and segmentation techniques based on light weight tools and tool carrier were used. The reliability of the equipment was approved by former projects experience. This choice of the dismantling tools was essentially based on safe operation and economical aspects.

According to that choice it was possible to minimize the dismantling equipment. Furthermore the area for segmentation activities was restricted and isolated from surrounding areas. Thereby contamination hazards for the rest of the control area was minimized. To take care of the health of the staff and to minimize the dose, the dismantling work on high activated parts was operated completely remote controlled. Manual segmentation and packaging jobs were done only on low activated component.

The first dismantling step 3.1 was the manual disassembling of the peripheral facilities of the RPV. The 22 shield compartments were segmented with grinders and flame cutters. In step 3.2 the eight coolant pipes of the RPV were cut with a pipe disconnecter.

Parallel to the before described preparative work, the testing phase for the segmentation equipment and for the high performance thermal dismantling tool was ongoing on a separate testing field outside the NPP.

After finishing the segmentation work at the peripheral facilities and the activities at the equipment testing field, the installation and the start-up of all necessary equipment (fig 2.) have been executed.



Fig. 2. Total view over the spent fuel pool with dismantling and packaging facilities

Before hoisting the RPV out of the reactor cavern, part of the insulation, instrumentation pipes and pipings surrounding the RPV-Flange were removed. This was necessary for the following separation of the RPV-Flange from the cylindrical part of the RPV. Separation of the RPV-Flange was necessary because of the RPV's 209 Mg. The maximum capacity of the polar crane was 180 Mg. To avoid an overload of the polar crane, the first working step was the separation of the RPV-Flange from the RPV cylindrical part before lifting the RPV out of the cavern. The separation was made with a rotating thermal cutting system positioned on top of the flange. After separation the RPV-Flange was transported to an interim storage place. The cylindrical part of the RPV was then transported with the polar crane to the final dismantling place, the turntable, inside the spent fuel pool.

In step 3.3 the RPV-Insulation consisting of aluminium foil and the surrounding stainless steel jacket was remote controlled segmented by the 6-axis manipulator with angle grinder and nibbler (Fig 3.). A parallel gripper at the second 6-axis manipulator was the "helping hand".

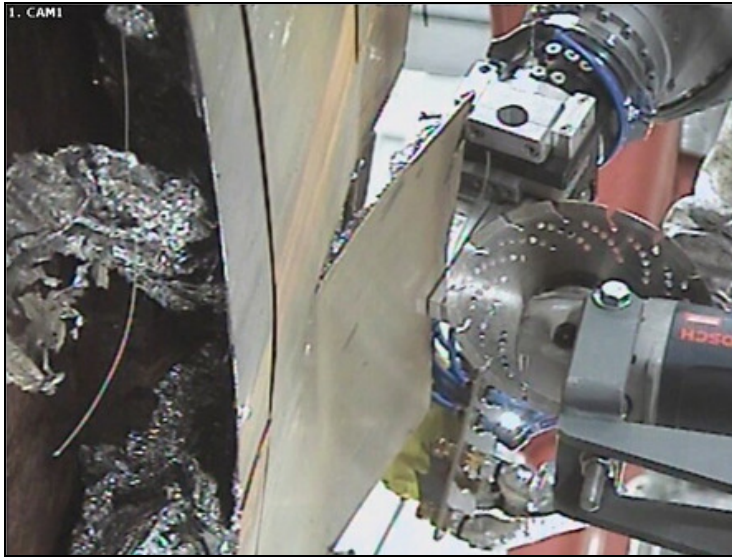


Fig 3. Remote controlled segmentation of the RPV-Insulation

After this, in step 3.4, the surrounding stainless steel flood container and transversal ring in the core area of the RPV were segmented. The flood container was segmented with the grinder into several sheets which then were inserted into a magazin for packaging into KONRAD containers. The transversal ring was segmented by the high performance cutting torch.

In step 3.5 the cylindrical part of the RPV (fig 4.) with a wall thickness of 199 mm was dismantled from top down to the RPV-bottom with the high performance cutting torch into single segments in accordance with the above described cutting plan.

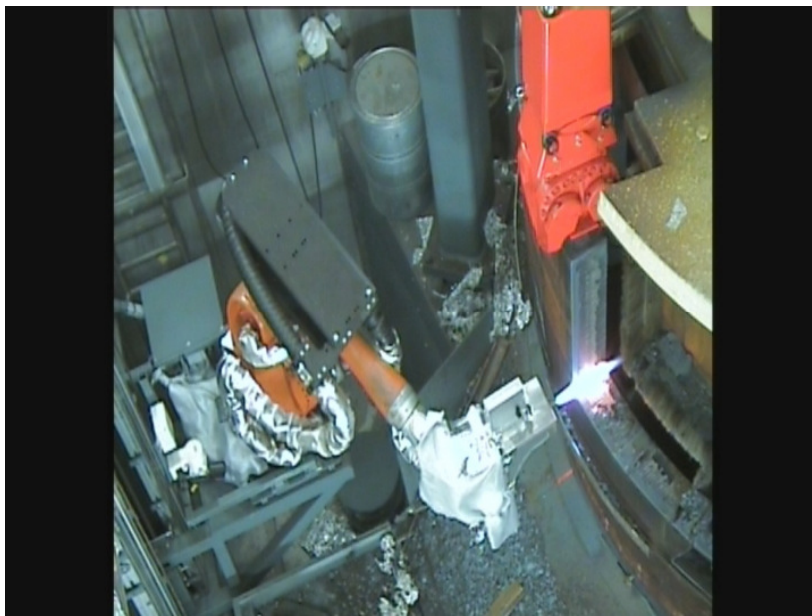


Fig 4. Final cut with gripped RPV segment

For dismantling of the RPV-bottom the substructure of the turntable had to be modified. RPV-bottom was cleaned from slag with a special slag sucking system.

After finishing the thermal dismantling of the RPV-bottom, the flange was transported from its interim place to the prepared turntable. V-notches were first cut into the stainless-steel-plated upper sealing face with a high grade milling cutter. After that the flange with its wall thickness of 478 mm was segmented with the high performance cutting torch into 16 single segments.

After finishing the dismantling works, the segmentation and packaging areas were cleaned and the before installed equipment was removed by the consortium Siempelkamp-NIS and EAS.

Conclusion

The customer's contract was based on a safe project execution without any carry over of contamination or aerosol migration from the dismantling area into other areas. These requirements were met by a sealed housing with ventilation system and remote controlled segmentation tools.

Furthermore the customer expected a cost and time optimized project development. The agreed project deadline and the budget limits were also met.

The planning, purchasing and start-up of the equipment took a period of 15 months. The dismantling of the RPV was performed within 4 months.

Because of the very successful project performance an additional order for the RPV lid segmentation was also placed to the consortium. The dismantling and packaging of the lid was performed within 13 working days.

An innovative project management, a highly professional team with an excellent team spirit crowned the success of this project and completely met the ambitious demands of the customer.