Dismantling of the Obrigheim NPP Reactor and Waste Management – 14500

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ABSTRACT

The Obrigheim Nuclear Power Plant (KWO) is located in the Neckar-Odenwald district in the Federal State of Baden Württemberg in Germany and was operated by the EnBW Kernkraft GmbH. The Nuclear Power Plant – a light water pressurized water reactor with 357 MW of electrical power – was commissioned on 29 October 1968. The power operation was stopped on 11 May 2005. In June 2009 the Energiewerke Nord GmbH was charged with the planning and dismantling of the reactor.

According to the German nuclear and radiation protection law, several licenses will be required for the realisation of this task. This also applies to the disposal of the waste produced by dismantling, which must finally be stored in the German final repository for low and medium-radioactive waste (underground repository Konrad).

For the dismantling of the reactor components physically separated cutting and packing areas will be installed and equipped in the reactor building. Here, the reactor components will be cut and subsequently packed according to the requirements of the radiation protection ordinance and the acceptance criteria of the final repository.

The presentation will start with the description of the basic frame conditions for the nuclear licensing procedure, important procedural principles, and necessary plant-specific conditions.

Based on these conditions, the dismantling of the reactor with its reactor components will be explained:

- RPV internals
    - Upper core structure
    - Lower core structure
    - Core structure support
    - Thermal shield
- Peripheral components (interfering edges for the dismantling of the RPV)
- Reactor pressure vessel
    - Reactor pressure vessel (RPV)
    - RPV lid
    - RPV insulation.

After the description of the cutting, packing and handling areas for the dismantling of the reactor (see figure 1) the major equipment for the remote handling and performance of the activities will be presented and the principal dismantling process will be demonstrated.

Due to the activity inventory, the RPV internals and the core zone of the RPV will be cut completely in the wet cutting areas fitting the packaging.

The other reactor components will be cut in the dry cutting areas.

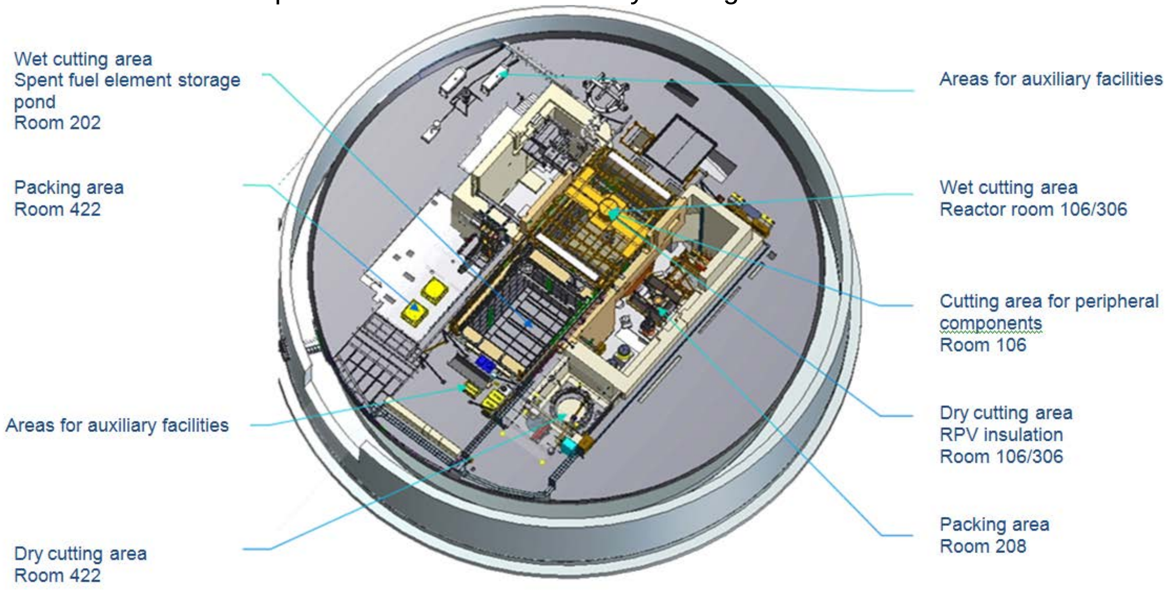

Fig. 1: Cutting, packing and handling areas for the dismantling of the KWO reactor

Later it will be explained, which data and information are needed to get a license by the authority responsible for the final storage of radioactive waste.
In the licensing procedure not only the radioactive characteristics will be assessed but also the overall production procedure of the waste product, its chemical characteristics as well as chemical and material characteristics of the waste containers. The extensive programme for the radiological characterisation of waste by calculations on the basis of production data and operational history will be described as well as the sampling and dose rate measurement.

The assembly of the equipment started at the beginning of June 2012 and was finished in June 2013. The equipment was installed room by room after release by the building expert of the licensing authority. After completion of the commissioning and functional tests of the individual equipment and after the complex functional test at the beginning of September 2013, the 'hot' cutting of the reactor will start.

Using of the cutting and packing of the upper core structure, as example the relevant work and test steps of the time schedule will be illustrated by means of the performed activities.

After the sampling and the dose rate measurement programme are explained, the steps for cutting and packing the segments in the wet cutting area will be described. The loading of the containers licensed for final storage will be shown as well as the data which have to be checked, measured and registered according to the acceptance criteria of the final storage and the regulation for hazardous goods.

In summer 2014 after the demountable RPV internals will have been remotely cut and packed, the equipment around the RPV will be dismantled, the RPV will be lifted and the RPV insulation will be remotely dismounted and packed. Finally the RPV with the thermal shield will be dismounted under water. The completion of the project is expected for spring 2016.

INTRODUCTION

The Obrigheim Nuclear Power Plant (KWO) is located in the Federal State of Baden-Württemberg in Germany and was operated by the EnKK-KWO. The Nuclear Power Plant – a light water pressurized water reactor with 357 MW of electrical power – was operated from 1968 to 2005. In June 2009 the Energiewerke Nord GmbH (EWN) was charged with the dismantling planning and dismantling of the reactor.

According to the German Atomic Energy and Radiation Protection Law such a measure necessitates corresponding licenses. This applies in particular to the disposal of the waste from dismantling that has to be shipped to the German final repository 'Konrad' for low- and intermediate level waste.

In spring 2010 EWN completed all application documents for the dismantling of the reactor pressure vessel (RPV) and the RPV internals and EnKK-KWO delivered them to the responsible Environmental Ministry of Baden-Württemberg. Since then it has been worked intensively on the design, construction and manufacturing of the facilities for dismantling. With a separate notification of amendment it was applied for the license to install and commission the facilities for the dismantling of the RPV and the RPV internals at the Environmental Ministry of Baden-Württemberg in October 2010. This notification of amendment was confirmed in summer 2012.

In September 2011 the work process and test plan and the technical information about the campaign for the removal of the radioactive waste resulting from the RPV with internals, peripheral components and secondary waste with the aim of final disposal in the Federal Repository "Konrad" was submitted to the Federal Office for Radiation Protection.

The installation started in June 2012 and ended in June 2013. After approval by the civil engineering expert of the licensing authority the equipment was installed room by room. The "hot" cutting of the reactor started after the completion of the commissioning and functional tests of the individual equipment as well as the complex functional test at the beginning of September 2013.

SCOPE OF DISMANTLING

The dismantling of the reactor comprises the following reactor components:

- RPV internals
  - Upper core structure
  - Lower core structure
  - Core structure support
  - Thermal shield
- Peripheral components (interfering edges for the dismantling of the RPV)
- Reactor pressure vessel
  - Reactor pressure vessel (RPV)
  - RPV lid

- o RPV insulation.

The KWO reactor is shown in **Fig. 1.**

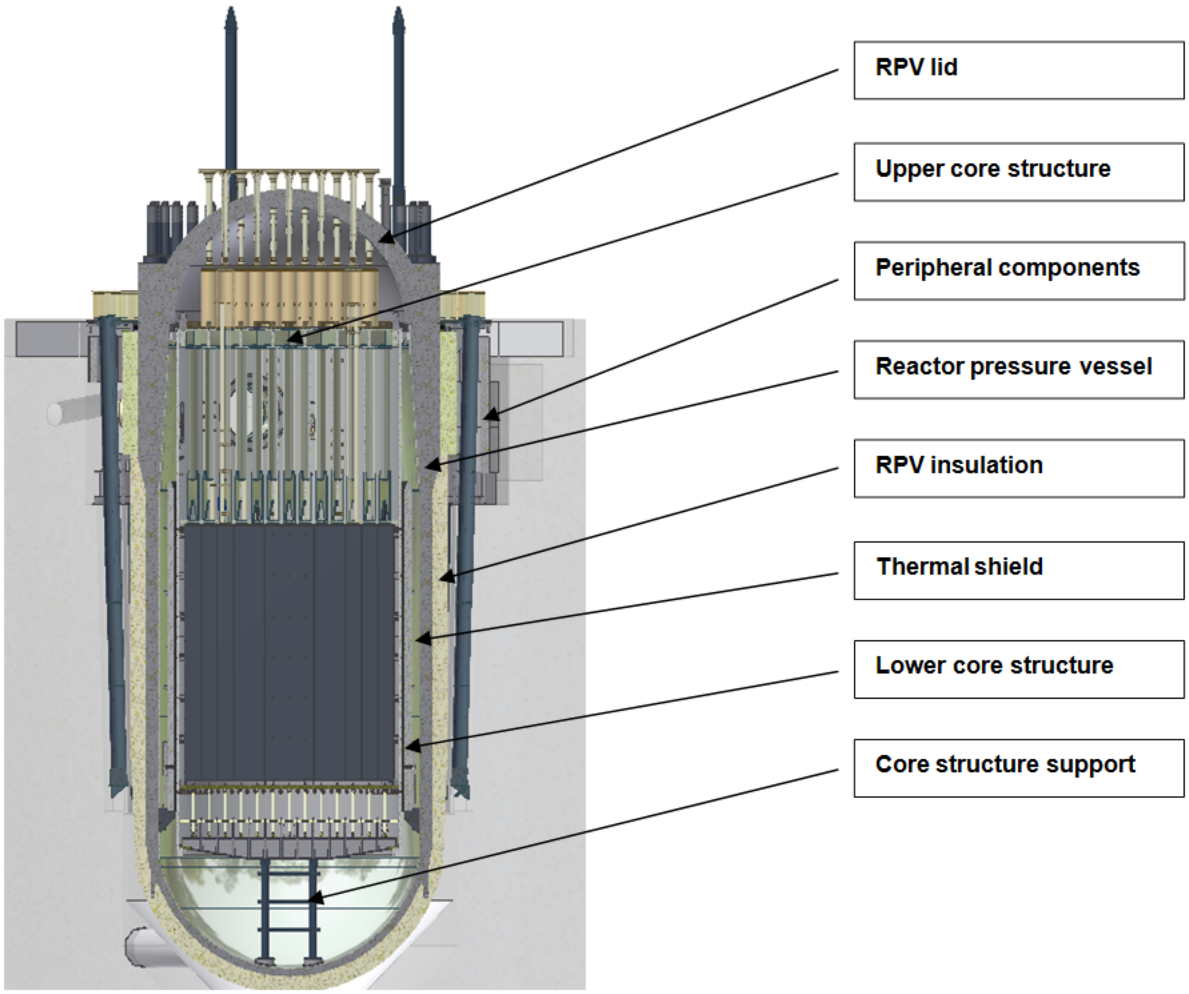

Fig. 1. KWO reactor

The activity inventory of the reactor components to be dismantled results in dependence from the installation position from

- activation processes by neutron radiation,
- contamination as a result of contact with main coolant and/or
- airborne contamination.

Due to the installation position in immediate vicinity of the core, the activity inventory of the reactor components - upper core support, lower core support, thermal shield and core structure support as well as partially the RPV with insulation – was mainly determined by activation processes.

The surface contamination of the reactor components charged with primary coolant results from an interference of material loss and deposition processes during the operation time.
Due to the activity inventory major part of the reactor components will be remotely dismantled, cut and packed.

DISMANTLING STRATEGY

Basic Principles and General Approach

For this project the experience and knowledge gained during the model dismantling of inactive reactor components in Unit 5 of the Greifswald Nuclear Power Plant (KGR), the dismantling of activated components of Units 1 to 4 of the KGR and the dismantling of activated components in the Rheinsberg Nuclear Power Plant (KKR) are used. Due to reuse of equipment the technologies for cutting and handling of KWO reactor components follow the processes already proved and tested in the frame of the dismantling of the reactor components of the KKR and KGR.

For the dismantling of the KWO reactor the cutting, transport and packing equipment, auxiliary facilities, shieldings and handling devices already well-tried in the KGR and KKR are used.

Progress in state of the art will be combined with knowledge gained during the dismantling of reactor components in the KGR and KKR and will be taken into account for the further planning and execution of the project to the extent necessary.

Radioactive waste will be packed according to the final storage conditions for the KONRAD mine [Acceptance requirements for final disposal of radioactive waste – Final storage conditions, state October 2010 – Final Storage KONRAD].

Cutting and Packing Areas

For the dismantling of the reactor components physically separated cutting and packing areas will be arranged (see **Fig. 2**). In these areas the reactor components will be cut and packed under consideration of the required protection goals especially the observance of the radiation protection requirements. The remotely controlled equipment in the cutting and packing areas is operated from a control room and a control station. Fig.2 shows the physical layout of the cutting and packing areas in the reactor building.

Cutting Procedures and Dismantling Order

The following cutting procedures will be used in the frame of the project:
- band sawing
- wire sawing
- core drilling
- shearing
- abrasive cutting
- CAMC-cutting
- plasma cutting
- autogenous cutting

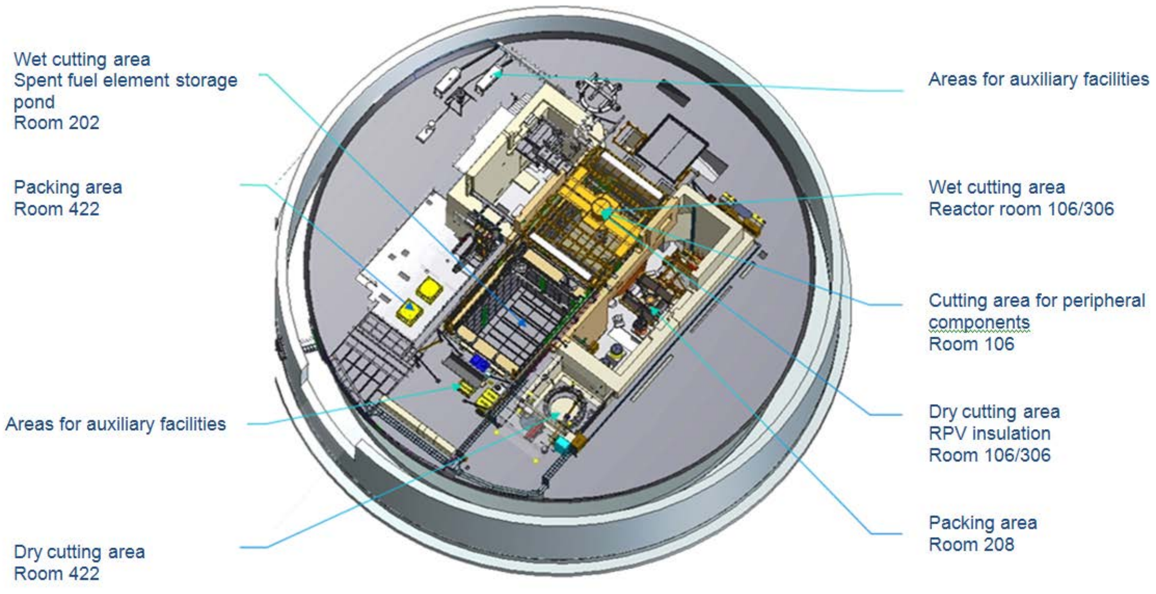

Fig. 2 Cutting, packing and handling areas for the dismantling of the KWO reactor

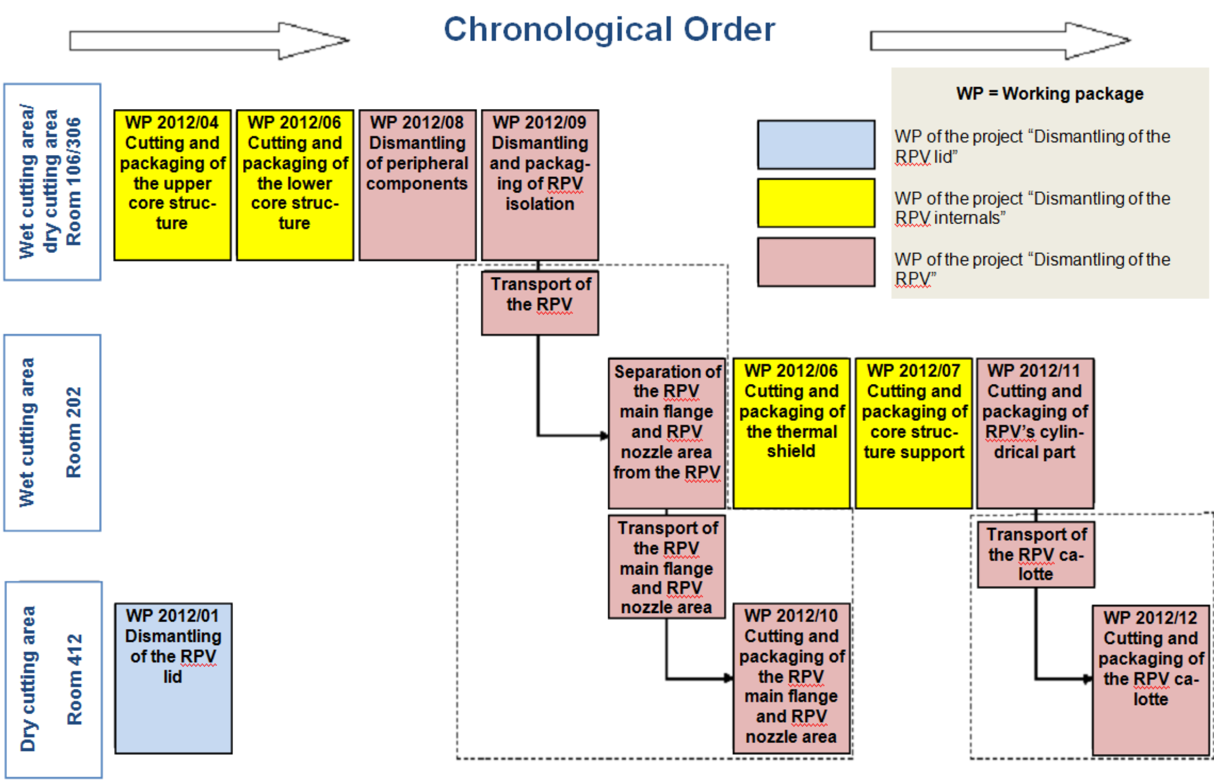

Fig. 3 Dismantling sequence

Due to the design of the reactor and the building structure around the reactor a concrete dismantling order is defined. The chronological sequence of the dismantling activities is presented in **Fig.3**.

The dismantling activities will start with the cutting and packing of the RPV lid. Parallel to the cutting of the RPV lid (blue background) the dismantling of the RPV internals upper core structure and lower core structure (yellow background) can be carried out in the wet cutting area in room 106/306. Then the water will be removed from the cutting area and the peripheral components of the RPV (red background) will be dismounted so that the RPV can be lifted. After the RPV insulation is removed, the RPV will be transported to the wet cutting area room 202. Here, the flange and nozzle part will be separated from the RPV and cut and packed in the dry cutting area room 412. In parallel, the RPV internals thermal shield and core structure support (yellow background) will be detached from the RPV and separately cut in the wet cutting area room 202. Finally, the remaining part of the RPV will be cut and packed, whereby the RPV bottom section is separately cut and packed in the dry cutting area room 412.

APPLICATION FOR WASTE CAMPAIGN AND PROCESS PROCEDURE PLAN FOR CONDITIONING

Regulation

The handling and final storage of radioactive waste in Germany is governed by stringent federal regulations. The former iron ore mine “Konrad” near Salzgitter has been chosen by the German Federal Government for final storage of radioactive waste with negligible heat generation. The overall responsibility for the construction and operation of the Konrad repository is with the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS).
In contrary to the final storage monitoring of waste processing and intermediate storage on plant sites is performed by authorities of the federal states (Bundesländer).
Both, federal and state authorities are advised by expert organisations (e. g. TÜV, Technischer Überwachungsverein).

The “Konrad Repository Storage Conditions and Product Control Measures” define waste acceptance criteria and related quality assurance measures. Before starting the dismantling of the reactor components the operator had to demonstrate adherence to all regulations for intermediate and final storage and to all specified limit values for transport of radioactive waste containers. By means of calculations, measurements or sampling we had to prove that all planned waste packages fulfill the Konrad acceptance criteria. There are limits for nuclides, activity and materials present in the radioactive waste and filling material. Waste containers are grouped in classes depending on chemical and physical properties. The dimensions of the waste packages are predefined by the Konrad acceptance criteria too. Prior to use for storage in Konrad respective waste containers need to obtain a license for use, transportation and storage.

Any waste package is characterized by:

- Total radio-activity per package
- Radio-activity of relevant nuclides per package
- Dose rate at surface and at specified distance

- Surface contamination
- Weight (cylindrical package 8 t, rectangular package 20 t)

Forecast

For each of the packages the so-called Inventory Guarantee Values for C-14, H-3, Ra-226, J-129, Kr-85, other beta/gamma emitters and other alpha emitters have to be tested against the requirements (limits) for permanent storage in normal operation condition.

H-3 and C-14 are present only in metallic structures and in the residual water. According to available data from calculation we have chosen in the planning phase packages that allow storing the highest amount of activity. During project execution we often found by measurement values which are an order of magnitude less than expected.

The other nuclide-activity-limits per package are calculated as the sum (aggregate value) of the quotients of the individual nuclide inventories divided by the corresponding limit value.
There are limits for an Assumed Accident and the Thermal Impact upon the Host Rock. (The limit for the Criticality Safety was meaningless in this project).

The nuclide specific limits to be used for determining the aggregate accident value depend on the applicable waste product groups (APG) and waste container classes (ABK) defined in the waste acceptance criteria.
For storage in the Konrad mine, the aggregate accident value must be less than 1 for each container at the time of entry into storage. If this value is between 0.1 and 1, a separate permission from the BfS must be issued for the storage. The acceptance of such containers is limited to no more than 1% of all. Alternatively, accident-proof packaging can be used.
The aggregate heat value limits the thermal effect on the host rock of the Konrad mine to 3 K. The applicable limit values for the individual radio-nuclides depend on the type of container used. The aggregate value should also be below 1 here. Unlike the aggregate accident value, these values can be averaged together with lower values of other containers.

Chemical element and compound limits for pollution of near-surface groundwater are also given.

For forecasting the expected dose rates shielding calculations for every type of planned package were performed.

Declaration

For the purpose of determining the nuclide inventory of each package at representative pieces activation and contamination samples will be taken. These samples will be analysed in a nuclide laboratory and for present nuclides proportionality coefficients to Co-60 as key nuclide will be determined. By means of inverse shielding calculations for a piece of waste, for a basket or for a whole container the nuclide inventory of the package will be calculated. The chemical constituents per package are listed. The package incl. lid are weighted. Dose rate and Contamination are measured. All these data become an integrated part of the package documentation.

Process Procedure

Every action in preparation, dismantling, conditioning, sampling, packaging, covering transporting is described step by step in the process procedure. It gained approval by the competent authority. The process procedure also contains test stages demanding personal presence of experts (authority).

CONDITIONING PROCESS

After the reactor component to be cut has been placed in the corresponding cutting area, dose rate measurements are carried out at the uncut component to verify the radiological assumptions used as the basis for the cutting plan. At the same time the necessary containers will be provided. The following containers are used:

- Cast iron container type II-15 (MOSAIK)
- Konrad-Container type II
- Konrad-Container type IV
- Konrad-Container type V

After the required test certificates of the waste containers and baskets to be loaded are checked on site, their quality check is conducted at the goods receptions as well as the check of the labeling according to the Radiation Protection Ordinance and the corresponding acceptance criteria of the final repository.

CONDITIONING OF THE REACTOR COMPONETS USING THE UPPER CORE STRUCTURE AS AN EXAMPLE

The upper core structure and the guide tubes for control rods are cut under water into packing size in the wet cutting area of the reactor room 106/306 (see **Fig. 4**) by mainly thermal cutting procedures.
Cutting is performed in the following order:

1. Cutting and packing of the guide tubes for control rods (see **Fig. 5** and **Fig. 6**)
2. Cutting and packing of the upper support plate with cover plate (see **Fig. 7** and **Fig. 8**)
3. Cutting and packing of the support bars
4. Cutting and packing of the upper grid plate

The cut segments will be packed under water into the baskets. Material samples from selected reactor components will be taken and evaluated. The material sample of the upper core structure will be taken from the lower grid plate. The sampling results are used as a basis for the activity determination for the waste product/waste package documentation.

The upper core structure with the guide tubes for control rods will be packed only into Konrad-containers of types II and IV. The parts cut under water in the wet cutting area will be packed into the baskets. The baskets with the lower activated parts are remotely transported in air without shielding by the reactor hall crane and traverse. The baskets with higher activated parts of the reactor components are remotely transported in air with a shielding bell also by the reactor hall crane to the packing area of room 208 and packed into containers suitable for final disposal.

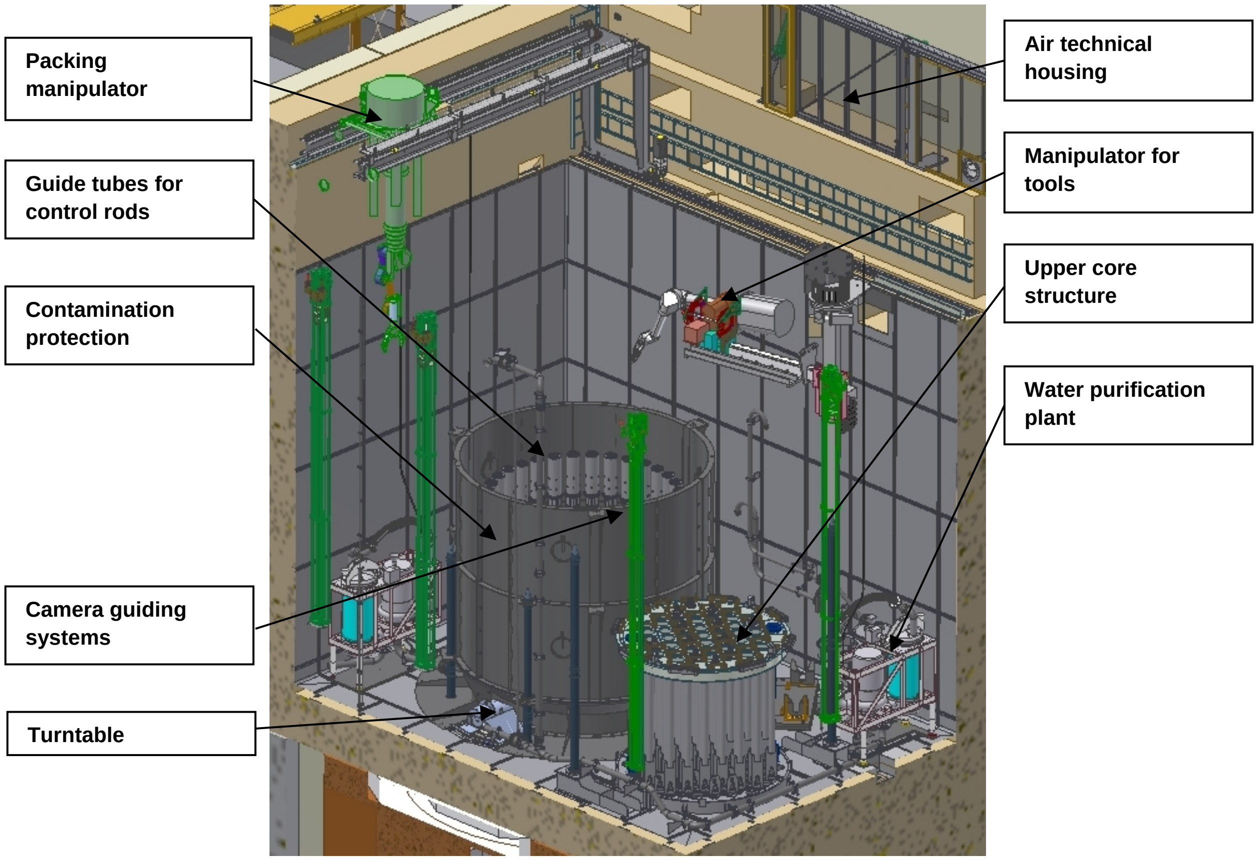

Fig. 4 Cutting of the guide tubes for control rods

Fig. 5 Cutting of the guide tubes for control rods

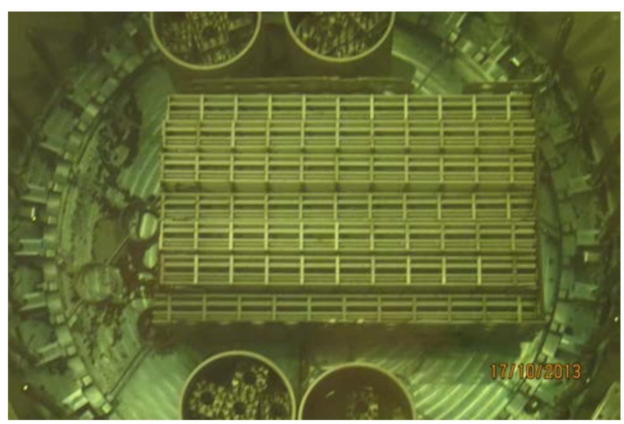

Fig. 6 Packing of the guide tubes for control rods

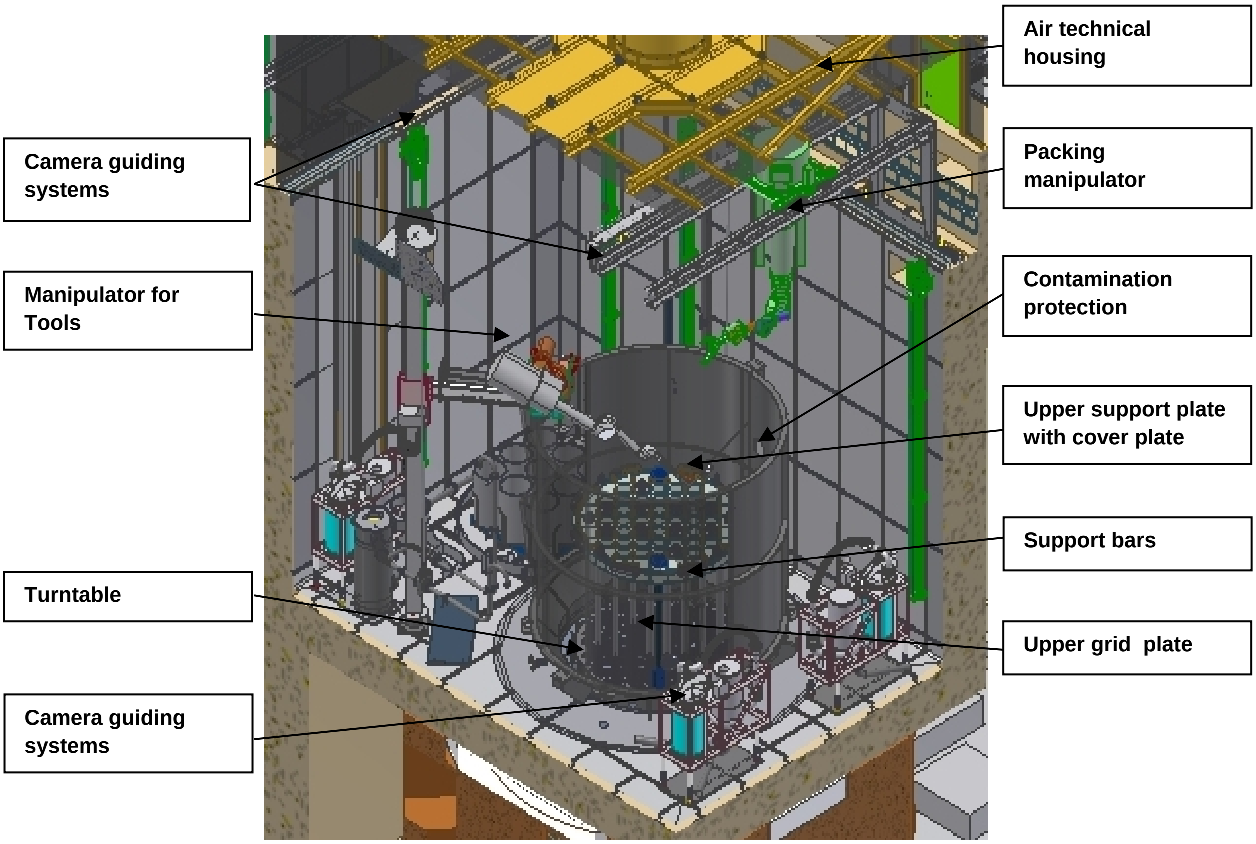

Fig. 7 Cutting of the upper core structure in the wet cutting area reactor room 306/106

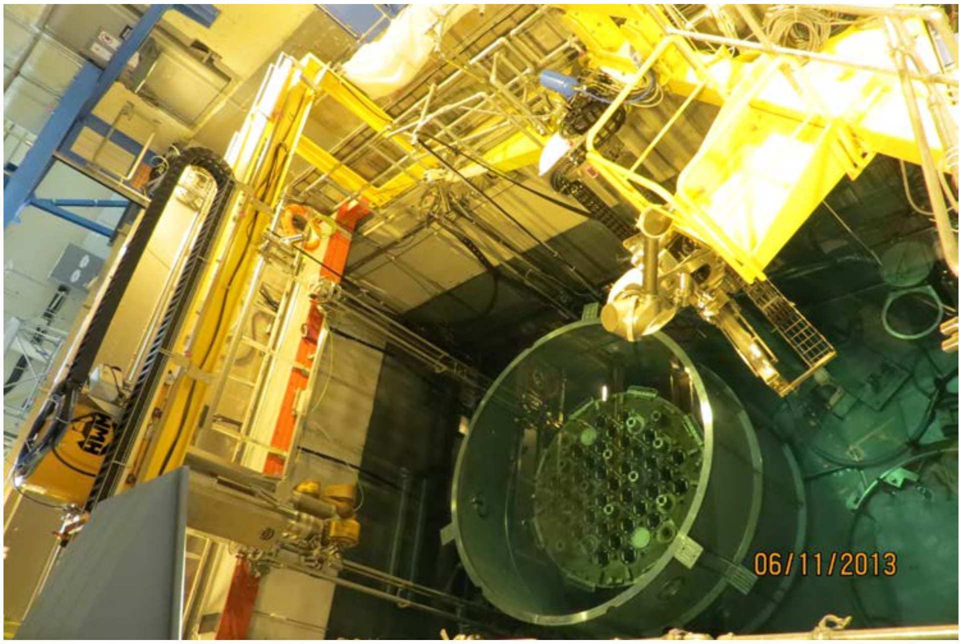

Fig. 8 Upper core structure inside the contamination protection

The following working and test steps are necessary for the loading:

1. Weighing the empty Konrad-Container
2. Placing the Konrad-Container in the shielding structure for Konrad-Containers in the packing area
3. After lid removal inspection of the sealing surfaces of the container body and its lid, check of the dimensional conformance of the load attachment points of the Konrad inner container lid
4. Identification test of the loaded basket
5. Transport of the loaded basket to the shielding structure for Konrad-Containers
6. Weighing of the loaded basket with a crane scale
7. Dose rate measurement of the loaded basket
8. Loading the Konrad-Container with basket (see **Fig. 9**)
9. Inspection of the sealing surfaces and seals for damages and dirt
10. Attaching and screwing the inner lid (see **Fig. 10**)
11. Orientation measurement of the dose rate at the loaded Konrad-Container
12. Transport of the Konrad-Container out of the packing area and parking in the material lock R422

Fig. 9 Packing of loaded basket assemblies

Fig. 10 Remotely controlled closing- of the container

The following measures are applicable for all Konrad-Containers loaded with parts from underwater cutting:

1. Pumping of free-moving liquids out of the Konrad-Container (see **Fig. 11**)
2. Checking if the criterion of “Maximum permitted quantity of free-moving liquid“ is met

Fig.11 Pumping of free-moving liquids out of the Konrad-Container

The following working and test steps will be carried out for all loaded Konrad-Containers:

1. Closing the inner lid
2. Attaching and screwing the Konrad-Container lid
3. Checking the specified torques
4. Sealing the loaded Konrad-Container
5. Weighing and determining the centre of gravity of the loaded Konrad-Container
6. Determination of the outside contamination of the loaded Konrad-Container
7. Dose rate measurement at the loaded Konrad-Container
8. Checking and complementing the labeling of the Konrad-Container according to the Radiation Protection Ordinance of the valid acceptance criteria of the final repository
9. Determination of the preliminary package activity
10. Setting the preliminary documentation on the basis of the preliminary activity values

Finally the packages will be stored in the KWO until the remaining hollow spaces of the Konrad-Containers will be filled and all waste packages will be transported to the Federal Final Repository “Konrad”.

For a later disposal of the waste packages in the Federal Final Repository “Konrad”, the necessary waste data sheets and the waste product/waste package documentation will be produced after conditioning and submitted to the Federal Office for Radiation Protection for approval.

FURTHER DEVELOPMENT OF THE PROJECT

After completion of the remote cutting and packing of the removable RPV internals in summer 2014, the equipment around the RPV will be dismounted, the RPV will be lifted, and the RPV insulation will be remotely dismantled and packed. Finally the RPV with the thermal shield will also be dismantled under water. The project end is planned for spring 2016.

CONCLUSIONS

In total EWN disposed of 6 RPV, 25 RPV internals and 5 annular water tanks of the reactors from the nuclear power plant sites in Greifswald and Rheinsberg. Two strategies have been realised – disposal as a large component with shielded transport of the reactor components to the interim storage facility with subsequent decay storage for later conditioning as well as the remote dismantling and packing of the reactor components.

The lessons of experience from these activities have proved to be a valuable prerequisite for the planning, manufacturing, installation and commissioning of the equipment for remote dismantling in order to comply with the challenges of the high safety standards in Germany.

It has been shown that an economic dismantling of the reactors is possible despite high safety and radiation protection requirements to meet the internationally valid protection aims.

The main challenge of the KWO reactor dismantling project is the limited space available due to the compact containment design. All handling processes have to be planned on a very detailed level. The advanced development of the nowadays available planning software allows a detailed three dimensional presentation of the original environment. Thus, all processes can be tested with a model.

The repeated use of equipment which have been successfully applied in operation and the application of practically tested handling processes will minimize potential problems.