The EWN dismantling operations and related techniques

Dismantling of the Reactor Pressure Vessels

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1. Introduction

The main aim of this phase was the testing, comparison and execution of the dismantling of highly activated reactor pressure vessel (RPV) and internals. The principal objectives of this project were thus the preparation, testing and model dismantling of the EWN reactors internals and RPVs.

This is thus the report of a "European première" concerning the complete dismantling and size reduction of reactor pressure vessels and internals of the most widely spread reactor types.

At the Greifswald site there are 8 units of the Russian pressurised water reactor type WWER 440 as shown in Fig. 1.

After the reunification of Germany, the units 1 to 4 were switched off and the trial operation of unit 5 and the construction works on the units 6 to 8 were stopped. For economical reasons, it was decided to immediately remove and not to enclose the facilities.

Due to the high activation level of the components of reactors 1 to 4, it was decided to use mainly remote handling technique for their dismantling. For the dismantling and cutting of the reactors 1 to 4, the concept first foresees a model dismantling to test the transport, cutting and packaging equipment to perform the later dismantling of the activated reactors 1 to 4 safely and optimally.

The not contaminated equipment of the units 7 and 8 will be transported into the steam generator room of unit 5 and will be cut there in the frame of the model dismantling. The tested tools and equipment will then be used for the dismantling in units 1 to 4.

For reactor unit 5, the cutting of the reactor components is not planned due to the short operation time and the low activation level. The individual components will be transported as one part to the interim storage on the site and after a decay storage of 40 to 70 years, they will be cut without remote techniques.

After the dismantling of the operational equipment, the preparations for the installation of the cutting equipment in steam generator room unit 5 were executed from June 1997 until March 1998. Approximately 780 t have been removed from the wall and floor areas to have space for the installation of the cutting equipment. From March 1998 up to September 1999, the main equipment was installed, and since December

1998 the systems have been under commissioning. In October 1999, the reactor pressure vessel was put into the dry cutting place and thus, model dismantling could start in unit 5. In comparison to the original time schedule, this meant a delay of approx. 10 months for the start of model dismantling.

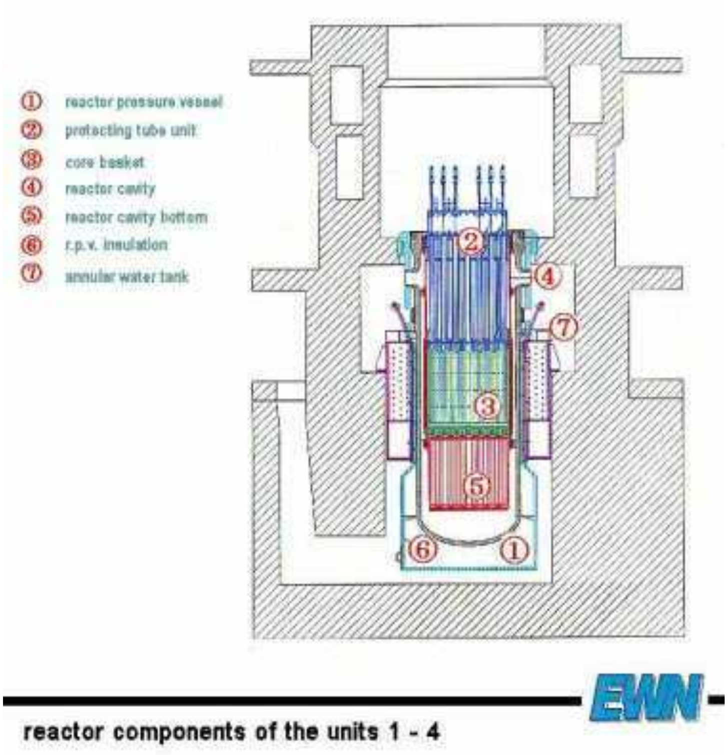

Figure 1. Russian pressurised water reactor type WWER 440

During model dismantling, several technical problems occurred, especially with the band saws and video technique which strongly affected or even stopped the tests. For these reasons, only few data are available for the evaluation of the cutting procedures and for the estimation of the time needed as well as for the radiological exposure to be expected for units 1 to 4.

Resulting from the time delay for model dismantling in unit 5 and from the knowledge that for the installation and commissioning in unit 2 a longer time has to be estimated, the start of active dismantling in unit 2 will be delayed for approximately 1.5 years.

2. Selection and testing of techniques

2.1. Selection for cutting in air or under water

2.1.1. Arrangement of cutting places

For the cutting of the activated reactor components, one cutting place is foreseen for each of two units (Fig. 2). For units 1 and 2, this cutting place will be arranged in the steam generator room of unit 2 and for units 3 and 4 in the steam generator room of unit 4. For each dismantling area, one dry cutting place is foreseen for the cutting of the reactor pressure vessels and the lower activated parts of the reactor cavities and protecting tube systems. For the cutting of the core basket, cavity bottoms and the higher activated areas of the reactor cavities and protecting tube systems, a wet cutting place will be installed.

The two cutting caissons as well as the packing station are implanted below openings to the reactor hall, so that the loading and unloading of these areas can be performed without problems with the overhead crane in the reactor hall.

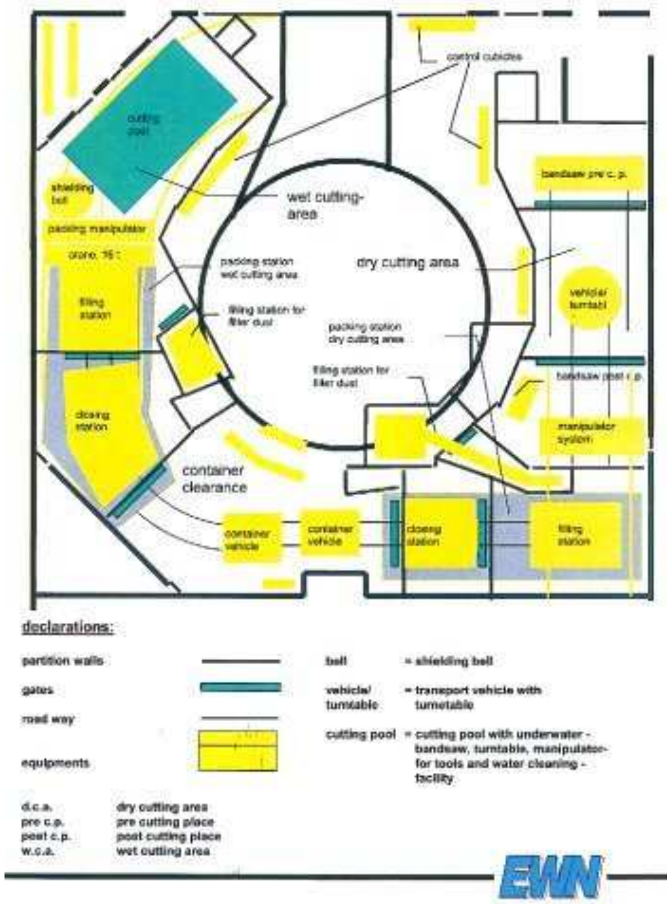

Figure 2. Order of the equipments in the steam generator box.

2.1.2. Dry cutting caisson

The dry cutting station is divided in a pre- and post cutting area divided by a shielding wall. Through a vertical gate in the shielding wall, it is possible to move a transport vehicle between the cutting areas. The dry cutting caisson is equipped with an under-pressure control system.

The component to be cut is placed in the pre-cutting area on a turntable. The turntable is mounted on the transport. The component is fixed with a wire hoist. In the pre-cutting area, the horizontal cuts are performed. With the transport vehicle, the piece is subsequently transported to the post-cutting area. There, the vertical cutting takes place into pieces suitable for packing and later final storage. The normal cutting tools are band saws. In the framework of the testing programme also autogenous and plasma cutting will be tested.

In the packing station which is directly connected to the caisson, the containers are loaded and covered with a manipulator. During filling, the container is equipped with a protective sleeve in order to avoid exterior contamination.

2.1.3. Wet cutting caisson

This caisson consists basically of a cutting pool with cutting devices, different transport and handling devices, water purification system, emptying and filling connections and a ventilation system.

The caisson is separately ventilated and kept at under-pressure. Neighbouring rooms are not radiologically influenced.

The component to be cut is placed in the caisson on a turntable. The cutting is normally performed with band saw, horizontal as well as vertical. Optionally, also plasma- and CAMC-cutting devices are foreseen. For the handling, two manipulators are foreseen. One is used for the handling of the cutting tool and the other one for the handling and transport of the pieces, which are placed in wiremesh baskets. The loaded baskets are transported to the packing station with an overhead crane and placed in a container. Subsequently, the container is automatically closed.

2.1.4. Cutting techniques (wet and dry)

Mechanical techniques/dry cutting area

For the pre- and post cutting stations, band saws are foreseen. With this equipment, the pressure vessel as well as the upper part of the protecting tube system and reactor cavity will be cut horizontally into rings (pre-cutting station) and following cut vertically to segments (post cutting station).

Main design features of band saw	**Band saw pre-cutting**	**Band saw post-cutting**
Cutting speed (adjustable)	15-80 m/min	15-80 m/min
Saw drive (continuously adjustable)	1-170 mm/min	1-170 mm/min
Maximum cutting length	ca. 3000 mm	1500 mm
Maximum cutting depth	ca. 500 mm	ca. 1100 mm
Total weight	ca. 20 Mg	ca. 10 Mg

Table 1. Comparison band saw pre-cutting and post cutting

On the post cutting place, 2 manipulators with a lifting capacity of 100 kg for the handling of tools and a manipulator with a lifting capacity of 500 kg for the handling of the cut reactor parts are arranged (Fig. 3).

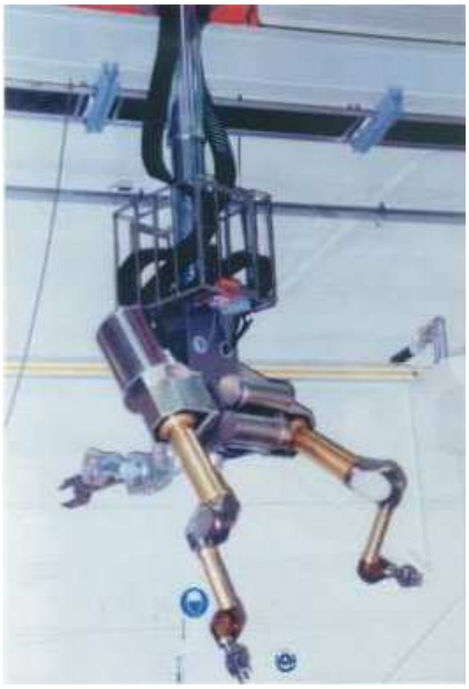

Figure 3. 2 manipulators on the post cutting place

Mechanical techniques/wet cutting area

- underwater band saw;
- underwater abrasive and cutting-off machines;
- underwater shears;
- underwater milling cutter;
- other underwater saws.

A high power band saw (vertical saw) is used as underwater band saw. It consists of a non-distortional upright in cluster-type design and a rigid non-distortional and vibration-free saw frame. The band exchange is performed from a platform of the cutting pond. It is possible to make horizontal and vertical cuts with the band saw, since the sawing blade can be turned.

The main technical data are:

- cutting speed: ca. 15-60 m/min;

- saw drive: 1-170 mm/min (continuously adjustable);
- cutting depth: ca. 450 mm;
- cutting height: 1000 mm;
- total weight: ca. 30 Mg.

Furthermore, there are a manipulator used as tool carrier with a lifting capacity of 100 kg and a packaging manipulator with a lifting capacity of 300 kg on the wet cutting place.

The cutting caisson has the following inner dimensions:

- length: 11 000 mm;
- width: 4 500 mm;
- height: 5 500 mm (unit 5), 6 600 mm (units 2/4).

Thermal cutting techniques

A thermal cutting device on a band saw frame is mounted at the dry cutting caisson of the pre-cutting place. The positioning of the cutting device to the reactor components is regulated by the feed range of the band saw.

The thermal cutting procedure at the post cutting place is performed by means of the packaging manipulator as a tool support system.

Reactor components of austenitic material will be cut by the plasma cutting device. Components of ferritic material will be cut by autogenous flame cutting.

For the underwater application in the cutting pond, contact-arc-metal-cutting (CAMC) and underwater plasma cutting are intended to be used as thermal cutting procedures.

CAMC is a procedure for thermal cutting of the metal materials by repeated short-circuit high-current arc generated by contact of the electrode and work piece. The melted material is rinsed out of the trajectory by means of a water flushing integrated in the electrode.

2.1.5. Casks

The test of loading, transport and handling of the casks forms a priority for model dismantling.

The concept foresees to pack the dismantled reactor components into transport and interim storage casks. The components will be stored for decay storage of at least 40 years in the newly built Interim Storage North (ISN) on the EWN site.

For the storage in the ISN, the dose rates of the casks have to be below the following limit value: in 2 m distance 0.1 mSv/h for square packages. Furthermore, a licence for the transport of the casks on road and rail will be needed.

For the storage of the dismantled reactor components (reactor pressure vessel, core basket, reactor cavity and cavity bottom, protecting tube unit and annular water tank), steel and concrete container are foreseen. The dismantling of the absorber and shielding assemblies is not planned. They will be loaded and finally stored in CASTOR casks.

The steel containers are intended to be used for the packaging of the reactor components with a higher activity (reference value for the classification is an activity of 10^{17} Bq/g).

The outer dimensions are:

- length: 2 000 mm;
- width: 1 600 mm;
- height: 1 450 mm.

The wall thickness is 180 mm or 210 mm.

Corresponding to the activity inventory to be stored, additional inner liners will be used. For the side walls and the cover, 30 mm steel, and for the container bottom max. 20 mm lead can be used.

For the less activated components, concrete container will be used for interim storage. The outer dimensions are equivalent to those of the steel containers, the wall thickness is 200 mm. Heavy concrete with a density of 3.5 g/cm^3 will be used as basic material.

The highest activated residues (core basket, reactor cavity, parts of the protecting tube unit) will be provided additionally to the storage in the steel container with a secondary shielding. The activity of the residues must be higher than 10^8 Bq/g.

The outer dimensions of the secondary shielding are:

- length: 2 660 mm;
- width: 2 260 mm;
- height: 2 060 mm.

The wall thickness is 280 mm.

The secondary shielding consist of a steel skeleton cover with backfill material of normal concrete with a density of 2.25 g/cm^3. A licence for the transport on road and rail is not foreseen.

2 prototypes of containers are foreseen to be tested in the frame of the model dismantling. According to the results the choice will be made and the serial production will be initiated.

2.2. Support positioning and driving system

For the model dismantling of the non activated reactor components of units 7 and 8 in unit 5, several transports with the existing crane facilities and corresponding load lifting devices have to be performed in the reactor hall.

For the transports, the following available crane facilities and load lifting devices will be used:

- bridge crane 250 Mg (reactor hall crane);
- bridge crane 32 Mg (reactor hall crane);
- grab tool with reactor protection container 71/35 Mg.

The following load lifting devices which have to be newly manufactured are foreseen:

- transport traverse for the RPV, lifting capacity 250 Mg including five screwed bolts M 140 x 6 which connect the shielding and transport traverse and the RPV;
- load lifting devices and load supporting points of the assembly "Load induction SG-mounting hatch of the wet cutting caisson";
- coupling piece for the transport traverse RPV with connecting bolt (lifting capacity 250 Mg);
- traverse for the horizontal transport of assemblies, lifting capacity 250 Mg;
- lifting and lowering device dry cutting caisson;
- transport crane wet cutting caisson (16 Mg);
- traverse for container.

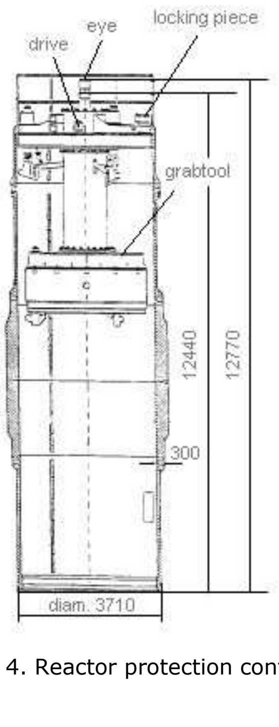

Figure 4. Reactor protection container

The reactor protection container (Fig. 4) with grab tool has the following functions:

- transport of the protecting tube system, core basket and reactor cavity with cavity bottom;
- biological protection of the operational personnel.

The protection container consists of 5 thick-wall cylindrical strakes. The strakes are connected with each other by bolts. The container is handled with the existing 250 Mg overhead crane.

By the dismantling of the core basket and the protecting tube system, the protection container is set down on the reactor flange. The grab tool goes by crane through the protection container to the part to be transported. After the interlocking, the core basket or protecting tube system is drawn in the protection container and transported to the cutting place.

2.3. System for the collection and filtration of swarfs and debris

2.3.1. Additional ventilation systems

The task of the systems is to suck filter dust, metal fume, carbon black aerosols and fuel gas produced in the frame of the remote dismantling of the reactor components in the steam generator room and to transport the cleaned exhaust air to the central exhaust air system for controlled release to the environment.

This exhaust air system generated a pressure difference between the cutting places and the accessible areas. The accessible areas are directly supplied from the external air system.

The additional exhaust air system generates a directed air stream from the accessible part to the cutting places and also a direct exhaust from the cutting places. The direct exhaust air from the cutting places is led through a cyclone separator. The cyclone separator separates the heavy particles from the air. The exhaust air then passes a HEPA filter, where 99.997 % of the airborne particles are separated. There are three filters from which two are always operated and the third is in standby position or cleaned.

From the accessible areas (rooms), the cleaning of the exhaust air streams works according to the same principle, whereby a cyclone separator pre-cleaning is not necessary.

2.3.2. Water cleaning system

The cutting pond has connections for water feed supply and discharge. The designed minimum filling value for the water cleaning system is ca. 270 m^3, the maximum value 390 m^3. During the cutting work, the water can be circulated and cleaned with the water cleaning system in the pond. The water cleaning system is necessary to maintain the required water quality in the cutting pond and to reduce the activity concentration of the pond water. The floating particles (material from the partition lines and exhausted material from the cutting tool) and coarse particles depositing on the ground will be released from the pond and separated in a filter system.

For the design of the water cleaning system for the wet cutting caisson, the following reference values were established (Table 2):

Cuttings ca.	1.6 kg/h
Portion	99 %
Cuttings, design value	2.0 kg/h
Activity	1.1×10^9 Bq/g (1)
Airborne particles	18 g/h
Portion	0.9 %
Water particles	2 g/h
Portion	0.1 %

(1) *average specific ^{60}Co activity for the core basket*

Table 2. Reference values for the water cleaning system design

The average entry of floating and airborne particles from the CAMC procedure is ca. 70 g/h.

The following water values have to be adhered to:

- floating particle content: < 3 mg/l;
- particle size: < 3 mm.

Due to radiation protection reasons, the whole water cleaning system is arranged inside the water pond and mounted in a steel framework, through which it is possible to insert the complete module into the pond and lift it out. The filter exchange will be done mainly under water.

2.4. Full scale testing of techniques

The major aims of the model dismantling are the testing of the tools and working processes to guarantee the adherence to the protection goals for the later cutting of the active components as well as the technical feasibility. By an extensive test programme in the presence of the authorised expert it will be proved that the used tools are suitable and a technical optimisation of the individual steps can be achieved.

Special emphasis is given to the expected radiation exposure of the personnel, the maximum application time of the tools and the minimisation of the secondary waste.

2.4.1. Approach for the realisation of the aims

To test the equipment for the cutting of the reactors 1 to 4 as realistically as possible, the original cutting technique will be tested with the non-contaminated original components of reactor 7 (core basket, cavity bottom, reactor cavity, protecting tube unit) and reactor 8 (reactor pressure vessel) in the low-contaminated steam generator room of unit 5.

The cutting of the reactor pressure vessel nozzles will be performed with the reactor pressure vessel in unit 7 in installation position. This pressure vessel is also not contaminated. Therefore, a newly developed milling device is foreseen to be used. The cutting of the connection nozzles is a necessary precondition to lift the reactor pressure vessel out of its installation position and to transport it to the dry cutting place.

At a later stage, the cutting of the annular water tank (including reactor insulation) with a wire saw will be tested on a model.

For the installation of the equipment and the execution of model dismantling, a separate licence was applied for: this was granted in May 1997.

The results of model dismantling will facilitate the granting of the licence for cutting the activated reactor components of the units 1 to 4.

2.4.2. Test programme structure

The test programme for model dismantling is hierarchically structured and includes the following levels:

- *test complexes*;
- *test measures*;
- *test processes*;
- *test steps*.

There are the following 10 *test complexes*:

- transport to the cutting places;
- cutting and handling technique for reactor pressure vessel;
- cutting and handling technique for core basket;
- cutting and handling technique for reactor cavity with cavity bottom;
- cutting and handling technique for protecting tube unit;
- operation of packing station and container handling;
- operation of support and auxiliary systems;
- maintenance;
- sampling RPV units 1 to 4 (EU-project);

- dismantling of RPV insulation and annular water tank.

These *test complexes* are divided into *44 test measures* with *274 test processes* and approximately *2.500 individual test steps*.

On the level of *test processes*, corresponding test plans will be elaborated for each process. Before testing, the authorised experts will announce in which test steps they want to participate. The test plans are the basis for the execution of the individual test steps and include the following:

- further subdivision of the test process into test steps;
- description of main items and goals of the test steps;
- reference to basic work documents (also drawing);
- description of results;
- personnel registration, time registration;
- personnel and training evidence.

After realisation of each test process (test plan), a corresponding test report will be prepared. The test report evaluates the test processes. The aim of the test report is to give the evidence that the technological processes with personnel participation under active conditions are performed under adherence of the limit and guide values of radiation protection and the facilities and equipment are qualified for the work.

The test report includes the following information about each test step:

- information about dose expectation on the basis of the calculated ambient dose rate at the working places of the activated units 1 to 4 and information on the efforts for the realisation of the test steps during model dismantling;
- summary information on the qualification of the newly installed facilities and equipment.

The test report will be prepared by EWN and following confirmed by the authorised experts.

On the basis of the reports for each test process, the final report will be prepared and submitted to the authorised experts for approval. This report forms the basis for the granting of the licence for cutting the reactors 1 to 4.

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3. Dismantling by various techniques

The available reactor protection container will be used for the transport of the reactor components (except the reactor pressure vessel). Before the reactor components can be transported to the wet and dry cutting station, the basic frame with the shielding and handling system in the hatch area above the cutting station must be mounted. The reactor protection container with the reactor component will be placed with the 250 Mg crane to the ring of the shielding and handling system. By means of the internal lifting facility of the reactor protection container, the component will be lowered down on the turntable of the wet and dry cutting station.

3.1. Cutting and packing in the wet cutting station

The RPV-components will be cut from top to bottom. During the cutting, the components are fixed installation on the turntable in the cutting pool and covered with water.

The cylindrical coat parts of the core basket, reactor cavity and cavity bottom are cut with an underwater band saw in the cutting pool. Holes with a diameter of about 70 mm are drilled into defined spots. First, vertical cuts are made into the cylindrical coat. Then, the reactor component is rotated with the turntable in a certain angle and further vertical cuts are made. The last vertical cut ends in the drilling made before.

The saw blade is rotated into horizontal cutting position (90 °). By driving out the horizontal carriage, the pre-cut segments are cut. The segment is held by the packing manipulator and after cutting under water put into the waste basket. The waste basket can accommodate several cut parts. The loaded basket is drawn into a shielding bell with sliding bottom. For this purpose, the bell is positioned above the water surface. After the waste basket is drained, the sliding bottom is closed and the shielding bell is transported with the crane to the packing station. After the sliding bottom and a shielding device is opened, the basket will be put in the filling box into the container. The weighing device in the filling box controls the loading process. When the container is loaded, the shielding door to the lid-closing station will be opened, the vehicle with the container goes to the lid-closing station and the door will be closed again. The lid is remotely put on the container. Then, the container lid is manually bolted or by the help of auxiliary devices. After registration of the radiological data, the container is transported to the storage place.

The wet cutting place is also designed for thermal cutting. In principle, the cutting process is similar to the mechanical cutting, i.e., all transport and preparatory works are identical, the cutting plan basically the same.

During the cutting process, the accumulated material from cutting is directly sucked off from the cutting point and collected in the filters of the water cleaning facility.

3.2. Specific cutting characteristics

In case of the protecting tube unit, the lower part (bottom plate) had direct contact with the fuel assemblies, thus, this part is more activated than the upper part (lower part 10^8 Bq/g and upper part 10^6 Bq/g). That's why it is intended to cut the bottom part of the protecting tube unit with a band saw in the cutting pool.

During cutting, the protecting tube unit is positioned on the turntable and held by the lifting facility of the reactor protection container. After the cut, the lower part remains in the cutting pool and the upper part is drawn into the reactor protection container. The crane of the reactor hall transports the reactor protection container with the upper part of the protecting tube unit to the dry cutting station for cutting.

The reactor cavity and cavity bottom of the reactors 1 - 4 are tightly connected by wedges and bolts. As the cavity bottom had to accommodate a part of the fuel assemblies during reactor operation, the activity is higher (10^8 Bq/g) than in the upper part of the reactor cavity (10^4 Bq/g - 10^6 Bq/g). That's why, also here, a horizontal cut is made. The cavity bottom with a part of the reactor cavity remains in the cutting pool and the upper part of the reactor cavity will be cut in the dry cutting station. The reactor protection container is used for transport.

3.3. Cutting in the dry cutting station

The reactor components are cut from bottom to top. In the pre-cutting station, rings will be cut with horizontal cuts. To balance the weight and for lowering the reactor components after cutting, the load is taken over by a flexible wire hoist.

For the cutting process, the band saw is driven from the intervention area to the pre-cutting area. The cutting is automatically performed and monitored from the control room by a camera.

When the cutting depth is achieved, the cutting device is driven out of the cut. The reactor component will be turned with the turntable. The draw spindle of the lifting and dropping device is pivoted so that the reactor component can be turned into both directions. he reactor component is turned with the turntable up to 180 ° and another cut is performed.

Due to weight balancing of the lifting and dropping device, the rings can be cut safely and in case the cutting device gets stuck, a further load balancing with the lifting and dropping device will help. If this will not be sufficient, cutting the saw blade can relieve the band saw.

The cutting device is driven back to the intervention area of the pre-cutting place and the shielding door to the cutting area will be closed. The cutting device will be prepared for the next operation. The transport vehicle with the turntable and the cut ring is driven to the post-cutting place.

Here, the cylindrical rings of the reactor component will be vertically cut. A packing manipulator takes the cut parts and transports them to the filling box. The fixing construction of the turntable holds the remaining part.

After cutting and packaging, the transport vehicles with the turntable and necessary fixing construction go back to the pre-cutting place. The dismantling steps will be repeated.

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4. Radiological survey and radioprotection optimization

4.1. Radiological inventory of VVER reactor and internals

The activity of the reactor components and core components for the KGR was calculated for the work planning of dismantling. The neutron flux distribution was determined in radial, axial and vertical direction, proceeding from a model loading with fresh fuel elements.

The material of the core components are mainly low cobalt content, austenitic steels with considerable alloying addition of Ni, Mn and Cr as well as further alloying additions of C-steel with only low alloying addition (Fe content ca. 96 %).

Component	Maximum activity		Average activity	
	Sum (Bq/g)	^{60}Co (Bq/g)	Sum (Bq/g)	^{60}Co (Bq/g)
CB core basket with facetted ring	2.1 E+09	6.7 E+08	2.0 E+09	6.4 E+08
CB core basket with cylinder	2.4 E+09	7.5 E+08	1.2 E+09	3.7 E+08
CB core basket with bottom plate	9.8 E+08	3.0 E+08	3.4 E+08	1.0 E+08
RPV core area with basic metal	3.0 E+07	2.3 E+06	1.0 E+07	7.7 E+05
RPV core area with plating (unit 3 and 4)	6.6 E+07	2.2 E+07	6.5 E+07	2.1 E+07
RC core area	5.5 E+08	1.8 E+08	2.5 E+08	8.5 E+07
RC cavity bottom with upper pipe unit	3.5 E+06	1.2 E+06	1.5 E+06	5.0 E+05
RC cavity bottom with pipe unit	3.7 E+05	1.2 E+05	7.8 E+04	2.5 E+04
PTU protecting tube unit with bottom plate	5.8 E+08	1.9 E+08	2.2 E+08	7.0 E+07
PTU protecting tube unit with pipe unit	1.7 E+07	5.4 E+06	2.7 E+06	9.0 E+05

Table 3. Mass specific activities for the reactor components of unit 1 (reference date 07/99)

Nuclide	Unit 1	
	Austenitic steel	Ferritic steel
^{54}Mn	< 0.1 %	0.6 %
^{55}Fe	43.1 %	87.2 %
^{59}Ni	0.2 %	< 0.1 %
^{63}Ni	23.1 %	0.8 %
^{60}Co	33.6 %	11.4 %

Table 4. The nuclide vectors for austenitic and ferritic steels (reference date 07/99)

Proceeding from these activity concentrations and the corresponding nuclide vectors, the following maximum dose rates of the individual components can be calculated:

Component	Dose rate (mSv/h)		
	50 cm	100 cm	200 cm
reactor cavity	2.9 E+04	1.8 E+04	8.4 E+03
core basket	1.6 E+05	9.7 E+04	4.5 E+04
protecting tube unit	2.6 E+03	1.1 E+03	4.1 E+02
reactor pressure vessel	3.0 E+02	1.9 E+02	9.3 E+01

Table 5. Maximum dose rate (core centre)

4.2. Radioprotection optimization to cope with ALARA

The planning of radiation protection for the dismantling of unit 5 is based on the following dose commitment limits:

- 1 mSv/day;
- 10 mSv/year.

For areas in the steam generator room, the following dose rate limits are valid:

- 300 μSv/h for areas of intervention;
- 100 μSv/h for accessible areas.

The complete dismantling excluding maintenance is performed remotely from a control panel. At this control panel, all important actual dose rates are shown.

The estimation of radiation exposure for the dismantling personnel in the steam generator room takes account of the following conditions:

- dose limits;
- equipment used;
- local and air-technical separated realisation of cutting activities (dry cutting station and wet cutting station);
- shielding and air-technical zones in dependence of contamination and dose rates use of the present building structure for shielding;
- limited exposure time (one shift working by 6 h presence with an average of 21.5 working days per month).

The estimation of the time for dismantling of the reactor components inclusive the assembling/dismounting of the cutting equipment leads to a duration of ca. 30 months for two reactors. As a result of this, there is a collective dose of 1.8 Sv for two reactors.

4.3. Aerosol production

During the cutting of the reactor components, aerosols will be produced. The authority has defined the following limit values for the release of aerosols:

- 5 E+10Bq/year (long-term release);
- 5 E+08Bq/day (short-term release).

For reactor cutting, only 30 % of the release values should be reached. The aerosol emission is mainly dependent on the used cutting procedure as shown in Table 6.

Cutting procedure	Dry cutting	Wet cutting
band saws	3 - 22 mg/cm²	0.003 - 0.2 mg/cm²
CAMC-arc cutting	-	1.2 -2.9 mg/cm²
plasma cutting	70 - 220 mg/cm²	0.7 -2.2 mg/cm²
oxyacetylene cutting	70 - 220 mg/cm²	-

Table 6. Maximum dose rate (core centre)

Based on a ratio of 9:1 for the mechanical and thermal cutting times in the cutting places of the steam generator room, the following specific aerosol emission rates for the main part of reactor components are obtained:

- dry cutting 42 mg/cm^2;
- wet cutting 0.47 mg/cm^2.

Considering also the following factors:

- average mass specific activity of the cut material;
- dimension of cutting surface of the activated part of the reactor component;
- cleanup efficiency of exhaust air filtering of 99.9978 %.

The following aerosol activity results from the individual reactor components (Table 7).

Reactor component	Aerosol activity (Bq)
core basket	2.4 +E06
reactor cavity and cavity bottom	3.7 +E06
protecting tube unit	9.7 +E05
reactor pressure vessel	5.1 +E06

Table 7. Aerosol activity results from the individual reactor components

The total release of 1.2 E7 Bq remains by magnitudes under the licensed annual release values for aerosols.

Maximum short-term release of aerosols can be expected in the dry cutting station during the cutting of an RPV-core segment. On the assumption that 3 segments will be cut vertically in the post-cutting place of the dry cutting station within a working day, an aerosol release of 5.3 E4 Bq/day will result, which is below the licensed short-term release value.

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5. Data Collection

Specific actual dismantling technical data were collected in the three projects throughout the execution of the whole contract. The most representative ones will then be transmitted to the EC database.

5.1. Transport of reactor pressure vessel

For the test of the reactor pressure vessel cutting, the reactor pressure vessel for unit 8 is used. It is not activated and not contaminated and was stored outside the technological facilities in a lightweight hall construction to be protected against weather influences.

In preparation of the transport to the steam generator room of unit 5, the nozzles for the reactor coolant pipes (diameter 500 mm) and for the core flooding systems and measurement connections were cut by thermal cutting techniques. For the reactors 1 to 4, these works are done in installation position with a milling facility.

With the transport to the steam generator room of unit 5 (Fig. 5), the transport of the reactor pressure vessel of unit 5 to the Interim Storage North was tested. Hereby, it was proved that the transport way and the crane is suitable for the reactor pressure vessel transport of unit 5 to the Interim Storage.

Due to the short operation time of reactor 5 and its low activity, the individual reactor components will be transported as a whole to the Interim Storage and will be manually dismantled and disposed of after a corresponding decay time.

Figure 5. Transport of the RPV of unit 8 to unit 5

Afterwards, RPV 8 was transported to the controlled area of unit 5. Before the RPV was put to the dry cutting place, it was brought from horizontal to vertical position with a special tilting device (Fig. 6 and 7). This was also a test for the later disassembling of the reactor pressure vessel 5, but then, the pressure vessel will be tilted from the vertical to horizontal position. On the basis of the test plan, the man-hours needed for the work were determined. On the basis of the known dose rates of the pressure vessel (in the flange area, nozzle area, core area, bottom), the average ambient dose rate for the individual activities were determined. For the removal of the RPV from its installation position and for tilting, a collective dose of 1.4 mSv was evaluated.

Figures 6. & 7. Tilting device for the reactor components

The RPV 8 was set down on a special holding device located in the upper hatch area and consisting of large bolts which remotely move into the traverse of the RPV. Thus, it is possible to set down the pressure vessel. For moving the RPV up and down, a wire hoist is used and a crane will not be needed.

The transport of the reactor pressure vessel and the positioning in the dry cutting place went according to plan without problems. To minimise the radiation exposure, the reactor hall crane and the wire hoist have to be improved concerning their remote handling ability when RDG 5 and the reactor pressure vessels 1 - 4 will be transported inside the reactor hall.

5.2. Reactor pressure vessel cutting

In the sequel of the tests, the reactor pressure vessel was put on the transport vehicle with turntable by the wire hoist. A load of 18 t is carried by the turntable, the remaining weight by the wire hoist (approx. 200 t). The first step is the cutting of the domed reactor pressure vessel bottom (Fig. 8). This will be done with band saw and oxyacetylene cutting. It is planned to mainly use the band saw and only when necessary oxyacetylene cutting.

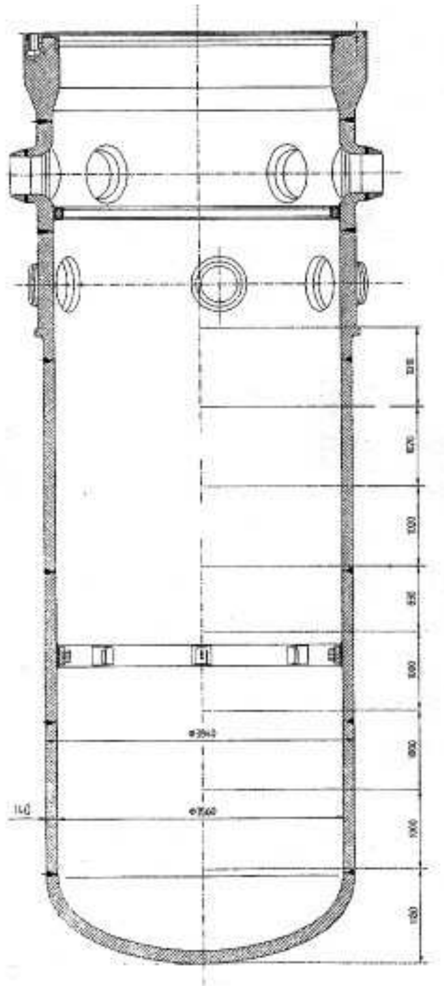

Figure 8. Cutting point of RPV

For the work performed until now, only the band saw was used (Fig. 9).

Figure 9. Cutting of the domed RPV bottom with band saw

By variation of cutting speed, cutting depth and tooth pattern of the sawing band, the band saw operation could be optimised. Great importance was attached to the optimisation of the produced metal shavings. As these shavings are sucked off near the production place and are routed to the ventilation system, small (maximum length 10 mm) and straight shavings are required. The shavings must not hook together to prevent plugging of the ventilation pipes. To optimise the shavings, the band speed was varied between 10 m/min and 70 m/min and the contact pressure of the saw band between 250 N and 700 N. To have an optimum shaving production, the saw bands should have the following parameters:

- 1st tooth shape: claws;
  - tooth space: 1.4 up to 2 teeth per inch;
  - band speed: 60 to 70 m/min;
  - contact pressure of the sawing band: ca. 600 N;
- 2nd tooth shape: claws;
  - tooth space: 2 to 3 teeth per inch;
  - band speed: 40 m/min;
  - contact pressure of the sawing band: ca. 500 N.

In parallel to the optimization of the cutting parameters, the cutting geometry has also been optimised (rotation angle of the reactor pressure vessel, cutting depth, cutting length, number of cuts). The aim was to guarantee a safe band saw operation with as less as possible cuts (reduction of cutting time) and to make a continuous cut through the circumference of the reactor pressure vessel. The following parameters were used for optimisation (Table 8):

Rotation angle of RPV (°)	Cutting depth of band saw (mm)	Cutting length (mm)	Number of cuts
14	175	801	25
36	250	947	10
51	325	1069	7
60	400	1173	6
72	475	1264	5

Table 8. Parameters for cutting RPV with band saw

It turned out to be advantageous to use the ending cut for the positioning of the new one. Furthermore, it was found out that big cutting depth lead to an instability of the saw band between both cutting points and the cut is not horizontal. The works for optimisation of the band saw operation will continue with the cuts on the cylindrical part of the reactor pressure vessel. All in all, the applicability of the band saw for horizontal cuts on the reactor pressure vessel could be proved.

After the cutting of the pressure vessel bottom, the remaining part of the vessel was lifted with the wire hoist and put on the support bolt. The vessel bottom was transported with the transport vehicle/turntable from the pre-cutting place to the post-cutting place.

As it is not possible to saw up to the centre of the vessel bottom, the cutting in the post cutting area is foreseen to be done in two steps:

1. Segment cuts will be made into the vessel bottom by band saw (Fig. 10).
2. The cutting of the middle part will be done by thermal cutting procedures.

Figure 10. Segments cut into RPV bottom with band saw

After stabilising the hydraulic facility for the band saw control, segment cuts up to a length of 70 cm could be made into the vessel bottom.

For further cutting with thermal cutting devices, it is planned to use plasma torches and oxyacetylene burner. For both burners, manual handling and use of manipulators will be tested.

A test to cut out a circular piece from the centre with a manipulator controlled plasma torch failed (Fig. 11). The plasma torch could not cut through a wall thickness of 14 cm from the inside. The austenite plating was completely melted in the burner surrounding but the melting material sealed the cut again before the burner could go through. The tests was continued from outside with an oxyacetylene burner (Fig. 12). For cutting, a gas burner was used. With this technology, the most part of the pressure vessel bottom could be cut. For the central part of the pressure vessel bottom (in a radius of ca. 80 cm from the centre point of the vessel bottom), a suitable technology for cutting is still investigated.

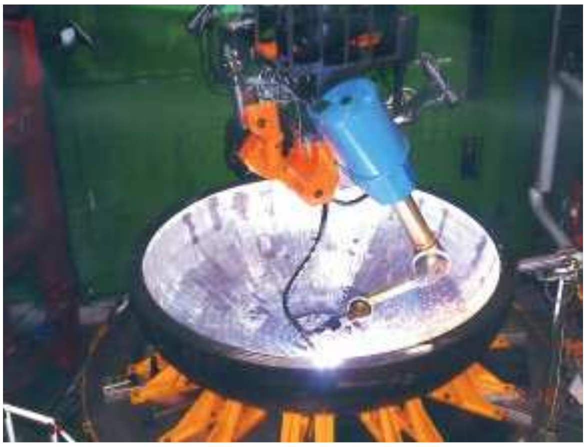

Figure 11. Plasma torch testing

Figure 12. Cutting of vessel bottom with oxyacetylene burner

5.3. Milling of the reactor pressure vessel nozzles

To remove the reactor pressure vessel from its installation position, it is necessary to cut all nozzles from the outer wall of the vessel. Otherwise, it would be necessary to remove bigger quantities of concrete above the pressure vessel.

For the removal of the nozzles, a milling facility was developed. For the test, the completely installed but never operated pressure vessel from unit 7 was used. In June 1999, the milling facility was brought into the vessel (Fig. 13) and it was started with the cutting of the nozzles. Due to the difficult accessibility to the nozzles, the remotely controlled device was brought into the reactor pressure vessel and the nozzles were cut from the inside to the outside as in the BR3 reactor.

For that, the device was suspended on the upper side of a carrying and shielding plate 200 mm thick which is put on the RPV flange and air sealed. On the part below, the device is fixed with 3 hydraulically movable tightening cylinders which are staggered by 120 °.

Figure 13. Moving of the milling facility into RPV 7

Figure 14. Cutting of a reactor coolant pipe nozzle

The milling module consists of the guide block driven via three axes and the milling spindle with milling head driven by an electric motor. Due to the wall thickness of the nozzles of 60 mm and a diameter of 780 mm, several tools are needed for the cutting of a nozzle. Therefore, the machine was equipped with a store and a changer device for the used milling discs. Thus, the milling facility is provided with a changer magazine that can accommodate 3 milling discs. Through an additional opening in the carrying plate, a gripper with holding rod can be inserted from the outside and provide the milling module with 2 further milling tools.

The tests were performed to prove the functionality of the milling facility and optimise the milling process (Fig. 14). During the tests, heavy vibrations occurred also at the milling module. They could be partly eliminated by changing the tightening cylinders. Nevertheless, extensive test measures have to be performed to guarantee a safe milling operation. By optimising the milling parameters, the time for milling a nozzle could be reduced from approximately 100 hours to 11 hours.

5.4. Cutting works of the core basket

The start of the transport and cutting works of the core basket have been delayed resulting from necessary improvements of the fixing and holding facility on the turntable of the wet cutting caisson. The dismantling of the cylindrical parts of the core basket started in December. The cutting plan is seen in Fig. 15.

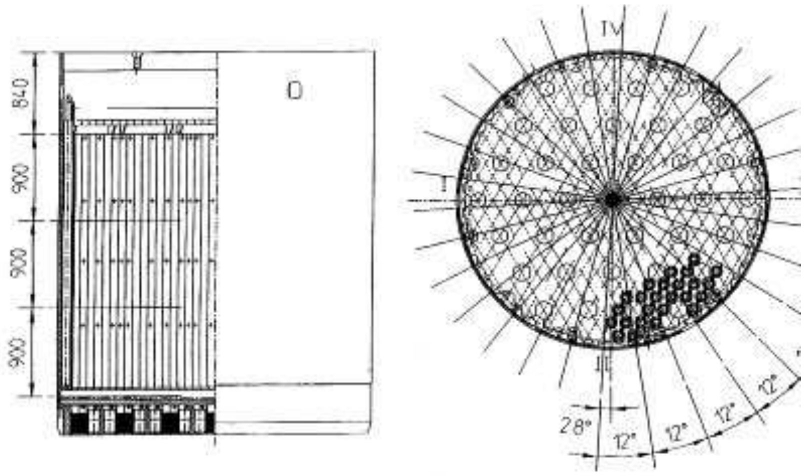

Figure 15. Cutting plan for the core basket

First, vertical cuts (figure 16) of approximately 840 cm length are made with the band saw from the upper edge of the cylindrical part of the core basket. After each cut, the core basket is turned with the turntable by 6 ° to 12 °. After the vertical cuts are made, an opening of approximately 80 mm diameter is burned out with a remote CAMC device or plasma torch at the end of the cut. Then, the band saw is positioned at the end of the vertical cut and the sawing band is turned in the opening by 90 ° and a horizontal cut can be made. While cutting, the manipulator holds the part which has to be cut. This procedure is repeated for all other rings according to the cutting plan (Fig. 16), until the cylindrical part of the core basket is dismantled.

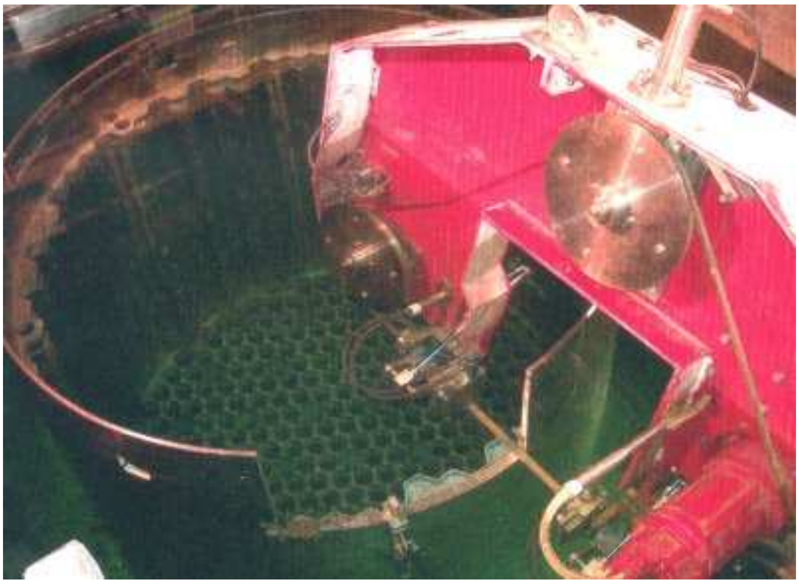

Figure 16. Cutting of core basket with band saw

The test cuttings performed until now have shown that the operation of the band saw has to be stabilised (hydraulic facility). Problems also occurred with the CAMC facility concerning the holding device of the graphite electrode. There were nearly no problems with the plasma torch.

6. Conclusions and main results

Although the model dismantling has not yet been terminated, it can be concluded that the techniques and procedures selected are suitable.

Delays occurred in the commissioning of several equipment, notably dry band saw, video technique and packing station. This was in all cases due to deliveries of equipment non-conform with specifications.

The preliminary results from the tests have furthermore verified that:

- air and water cleaning systems are properly functioning during operational conditions;
- the emissions (air and water) are magnitudes below the licensed limits;
- the dose commitments evaluated for the different tasks until now are close to the planning values.