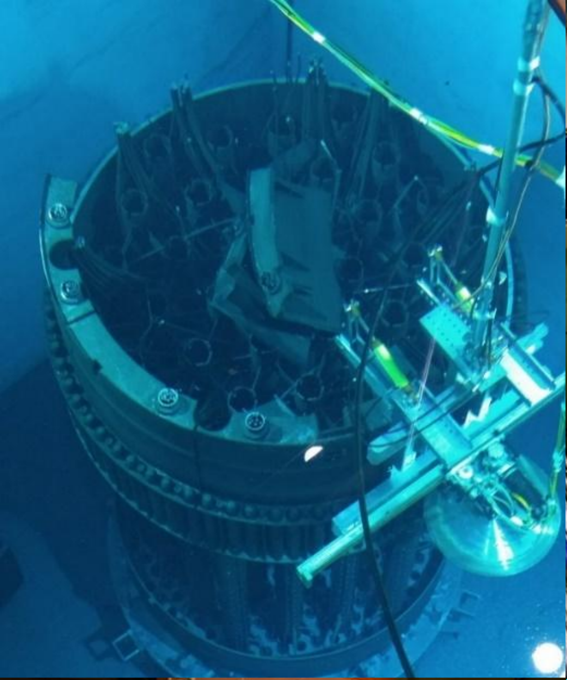

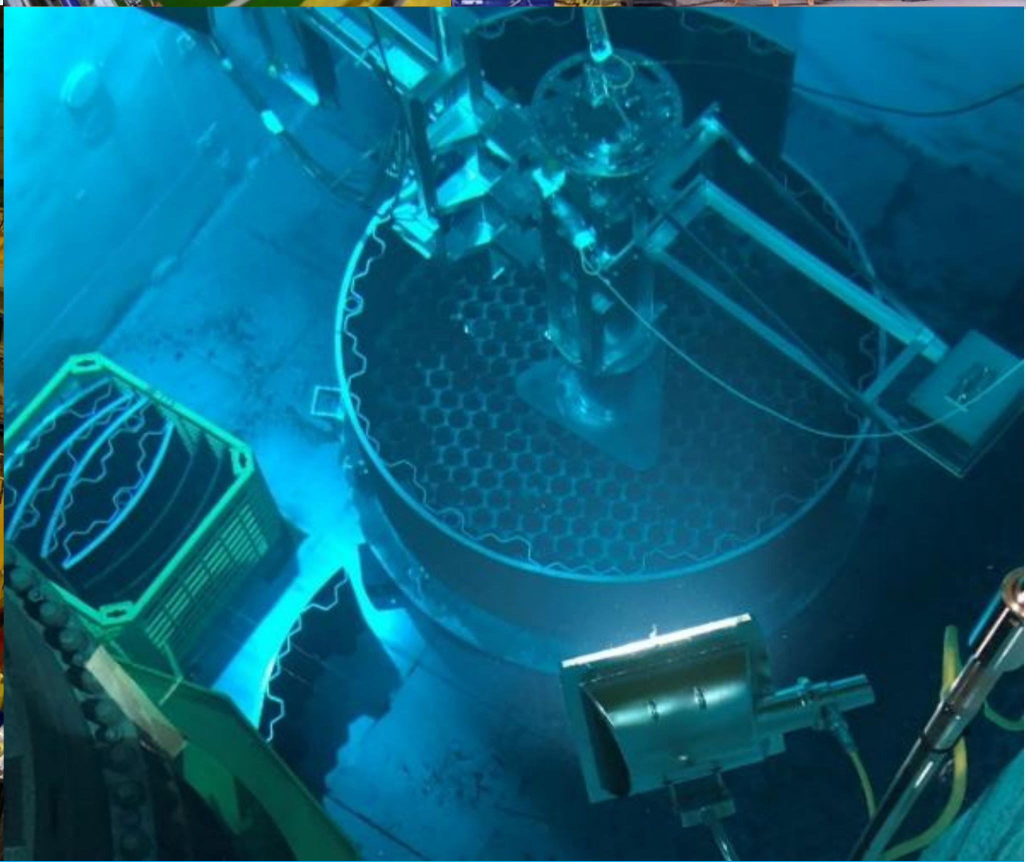

Remotely operated fragmentation of activated components at V1 NPP

CASE STUDY

KP-JAVYS-006

14/01/2025

javys
jadrová
a vyraďovacia
spoločnosť, a.s.

Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation[1] establishing a dedicated financial programme for decommissioning nuclear facilities and managing Radioactive Waste (RAW). This instrument covers the co-funding of the decommissioning programmes of Bulgaria, Slovakia, and the decommissioning of the Joint Research Centre (JRC). A separate Council Regulation[2] was adopted for the decommissioning programme of Lithuania.

The EC JRC is mandated to foster the spread of decommissioning knowledge across all the European Union Member States and facilitate knowledge sharing arising from implementing the abovementioned decommissioning programmes, funded by the Nuclear Decommissioning Assistance Programme (NDAP).

The decommissioning operators from the NDAP (NDAP Operators) implemented and tested a knowledge management methodology in 2021 through Project ENER/D2/2020-273. Using this methodology, the NDAP Operators can develop Knowledge Products that are currently available to share with other European stakeholders. In addition, this methodology is under implementation in the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which becomes a knowledge generator extracting the knowledge from the ongoing decommissioning activities at the different sites (Geel, Ispra, Karlsruhe, and Petten).

The JRC NDWMD aims to become a Centre of Excellence in nuclear decommissioning knowledge management and develop a decommissioning knowledge platform which allows exchanging information and building on the best practices in the EU inside the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project is expected to start in 2024 to develop ties and exchanges among EU stakeholders and document explicit knowledge and make it available through multi-lateral knowledge transfers on decommissioning and waste management governance issues, managerial best practices, technological challenges, and decommissioning processes at both operational and organisational level, to develop potential EU synergies.

This is a Knowledge Product prepared by the JAVYS, a.s. for the NDWMD.

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[1] Council Regulation (Euratom) 2021/100 of 25 January 2021 establishing a dedicated financial programme for the decommissioning of nuclear facilities and the management of RAW, and repealing Regulation (Euratom) No 1368/2013

[2] Council Regulation (EU) 2021/101 of 25 January 2021 establishing the nuclear decommissioning assistance programme of the Ignalina nuclear power plant in Lithuania and repealing Regulation (EU) No 1369/2013

PRODUCT DESCRIPTION

The knowledge product "Remotely operated fragmentation of activated components at V1 Nuclear Power Plant (NPP)" is a case study prepared by a team of experts from the decommissioning project implementation department at V1 NPP in the Slovak Republic. The case study conveys the experience gained during the execution of the Bohunice International Decommissioning Support Fund (BIDSF) project D4.2 – *"Dismantling of Reactor Coolant System Large Components,"* mostly sponsored by the European Commission via the NDAP between 2017 and 2023.

This case study aims to assist the nuclear power plant personnel with planning future decommissioning works. Conveying and maintaining knowledge about important details of such a complex project, such as dismantling/cutting processes and operational needs, will help prepare personnel to successfully implement the primary circuit in future decommissioning projects and identify adequate space to incorporate improvements.

This document has been developed to disseminate and share knowledge with all EU Member States. The knowledge was acquired during the decommissioning and radioactive waste management activities performed with NDAP funding under Council Resolutions (EURATOM) No.1368/2013 and No. 2021/100 in the frame of Slovakian V1 NPP decommissioning.

ABSTRACT

This case study provides information to significantly reduce the risks of failure of the most technically challenging activities during nuclear decommissioning implementation. Using the example of the successful implementation of remotely controlled fragmentation of large, activated components of the V1 NPP primary circuits, the end-users of this product will be presented with information, tips and recommendations that they can apply when planning the implementation of similar activities. It is suitable for the nuclear decommissioning operators as well as for the regulatory authorities.

OBJECTIVE

The objective of this case study is to provide an example of successfully implementing a primary circuit dismantling and cutting project from the customer's perspective, identifying the necessary infrastructure and devices, basic technological steps, and conceptual and technical details critical to the project's success.

This case study describes the experience of remotely controlled fragmentation of large, activated components of the V1 NPP primary circuits. It also describes lessons learned from the use of technical means and civil structures that were also used during the V1 NPP operation.

APPROACH

This document was developed by the JAVYS project team from the departments responsible for planning and implementing the V1 NPP decommissioning project. The team incorporated experiences from executing the BIDSF project D4.2 – *"Dismantling of Reactor Coolant System Large Components"* The case study focuses on the lessons learned from remotely controlled activated components collected during its implementation.

The primary sources of the information for the development of this study were the personal experiences of the project team, which were recorded in the form of monthly progress reports, plans for cutting activities execution, reports on specific activities implementation, licensing documentation for approval processes and photo documentation developed during the project implementation, among other formats.

RESULTS, FINDINGS AND INSIGHTS

The fragmentation process of the V1 NPP reactor coolant system's large components was carried out primarily using bands and circular saws in a water environment, which are already considered proven technologies worldwide. Such processes allow for high optical capabilities and other controllability of the underwater cutting process, thus minimising the radiological doses for the operating personnel. The structural design of the cutting tools used, even in low quantities in the fragmentation process, allows for even very complex shapes of the primary circuit components to be cut. This is made possible by the great variability of the fixtures used to fix the cutting equipment so that the components can be fragmented. Technical equipment from the power plant operation, such as a 250-tonne crane and special shielding containers, are often used in performing such activities. They thus allow for safe handling of the activated components.

TARGET USERS

Potential users or beneficiaries of this product are any entities involved in a primary circuit-cutting project before and during its implementation. It can be used by decommissioning phase planners where the cutting of a primary circuit´s activated components is planned, the timing of all phases of the project needs to be determined from the preparation to the implementation design, the procurement of equipment for the specific parameters of the primary circuit, the actual performance of the cutting tools and the management of all types of radioactive waste produced. Two main target users have been identified:

- Regulatory authorities and State supervisors, who must be able to assess the project's licensing documentation issued by the operator from all safety points of view.
- Nuclear operators of a nuclear power plant in the pre-decommissioning and decommissioning phase who would cooperate during the preparation, execution and supervision of the work and determine the prerequisites for successful project implementation.

APPLICATION, VALUE AND USE

Cutting off large, activated components of the primary circuit is one of the biggest technical challenges within the decommissioning process and is unique to each type of nuclear power plant. With the completion of the remotely controlled underwater fragmentation operations of the activated primary circuit components and subsequent RAW management, 99.9% of the radioactivity was removed while significantly reducing the level of potential radiation risk by the end of V1 NPP´s decommissioning.

The case study will provide information that significantly reduces the risks of failure of the most technically challenging activities that can occur during the implementation of nuclear decommissioning. Using the example of the successful implementation of remotely controlled fragmentation of large, activated components of the V1 NPP primary circuits, the end-users of this KP will be presented with information, tips and recommendations that they can apply when planning the implementation of similar activities. It is suitable for the NPP Decommissioning Operators as well as for the Regulatory Authorities.

The case study demonstrates how massive building structures must be used to implement remotely controlled fragmentation activities of activated large components of NPP primary circuits. It will also present the use of high-level technologies with the aim of a high degree of successful repeatability of individual technological actions. At the minimum, these factors guarantee an almost zero impact of the performed fragmentation activities of activated large components of the NPP primary circuits on nuclear, industrial and environmental safety.

The case study, which conveys and explains the above-mentioned activities, describes the key aspects of cutting off large, activated components of V1 NPP's primary circuits and thus will, at least, allow the target users to:

- have an idea of the V1 NPP primary circuit – WWER-440/230,
- be aware of the necessity to use technical means and building structures when cutting the large, activated components of the V1 NPP´s primary circuits, which were also used during their operation,
- to have an overview of current procedures and techniques for cutting off large, activated components of the V1 NPP´s primary circuits,
- and be aware of the dependence of the cutting plans for large, activated components of the NPP primary circuit on the available level of RAW management.

The application of the main principles presented in this case study helps avoid the negative impact of these activities on the following decommissioning works.

KEYWORDS

CUTTING, WASTE CHARACTERISATION, REMOTE OPERATIONS, MATERIAL MANAGEMENT, CIRCULAR SAW, BAND SAW, POOL, SHIELDING VIA WATER, PRIMARY CIRCUIT, LARGE COMPONENT.

TABLE OF CONTENTS

ACRONYMS AND DEFINITIONS

BIDSF	Bohunice International Decommissioning Support Fund
BTS	Basket Transfer Station
C-30	SNF transportation container
D4.2	BIDSF project “Dismantling of reactor coolant system large components”
FCCs	Fibre-concrete containers
ILW	Intermediate level waste
ISF	Interim Storage Facility
JAVYS, a.s.	Nuclear and Decommissioning company
LLW	Low-level waste
NRR	National Radioactive Waste Repository (in Mochovce)
PRV	Reactor Pressure Vessel
RAW	Radioactive Waste
RIS	Reactor internal structure
RPV	Reactor Pressure Vessel
T 12	Storage cask T 12
T 13	Storage cask T 13
V1 NPP	Nuclear Power Plant V1
WCW	Wet-cutting Workshop
WWER	Water-water Energy Reactor

LIST OF FIGURES

LIST OF TABLES

1. BACKGROUND

In the context of the negotiations for accession to the European Union, the Slovak Republic committed to shut down and decommission Unit 1 and Unit 2 of Jaslovské Bohunice V1 Nuclear Power Plant (V1 NPP) by 2006 and 2008, respectively. The first stage of the V1 NPP decommissioning started in July 2011. After the planned works implemented under the Bohunice International Decommissioning Support Fund (BIDSF) projects focused on non-contaminated components and structures, the decommissioning programme smoothly moved into its second stage, focused on contaminated and activated components and structures.

In general, the dismantling and fragmentation of standard components of a nuclear power plant is often a repetitive process, which is already very well mastered, i.e. without significant risks. However, the fragmentation of large, activated components of the primary circuit is one of the biggest technical challenges within the decommissioning process and is unique to each nuclear power plant. With the completion of the fragmentation operations and subsequent radioactive waste (RAW) management, 99.9% of the radioactivity is removed from the power plant, significantly reducing potential radiation risk by the end of the decommissioning.

This case study provides information to significantly reduce the risks of failure of the most technically challenging activities of the nuclear decommissioning implementation. Using the example of the successful implementation of remotely controlled fragmentation of large, activated components of the V1 NPP primary circuits, the end-users of this knowledge product will be provided with information, tips and recommendations to apply when planning their implementation of similar activities. The case study is suitable for decommissioning operators and regulatory authorities.

1.1. Challenge

The immediate dismantling option of the V1 NPP could not have been implemented using the currently available methods and means nor without the pre-dismantling decontamination of the primary circuit. It must be noted that employees worked in an environment with high dose rates. However, these were considerably mitigated by water shielding when cutting the activated components of the primary circuit and steel shielding when handling the cut fragments. This procedure proved to be correct.

1.2. Constraints

Time constraints

The V1 NPP´s decommissioning planning scheduled a well-defined end of its process. Thus, the time for fragmentation of the selected components was also precisely defined and constituted the critical path. Due to the time shift in the decontamination of V1 NPP´s primary circuit, it was necessary to shorten the length of the cutting period. The original design considered implementing fragmentation activities in one pool, but two cutting pools were constructed due to the need to reduce the cutting time.

Financial constraints

The operator had to provide financing not only for cutting the selected components but also for storing shielded containers in interim storage of solid RAW, as well as treatment and disposal of some parts at the Mochovce National Radioactive Waste Repository (NRR), when possible.

Technical constraints

Underwater component cutting operations require technologies that can operate under hydrostatic pressure, which can also be partially converted to hydrodynamic pressure. Companies carrying out such activities must have such constraints technically resolved and verified, as required by the procurement documentation in the case of V1 NPP. The contractor had to use tools that had been tested many times on other underwater cutting projects and had no problem with high dose rates.

1.3. Relevance

This case study may help the team responsible for the primary circuit-cutting project's preparation and implementation phase to develop a comprehensive technical specification. It is a practical example of how to set cutting objectives concerning feasibility, the primary purpose, and maintaining the highest safety standards. Attention is also paid to specific measures to optimise the radiation protection of workers during the cutting of activated primary components, as these components have very high activity of the order of up to 10^{13} Bq/kg.

Currently, there is no public information similar to the one embedded in this case study regarding the cutting of the large, activated components of the primary circuit of a WWER-type reactor, which is of the highest interest, accounting that this crucial task is to be addressed, in the early decommissioning stages.

Nuclear operators, decommissioning and waste management operators or regulatory authorities that will address the nuclear power plant decommissioning in the future or are in the early decommissioning phases may obtain comprehensive information on the cutting process of the reactor primary circuits. The case study provides a basis for them to develop a proper plan for cutting processes, selection of optimal method for cutting and consequent radioactive waste management.

2. SCOPE AND STRUCTURE

The scope of the case study is to explain how the remotely operated fragmentation was implemented at V1 NPP, to convey the lessons learned during the process and to summarise key takeaways such as results of the process, organisation and human aspects, regulatory and licensing aspects, quality and benefits to the operator as well as other organisations. This is significantly supported by a case study covering the following:

- introduction summarising the sources/documents based on which it was developed, together with a description of the project background,
- a conceptual description of the objectives of implementing the primary circuit components fragmentation activities,
- an overview of cutting techniques/tools and necessary workplaces, such as cutting pools, water treatment, cranes, packaging techniques, characterisation, and final packaging into fibre-concrete containers (FCCs),
- the use of drawings and photos of the fragmented components of V1 NPP´s primary circuit,
- examples of the fragmentation process of the different types of components presented using 3D visualisation and photos of the real process,
- and the overall results, organisation and human aspects, regulatory and licensing aspects, quality, benefits for operators and other organisations, and references.

3. OVERVIEW

The case study describes the cutting process of the large-sized activated components of V1 NPP´s primary circuit (hereinafter referred to as the primary circuit components), which was implemented via remotely operated cutting devices underwater.

The WWER-440/230 nuclear reactor´s design ensures, among other things, a relatively uniform distribution of the neutron flux parallel to its vertical surface. The continuous presence of this neutron flux in the reactor activates its parts, and the activation level of the irradiated components is proportional to the intensity of the neutron flux. During decommissioning, the dismantling and cutting of said components becomes one of the biggest challenges. The V1 NPP primary circuit components were sequentially disconnected from their related systems in the standard working position and transported to the cutting positions in the cutting pools. Therefore, it was necessary to build cutting pools, where, using remote-controlled tools, these large components were cut to dimensions, allowing them to be handled within the designated RAW management process. Once fragmented to the defined sizes, the newly created fragments were packaged into specific package forms and sent for disposal or long-term storage.

4. SUMMARY OF LESSONS LEARNED

This section summarises aspects, lessons learned, and recommendations verified in practice from the V1 NPP primary circuit components cutting process. This process has required special attention and can generally significantly impact the feasibility of the process itself, whether from the technical, legislative, time or, ultimately, financial aspect.

It is important to consider these aspects, lessons learned, and recommendations at the inception of the tender documents preparation stage and the contractor's selection for the cutting of the primary circuit components or the planning stage. JAVYS, a.s. recommends the following for other decommissioning and waste management operators planning to carry out similar activities.

Organisational and management recommendations

1 **Experienced contractor:** It was crucial to guarantee a successful and safe project implementation to choose an experienced contractor with vast experience in the fragmentation of reactor internals and reactor pressure vessels (RPV).

2 **Detailed design of the prerequisites:** A well-developed detailed design was used to create the prerequisites for successful implementation. The contractor was enabled to use proven systems and components and to work with experienced subcontractors onsite.

Characterisation and RAW management

1 **Characterisation to select the cutting method:** Sampling, characterisation, and analysis of activated components are always the first steps of proper planning, as their results are used to select the appropriate cutting method.

2 **A thorough characterisation:** Thorough characterisation resulted in significant savings in terms of the volume of fragments stored in the ISF by partially storing the fragments in the FCCs at the Mochovce NRR.

3 **Treatment methods and streams:** The characterisation should classify the activated components into essentially low-level waste (LLW) and intermediate-level waste (ILW) to inform appropriate treatment methods. A new RAW stream (activated RAW) was created.

4 **Timing:** The characterization of RAW is a very important topic in the case of handling activated components as well, especially in the context of eventual partial disposal in a RAW repository. Sequential characterization is recommended before fragmentation of the activated components, as well as confirmatory sampling during cutting and final sampling after cutting. The result will be optimal use of disposal facility Waste Acceptance Criteria and accurate characterization of activated RAW in the interim storage for the purposes of their future RAW management.

Structural and logistic aspects

1 **Using two pools enables timesaving:** Establishing two pools in the containment resulted in significant time savings regarding the RPV fragmentation scheduled planning.

2 **Storage capacity optimisation:** The Interim Storage Facility (ISF) capacity was optimised by analysing the availability of a suitable package form. Significant financial savings were achieved using its package forms and additional variable shielding.

3 **Using existing containers and cranes:** Existing shielded transport containers, used during the operation, were used to transport the reactor internals and shielding assemblies. The existing 250-tonne cranes handled the transport containers and the shielding bell.

4 **Special ISO transport containers:** A final liquid RAW treatment facility in Mochovce NRR was involved in the RAW treatment process. For this purpose, a special ISO transport container with internal shielding was provided so the fragments could be transported outside the Jaslovské Bohunice site for cementation into the FCCs.

5. CASE STUDY

5.1. Sources of Information

The sources of information used to develop this case study are as follows:

- Programmes of work for activities related to the fragmentation of V1 NPP´s primary circuit components [1];
- Evaluations of the programmes of work for activities related to the fragmentation of V1 NPP primary circuit components [2];
- BIDS D4.2 Project Technical Specifications [3];
- Photos and videos from the implementation of V1 NPP primary circuit components fragmentation [4];
- Interviews with the Project Manager and members of the BIDSF D4.2 project team [5].

5.2. Background

The primary circuit of a WWER-440/230 (**Figure 1**) reactor inherently includes contaminated and activated large components. Activated components are the most notable carriers of dose rates and are exclusively located in the RPV during the operation.

Cutting activated components presents one of the biggest technical challenges within the decommissioning process and is unique to each type of nuclear power plant. This process is undertaken in specific workplaces (**Figure 2**). After completing the remotely controlled underwater fragmentation operations of the activated primary circuit components and subsequent RAW management, 99.9% of the radioactivity was removed from V1 NPP while significantly reducing the level of potential radiation risk by the end of the decommissioning process.

The activated components' activation level is relatively proportional, particularly to their position in the reactor relative to the reactor core where the fuel is located. Their position relative to the reactor core also drives the shielding required when cutting them. Even the lowest level of dose rates from activation when cutting the primary circuit components requires massive shielding. In the conditions of V1 NPP, a water environment was chosen as the shielding.

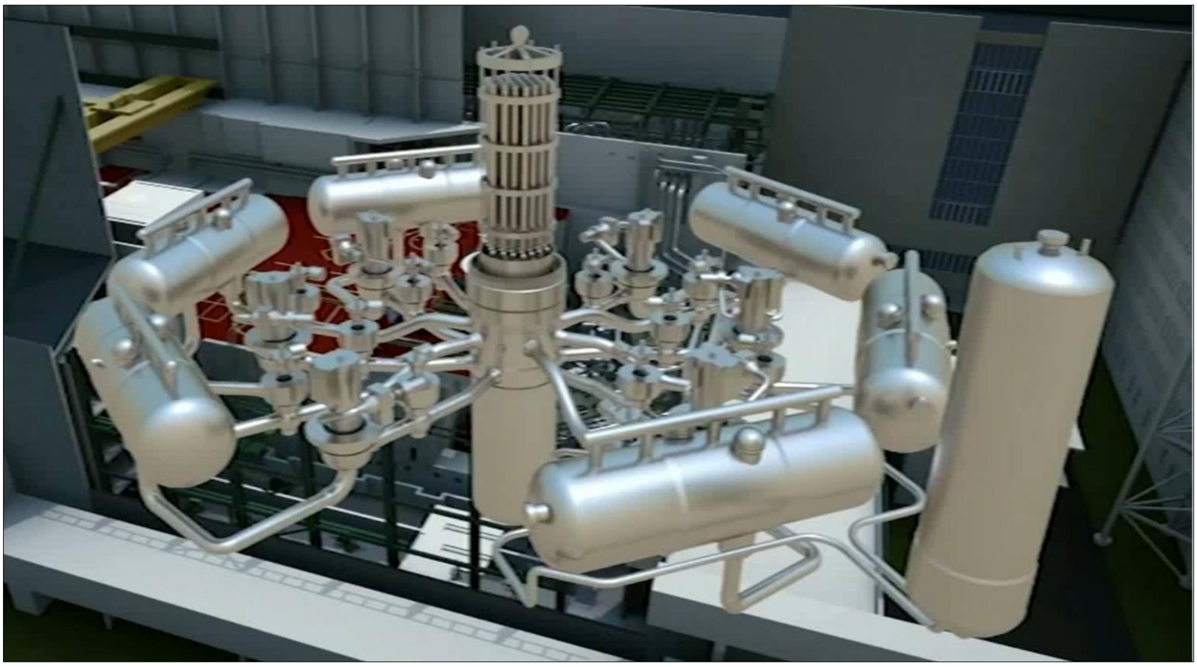


Figure 1. 3D Layout of the WWER-440/230 primary circuit

Figure 2. Construction of the wet-cutting workshop (left). RPV in the wet-cutting workshop (right)

5.3. Description of the Project

Within the BIDSF D4.2 Project, which forms the basis for preparing this case study, the cutting of large, activated components of the WWER-440/230 reactors at V1 NPP was carried out. The aim of the activities of this project was dismantling, fragmentation and partial RAW management of the following (technically most difficult to cut) activated components of V1 NPP´s reactors:

- protective tube unit (2 pcs),
- core baskets (2 pcs),
- bearing shells of the reactor core (2 pcs),
- reactor pressure vessels (2 pcs),
- reactor shielding assemblies (72 pcs),
- and absorbers (159 pcs).

Large, activated components were successively fragmented into defined pieces under water and placed into the FCCs using metallic transport baskets. The process of cutting of the activated components took 22 months. The FCCs filled in this way that met the limits and conditions for disposal at the Mochovce NRR were filled with cement grout and disposed of at the repository. The full FCCs that did not meet these conditions were stored at the ISF. In this case, they are stored until they can be disposed of at the NRR in Mochovce or the planned deep geological repository when available.

5.4. Equipment, Components, and Cutting Process

5.4.1. Fragmentation equipment

The following sections describe the most frequently used cutting tools and equipment for cutting the V1 NPP primary circuit's activated components underwater.

5.4.1.1. Devices for segmentation

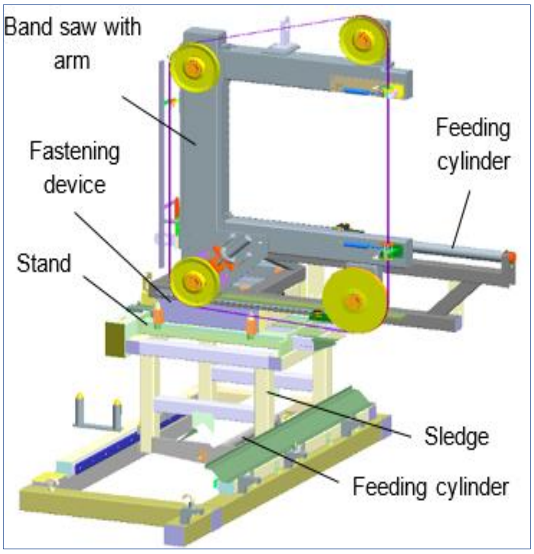
The toolbox for implementing the underwater segmentation of V1 NPP´s primary circuit contained, in particular, many different disc saws, a band saw, and shearing tools. These tools were remotely controlled and operated from a work bridge or the reactor hall floor. V1 NPP´s operation techniques were also used to transport large components as part of the segmentation process.

All cutting tools are designed to optimise their performance for specific cutting tasks. They are modular and flexible, allowing operators to adjust them when needed. The tools are made of stainless or painted carbon steel (motors, cylinders) to allow underwater usage and are easily decontaminated. Tools and metrology are designed to diverge as little as possible from earlier projects to ensure that these projects' experience and "know-how" are considered.

Most of the tools are powered by a hydraulic power pack, which uses a water-glycol emulsion approved for use in the operating Nordic plants and other power plants where underwater cutting has been performed.

BAND SAW

The band saw (**Figure 3**) is the most efficient and optimised cutting tool. It can cut all materials, including very thick materials, for a long time without blade replacement and is relatively unaffected by vibrations.



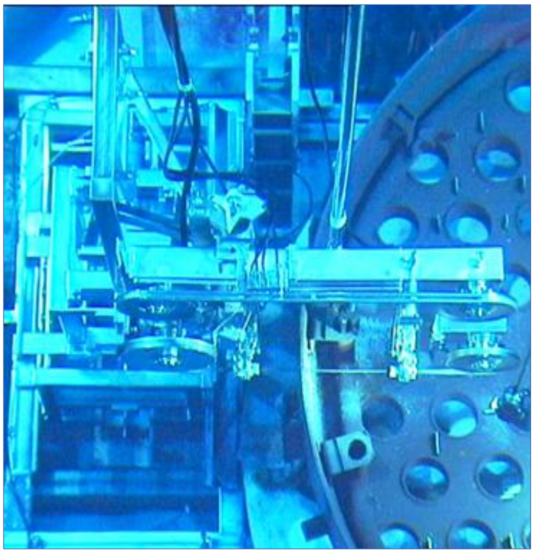


Figure 3. Band saw schematic (left) and its use underwater (right)

Developing a single-purpose piece of equipment that used an endless belt underwater to cut off the individual reactor internal components and the RPV was necessary.

The sawing process produces chips, which must then be handled.

Commonly available configurations of cutting equipment could not be used. Poor construction design may make the equipment unusable.

When cutting different types of materials, it is necessary to analyse which endless saw blade to use, attending to the quality of the blade, size, and hardness of the teeth to avoid jamming, breakage, or high wear of the teeth.

DISC SAW

The disc saw (**Figure 4**) is a versatile tool equipped with different clamping and lifting devices. More than 60 different clamping devices have been designed to cut the complicated geometries of the different reactor vessel internals in previous segmentation projects. The disc saw design enables the saw to cut deep cuts with a swivelling arm and long cuts with a sledge running along a rail. The feeding of the arm and the sledge is controlled by an "intelligent" electrical system that optimises the cutting speed for the different cutting conditions. The cutting speed varies depending on the object's thickness and material and the saw disc's condition. A typical saw disc's thickness ranges between 4 and 8 mm.

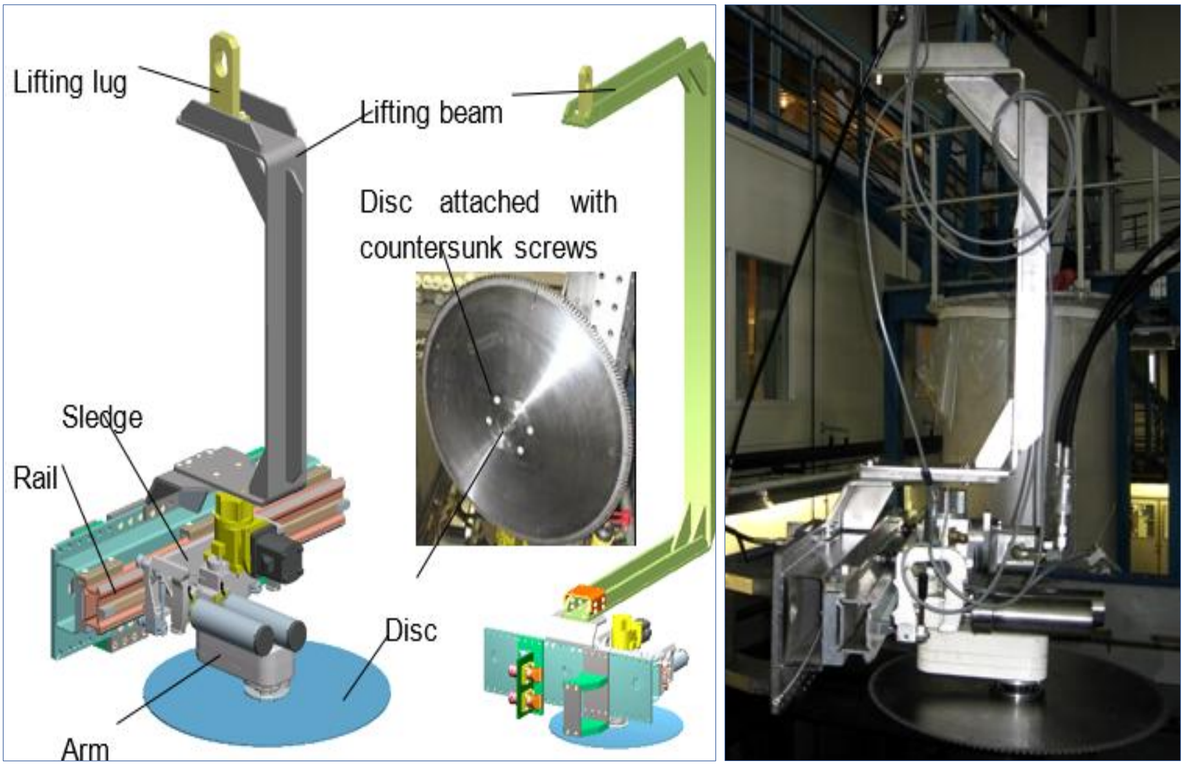


Figure 4. Disc saw schematic (left) and the real tool (right)

For cutting individual internal parts of the reactor and also the RPV itself, it is advisable to use cutting using an endless band under water (band saw).

Commonly available configurations of cutting equipment could not be used. Poor construction design may make the equipment unusable.

When cutting different types of materials, it is necessary to analyse which endless saw blade to use, attending to the quality of the blade, size, and hardness of the teeth to avoid jamming, breakage, or high wear of the teeth.

5.4.1.2. Shearing tools

Shearing is a fast, easily handled-cutting method that does not produce chips. Three types of cutting blades, Straight, Parrot, and Eagle, can be easily changed depending on the situation and shape of the object to be sheared. Different adapters hold the tool, and it's handled with extension poles (**Figure 5**).

Figure 5. Shearing and clamping equipment (straight, parrot and eagle type)

The advantage of shearing is that no chips are produced, which must be handled afterwards. The equipment must be designed so that the shearing pressure does not destroy individual parts.

However, not everything can be cut; it depends on the thickness, type of material, and cut availability.

5.4.1.3. Wet-cutting workshops

To cut the large components of the V1 NPP primary circuit, it was necessary to establish new wet-cutting workshops (WCWs) capable of shielding the high dose rates, allowing control over the cutting process, and providing sufficient cutting capacity concerning the specified schedule (**Figure 6**). Fragmentation was carried out using remotely controlled and monitored instruments, almost entirely underwater, in two purpose-built pools aiming at radiation shielding.

Each wet-cutting workplace was equipped with the following major equipment and systems:

- 2 x overhead cranes,
- 2 x working platform,
- 8 x hydraulic power supply source,
- 4 x in-water cameras and lighting,
- 2 x working lights,
- 1 x column crane and 2 x air compressor,
- 1 x water filtration and cutting turntable,
- 1 x centring structure.

Considering the need to meet the set cutting end date, the maximum capacity of the cutting equipment, safety, and the required amount of cutting, two workplaces/pools (**Figure 7**) were set up along with four turntables. These were able to cut four large, activated reactor coolant components simultaneously.

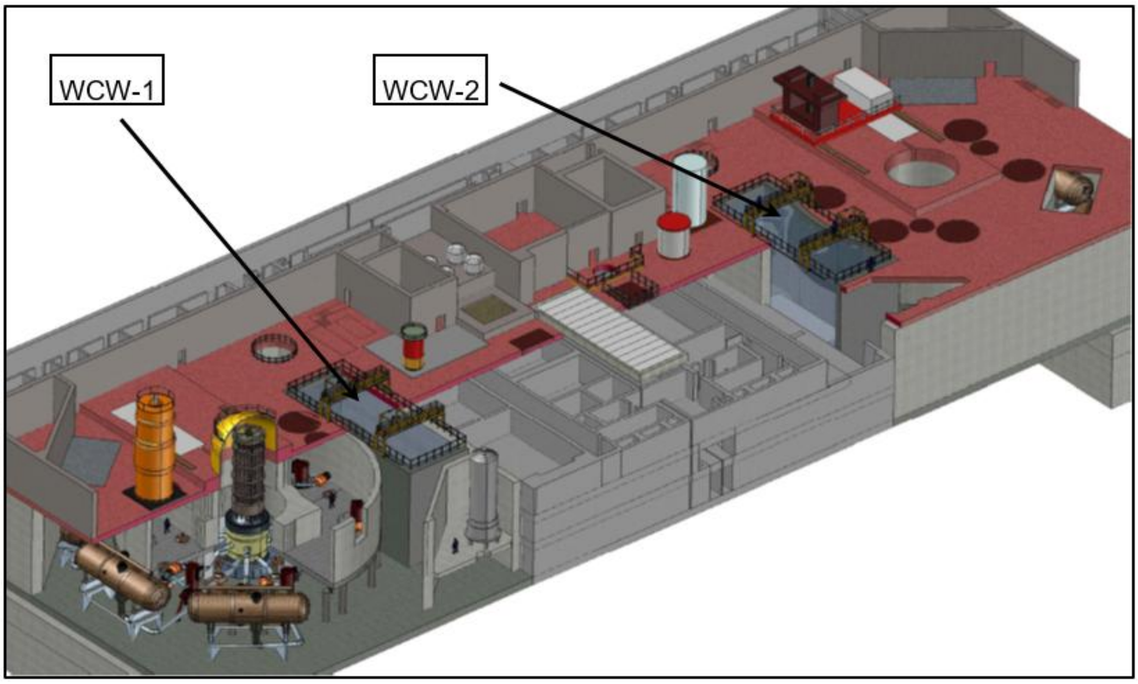


Figure 6. The general layout of the WCWs and their auxiliary areas in the V1 NPP reactor hall

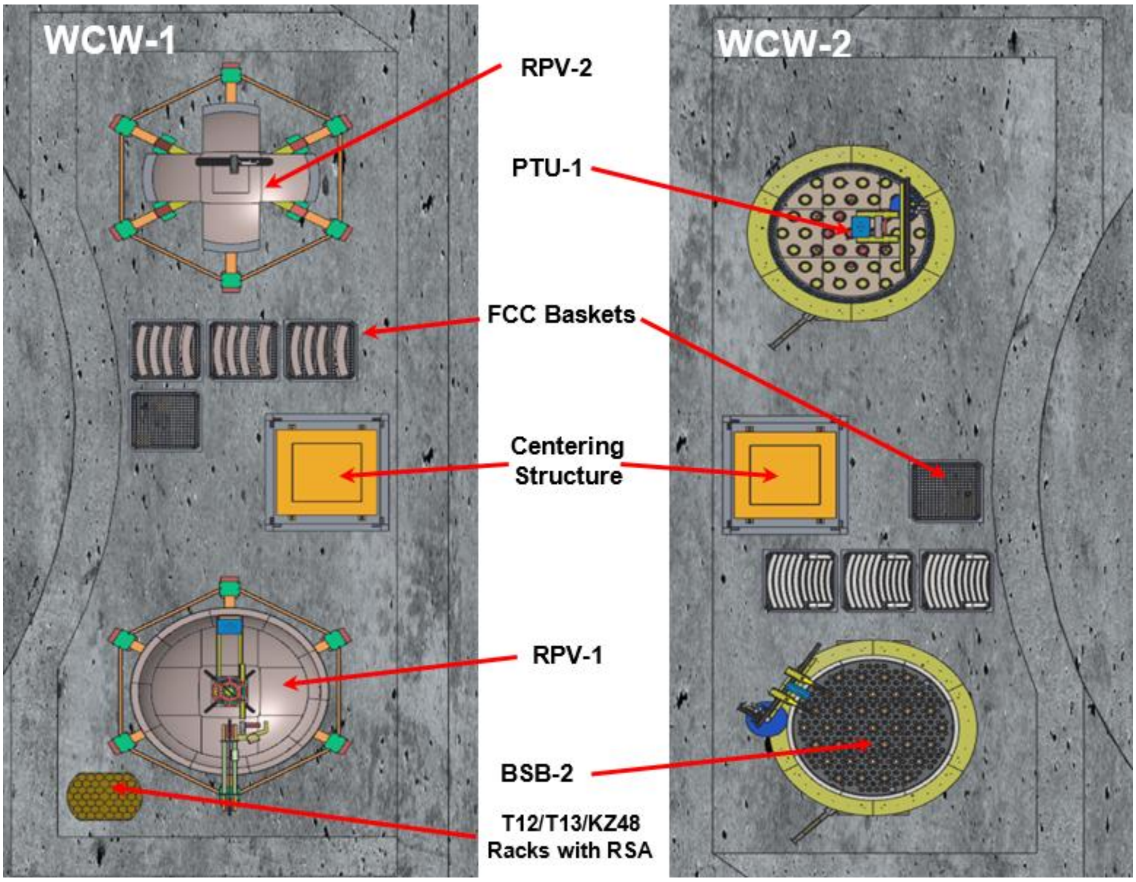


Figure 7. Internal layout of the WCW workplaces as of January 2021

The most commonly and regularly used cutting tools were stored near the WCWs for quick access. These included lifting/handling tools, band saw equipment including the drive unit, circular saw equipment including the drive unit, spare parts, and consumables such as saw blades.

Instruments that were used occasionally were stored away from the pool in the reactor hall. This area was within reach of the overhead crane and was about 200 m² in size. It was divided into several areas. Instruments used last or rarely used were stored in an accessible location, which did not need to be in the reactor hall. The same applies to bulk storage of auxiliary material, if necessary.

It is crucial to assess the number of WCW workplaces needed to handle the entire task, their internal and external dimensions, and their location within the controlled area.

If even one parameter is poorly assessed, the task may not be completed in time, and the total implementation costs will increase significantly.

5.4.1.4. Water treatment and metallic chips collection system

The WCW had a filtration/exhausting system to collect impurities and chips. A hose with a nozzle operated by a rod was used for cleaning. The system was easy to operate and could be placed anywhere in the pool, allowing access to the entire pool area. Different stands were used depending on whether the equipment was hung on the wall or at the pool's bottom. The exhausting system has two stages of filtration (**Figure 8**): a pre-filter before the pump and a fine filter. The pre-filter has a relatively large mesh compared to the fine filter.

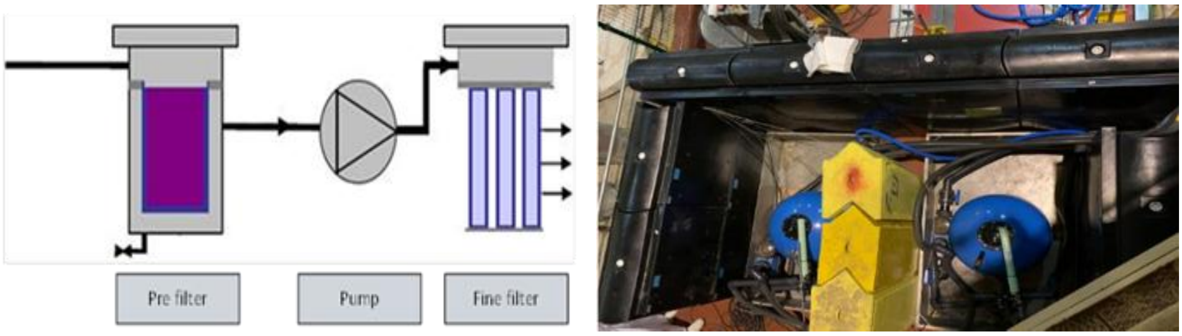


Figure 8. Filtration system layout (left) and shielded pumps in the reactor hall (right)

During cutting, the suction hose was positioned next to the tool to pick up chips and debris. As the cutting tools create a water vortex, only a small part of the total chip volume is collected in this way. The remaining chips were collected in campaigns outside the cutting process. The exhausting system collected the chips into the pre-filter liners, which were then emptied or stored with the rest in containers. During the cleaning campaigns, chips were collected in piles and picked up using a scooping tool and/or suction device (**Figure 9**).

Figure 9. Scooping of chips not captured by exhausting from the bottom of the WCW

The equipment was not efficient enough in the first stages of cutting. Because the water was becoming turbid, additional equipment (to increase the filtration capacity) was necessary to purify and filter it.

The water treatment system and the collection of metallic chips needed to be reconsidered for the next cutting technology application.

The cutting sequence of the individual components also needed to be carefully considered.

5.4.1.5. Auxiliary equipment

All fragmentation, management, characterisation, and handling activities implemented within the WCWs require specific equipment, such as working platforms and overhead cranes (**Figure 10**).

The underwater fragmentation activities of the wet cutting sites were remotely controlled by operators operating at +10.50 m level working platforms, which consisted of sliding platforms that moved in a north-south direction on both sides of the WCWs, allowing operators to supervise cutting operations and to place auxiliary cutting equipment such as hoses, hydraulic power supplies and monitoring equipment on the platform. The superstructure crane with an electric chain lift of 1.5 t moved east-west across the platform and was used to handle extension rods carrying cutting tools into the water. Last, 5 t gantry cranes were used to handle fragmented pieces, auxiliary structures and equipment, and support service activities on the working platforms at each fragmentation site.

The tools for implementing segmentation of the protective tube's unit, the core basket, the bearing shell bottom, the RPV, the absorbers and the shielding assemblies underwater consisted of various disc saws, band saws, and hydraulic and electrical auxiliary equipment, which were remotely controlled by operators from a working platform.

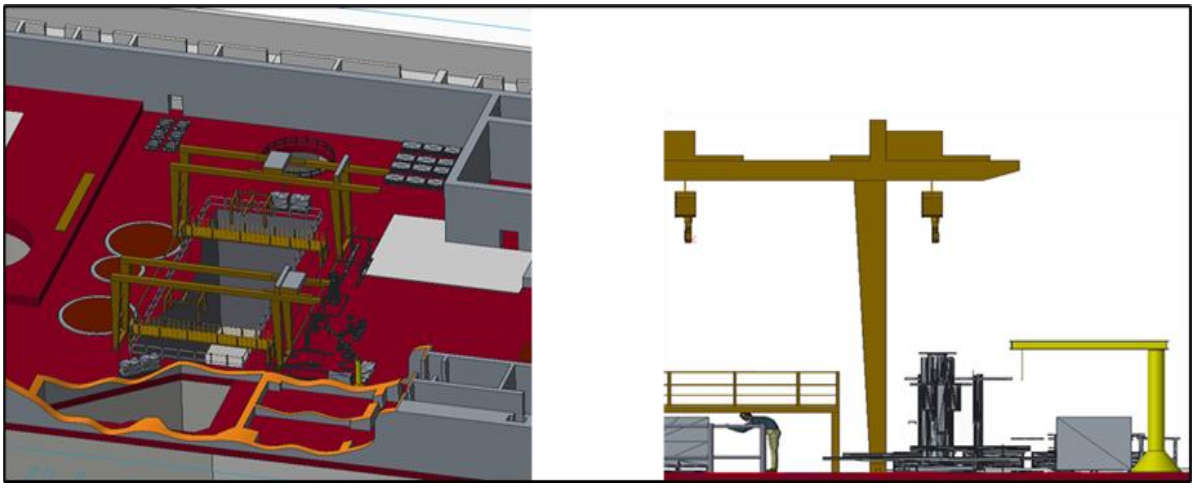


Figure 10. Working platforms and overhead cranes for the WCW

Ensures the remote control of the cutting devices is in several positions and that fragments from the wet cutting workshops are smoothly handled.

The working platform floors were contaminated after the handling tools were used. Therefore, each surface around the WCW must be monitored. If contamination is detected, mitigation measures (deep cleaning of the tolls from the WCWs) must be taken.

5.4.1.6. Cutting and packaging support equipment

The support equipment comprises a centring structure (**Figure 11**), a shielding bell (**Figure 12**), and an octopus characterisation device (**Figure 13**). This equipment was used for operations after segmentation, i.e., from individual fragment characterisation to the filled FCC basket removal from the WCW.

The centring structure aimed to correctly position the empty baskets on the fragment and ensure:

- that the shielding bell has correctly captured it once it is complete,
- and the characterisation of the basket by the octopus characterisation device, a scanning device equipped with eight gamma probes.

The bottom of the shielding bell was always positioned below the baskets. When the shielding bell catches the basket and the bottom, it can lift above the water surface for drainage.

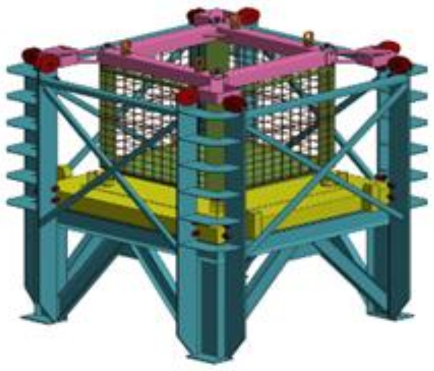


Figure 11. Centring structure

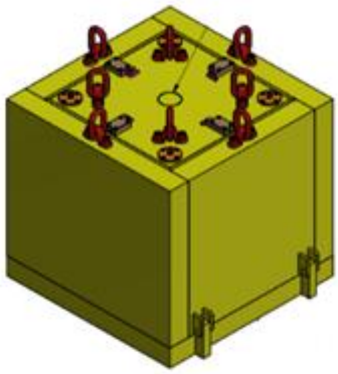


Figure 12. Shielding bell

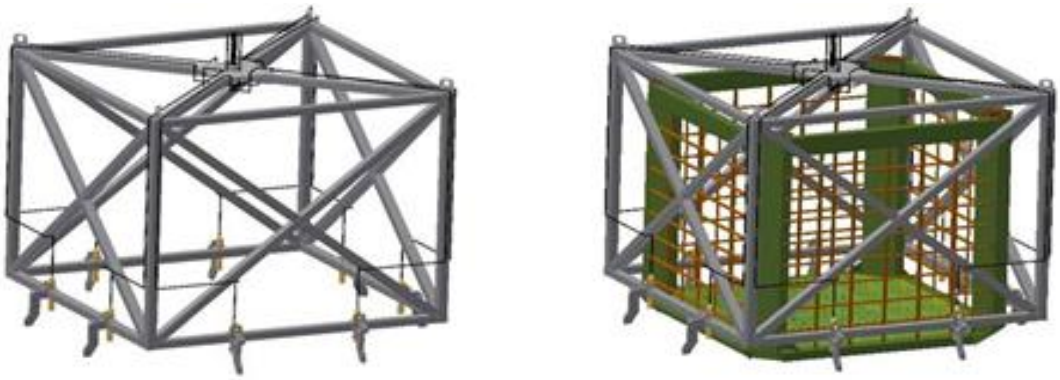


Figure 13. Octopus characterisation device

When designing individual devices, it is essential not to underestimate the individual parts due to the robustness of their construction, especially in the case of the shielding bell.

Choosing the correct methodology for characterising the individual components in the basket.

Accurate crane coordinates are essential when handling baskets at the bottom of a WCW.

5.4.1.7. Equipment to transport components to the cutting pools

The large components of the V1 NPP primary circuit were handled using existing equipment. The used container is designed to transport reactor internals (RIS container, **Figure 14**) and a 250-tonne crane at the reactor hall.

The RIS container comprises the shielding container and the internal lifting equipment:

- The shielding container, which has a cylindrical shape and five segments, provides biological shielding for the operating personnel while transporting the reactor internals.
- The lifting equipment consists of an upper and a lower frame connected by a central bar. In both frames, there is a trio of extending mechanisms providing for the attachment of the RIS container. There is a lifting eye on the upper frame.

Figure 14. RIS container

After being transported via RIS container, the activated components are placed on an unloading rack on the WCW (**Figure 15**). This allows the transported activated component to be moved from the RIS container to a specially designed turntable at the bottom of the WCW, where it is gradually cut underwater. Once the transported activated component is placed on the WCW turntable, the unloading and transport jig handles other cut components in the WCW area.

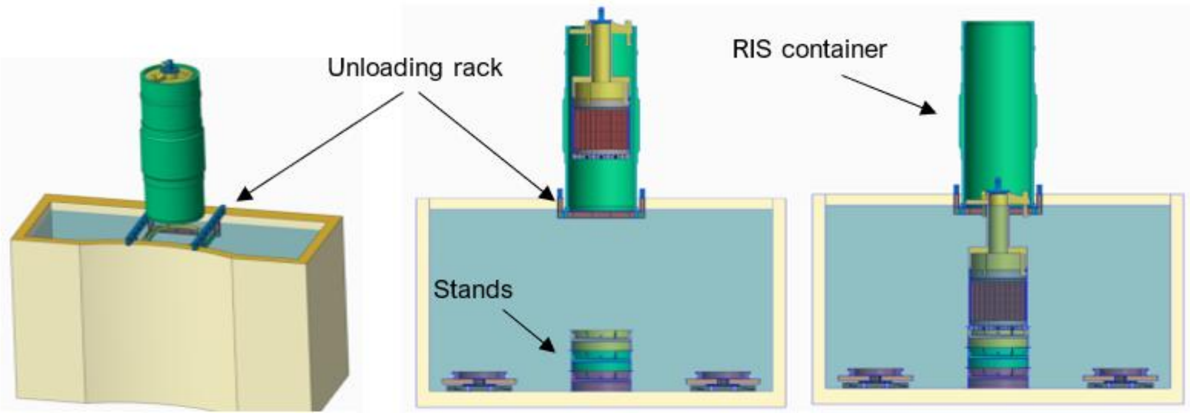


Figure 15. Process of unloading the transported activated component in the WCW

In addition to such a support structure, time-tested equipment was used. This equipment was also used during the operation of the plant.

Due to the age of the equipment, it is necessary to carry out more frequent operation inspections.

5.4.1.8. Basket transfer station

A basket transport station was set up at the bottom of the Unit 1 spent fuel storage pool and in the universal nest. The basket transport station (**Figure 16**) was used to relocate the baskets to the respective FCCs using a shielding bell and to seal (lid) these bins under radiation-suitable and safe conditions.

All operations of relocating the baskets into the containers and closing them with the respective lids are controlled from the level of the Reactor Hall at Unit 1, where a local control panel with a supporting camera system is located. An additional camera system has been installed at the crane operator´s place on the 250-tonne crane to better handle the basket transport station shielding bell.

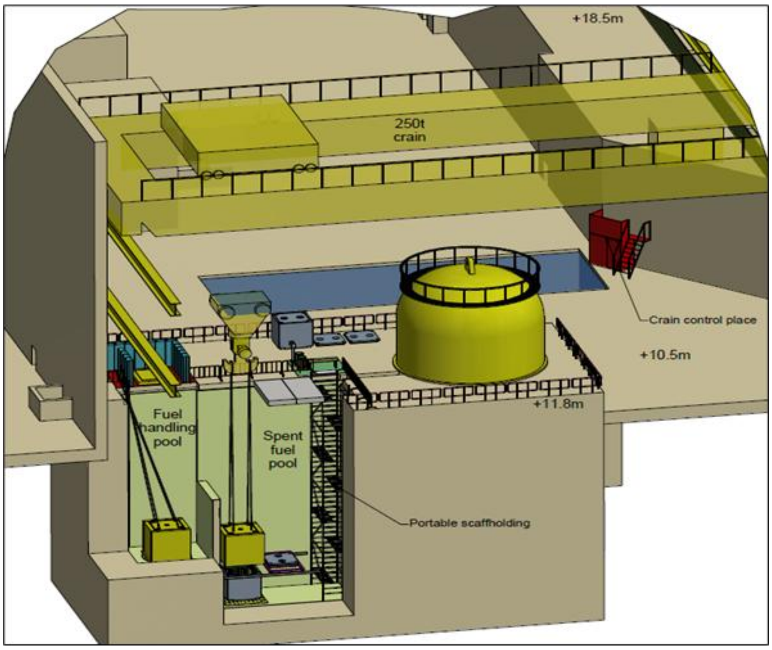


Figure 16. Overall layout of the basket transfer station (left) and basket transfer station (right)

The best possible location for the basket transport station was selected. After dismantling the equipment and cleaning the area, the ideal space for the equipment placement was created to shield the operating personnel from radiation.

Carefully assess the location of the basket transport station in terms of the space required for equipment to protect service personnel from radiation.

5.4.2. Selected large, activated components for fragmentation

Figure 17 presents the main components of the WWER-440/230 reactor that were exposed to high neutron flux during its operation.

The following acronyms in the figure stand for:

- **RVH:** Reactor Vessel Head;
- **RPV:** Reactor Pressure Vessel;
- **PTU:** Protective Tubes Unit;
- **CB:** Core Basket;
- **BSB:** Bearing Shell Bottom.

This has caused them to activate and emit very high dose rates. Their processing requires very efficient shielding (water, steel).

The following case study sections describe the primary circuit's large components and demonstrate the approach to cutting such components.

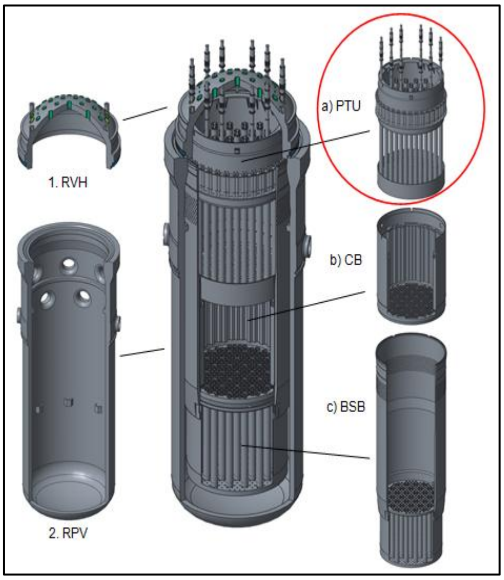


Figure 17. Large-size activated components of the WWER-440/230 reactor primary circuit

5.4.2.1. Bearing shell and bearing shell bottom

The cavity with the bottom is the main bearing element for reactor internals (**Figure 18**), enabling the basket to be mounted and anchored on the bottom (**Figure 19**), the protective tubes unit to be mounted on the basket, the coolant flow to be arranged inside the reactor, and the intensity of the neutron flux to the reactor vessel to be lessened. The bottom of the cavity is a rest for the core basket and is also used to arrange channels to extract fuel assemblies from the core.

The bottom of the cavity mounted and anchored inside the cavity consists of upper and lower spacing grates adjoined by 37 protective tubes with damper tubes inside. To allow the coolant to enter the space between tubes on the bottom, the lower grate has 1662 pieces of ø40mm openings.

Basic technical data of these components:

- Maximum diameter (shaft flange): ∅ 3,366 mm
- Maximum height: 11,102 mm
- Maximum wall thickness: 80 mm
- Wall thickness in the AC area: 60 mm
- Material - steel grade: 08Ch18N10T
- Weight: 71,350 kg

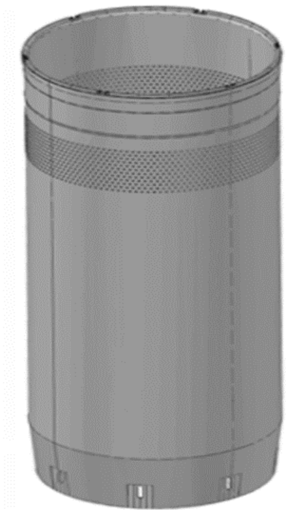


Figure 18. Reactor bearing shell

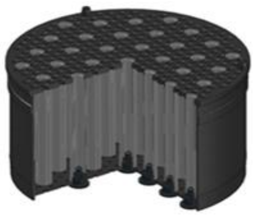


Figure 19. Reactor-bearing shell bottom

5.4.2.2. Shielding assemblies

The reactor shielding assemblies are designed to reduce neutron and thermal fluxes to the WWER-440/230 reactor pressure vessel (for reactor vessel side protection). They are similar in dimensions to the fuel assembly. **Figure 20** shows an example of a shielding assembly, where the following numbers represent the:

1. Bundle of absorber rods;
2. Duct tube;
3. Head;
4. Bottom nozzle;
5. Absorber;
6. Upper support slab;
7. Lower support slab.

During operation, each reactor is provided with 36 shielding assemblies installed around the reactor core. The shielding assembly is installed in a core basket's bottom socket by the bottom nozzle, its spherical surface resting on the cone part of the socket. During reactor operation, the shielding assembly does not move. The metal of the duct, bundle rods and coolant reduce neutron flux to the reactor pressure vessel.

The bundle consists of seven ø48 mm solid section rods anchored in the lower and upper support slabs. The lower support slab is welded to the shielding assembly's bottom nozzle, whereas the upper is welded to its head.

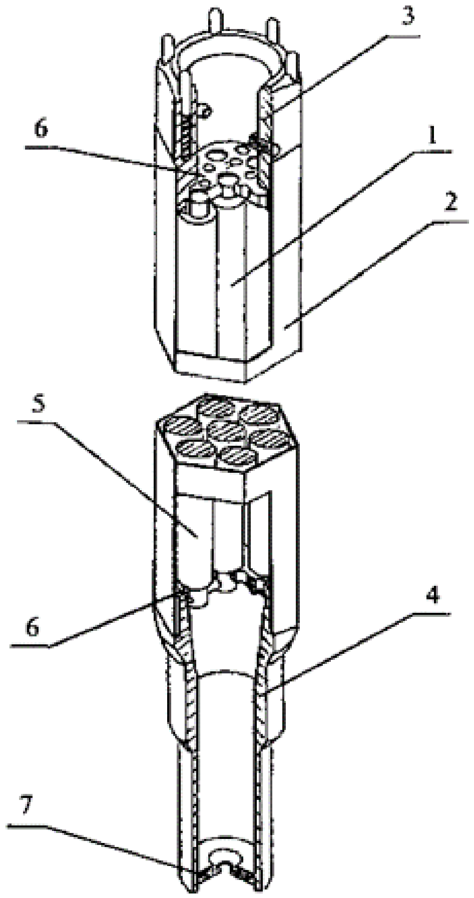


Figure 20. Cross-section of a reactor shielding assembly

5.4.3. Description of the cutting process

The following sections describe the underwater cutting process and the transport methods applied to the V1 NPP´s primary circuit's components described above. They are also focused on the partial management of the cutting fragments.

The large components of the V1 NPP primary circuit described can be grouped into three groups based on shape and cutting technique, as shown in Table 1.

Table 1. Large components classification

GROUP 1	GROUP 2	GROUP 3
Simple, intermediate ring with simple bottom	Complex structural node	Hexagonal inhomogeneous cross-section
• Reactor pressure vessel. • Core basket. • Reactor bearing shell – upper part	• Protective tube unit. • Bearing shell bottom – lower part.	• Shielding assemblies. • Main control assembly absorber parts.

The case study provides a representative example of underwater cutting for each group. This approach introduces the reader to the methods of cutting all large and activated primary circuit components.

5.4.3.1. Groups 1 and 2: simple intermediate rings and complex structural nodes

The procedure for cutting the reactor-bearing shell illustrates the cutting of these component types. This example describes the cutting of a simple geometric shape—the intermediate rings of the bearing shell—and a complex structural node—the bottom of the bearing shell.

Cutting planning and workplace layout

Fragmentation and packaging plan of the bearing shell and its bottom

Figure 21 provides a step-by-step plan for segmenting the reactor bearing shell and the bearing shell bottom. This plan aimed to optimise the cutting process regarding radiation, mass, and volume filling of the FCC baskets. The tools and equipment described in Section 5.4.1 were used to cut the bearing shell bottom.

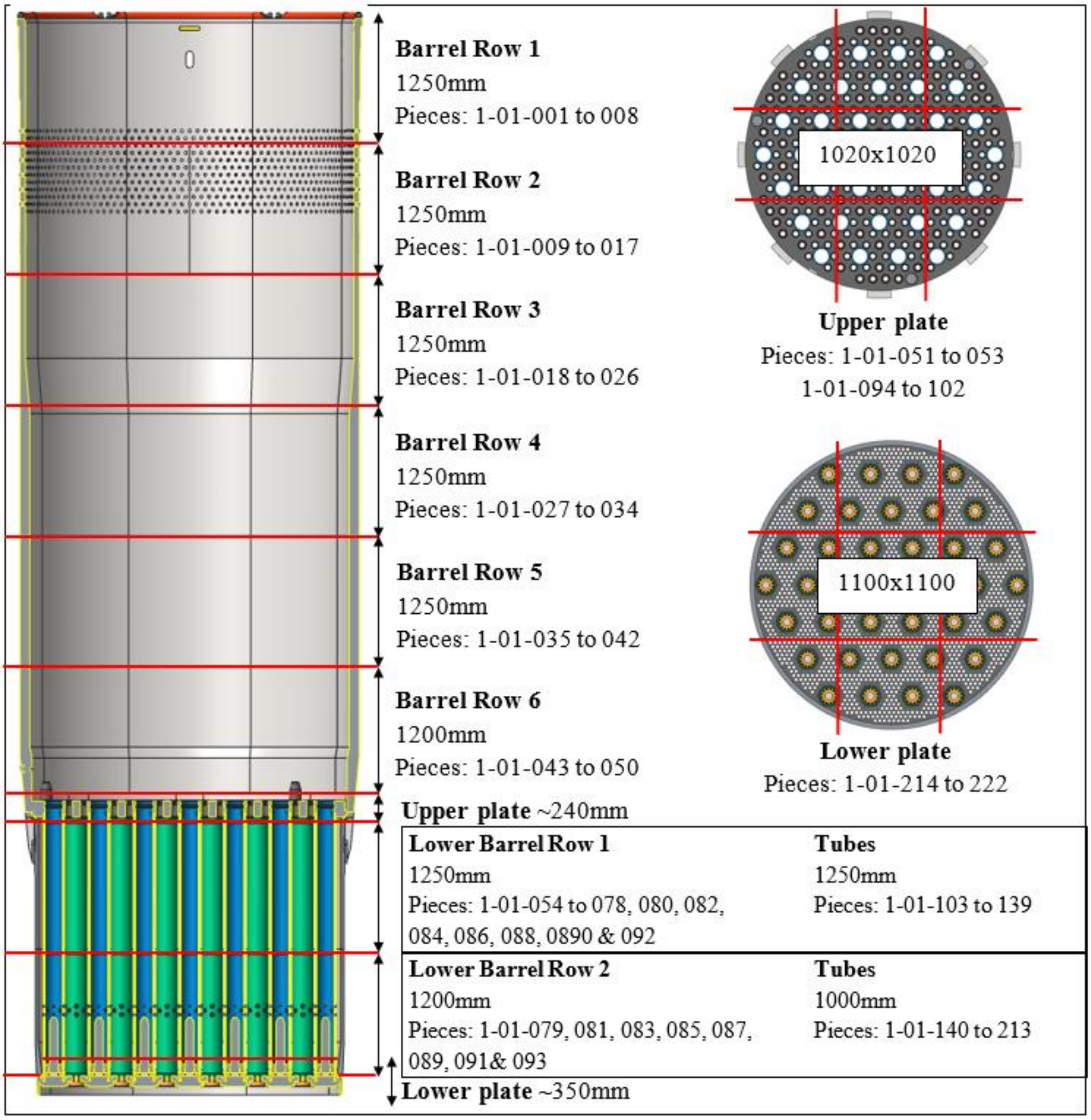


Figure 21. Cutting plan for the reactor bearing shell and its bottom fragmentation

Fragmentation workplace

As shown in **Figure 22**, the reactor bearing shell and its bottom were cut at the wet-cutting workplace at Unit 2 (WCW-2), specifically at position 2B (WCW-2B).

Spare parts and auxiliary equipment, such as a stand for handling the reactor internals, were stored close to WCW-2 (grey rectangles in **Figure 23**). A service area was required near each pool for equipment preparation and repair (green rectangles in **Figure 23**). After the segmentation and packaging, a basket transport station was used to finalise the package form. The basket transport station was set up at the bottom of Unit 1 of the former spent fuel storage pool in its universal nest.

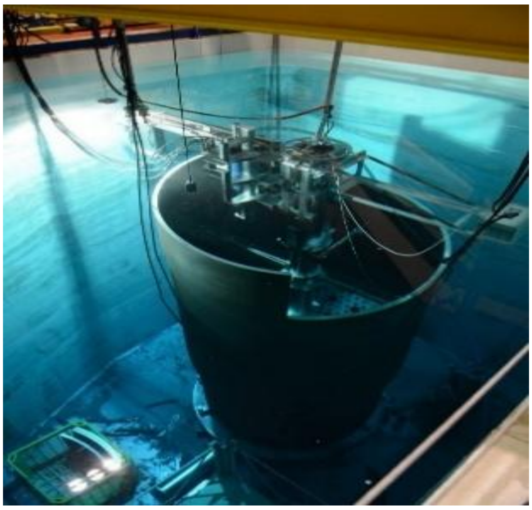


Figure 22. Wet-cutting workplace of Unit 2, position 2B

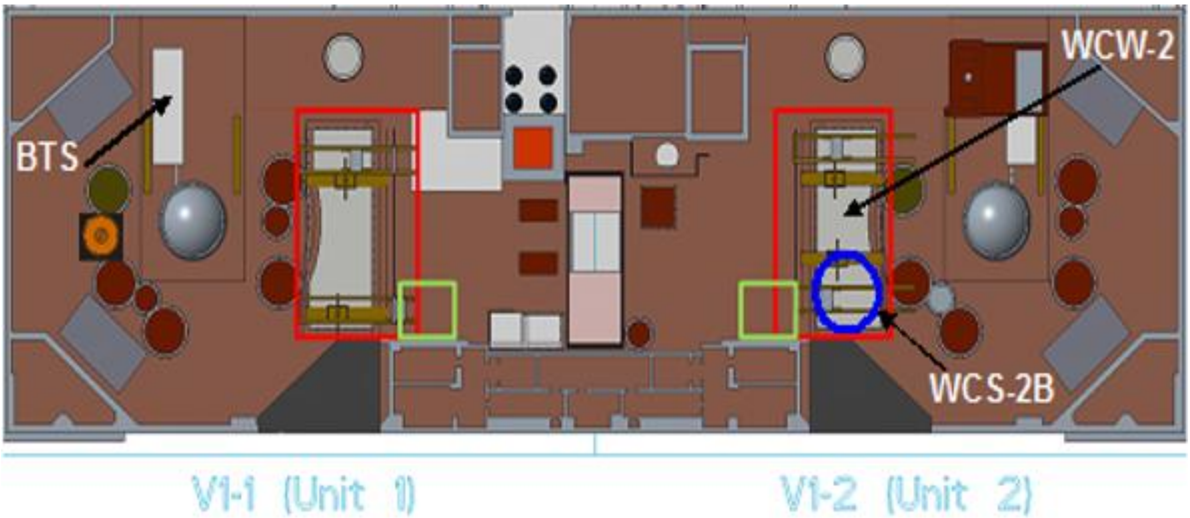


Figure 23. Wet-cutting workplace of Unit 2 general layout

At this wet-cutting workplace only internal reactor parts made of stainless steel were cut, which guaranteed a better quality of water transparency.

Steps of the cutting process

Transport and handling

The bearing shell and its bottom were handled using an existing RIS container and a 250-tonne crane (see Section 5.4.1.7). After being transported in the RIS container, the RIS container was placed on the WCW unloading rack. Special lifting equipment installed inside of the RIS container was developed to unload the bearing shell and its bottom from the RIS container. Then, the bearing shell and its bottom were moved to specially designed support pedestals at the bottom of the WCW. The bearing shell and its bottom cutting were performed on a turntable installed at the WCW-2B position. The shell was segmented underwater by mechanical cutting tools (band and disc saw), controlled and operated from the working platforms.

The RIS container is a time-tested device for transporting activated equipment from the reactor to the inspection shaft.

Since the RIS container was used during the operation of the V1 nuclear power plant, experienced and trained service personnel were needed for its use in this project. Securing it was not easy.

Cutting of the bearing shell

The bearing shell and its bottom were cut based on the same principle as the core basket or reactor pressure vessel. A tall column was mounted and secured against the bottom of the bearing shell. Due to the column's cutting height, several spreader brackets were placed at various levels to ensure its stability. A band saw was attached to the top of the column, and several deep vertical cuts into the bearing shell were made. A disc saw was used to remove the first piece, making a horizontal cut between the previously made vertical cuts. The remaining pieces in that row could then be removed using the band saw by inserting the band saw blade into the hole left by the removed pieces and turning the saw blade in the horizontal direction. The band saw blade twisted 360° around the inside as it cut and removed the pieces individually, clamping the hydraulic clamping/lifting tools on each piece before releasing them. The procedure was then repeated for each row of the shell to be cut away, removing one tall section of the column each time (**Figure 24**).

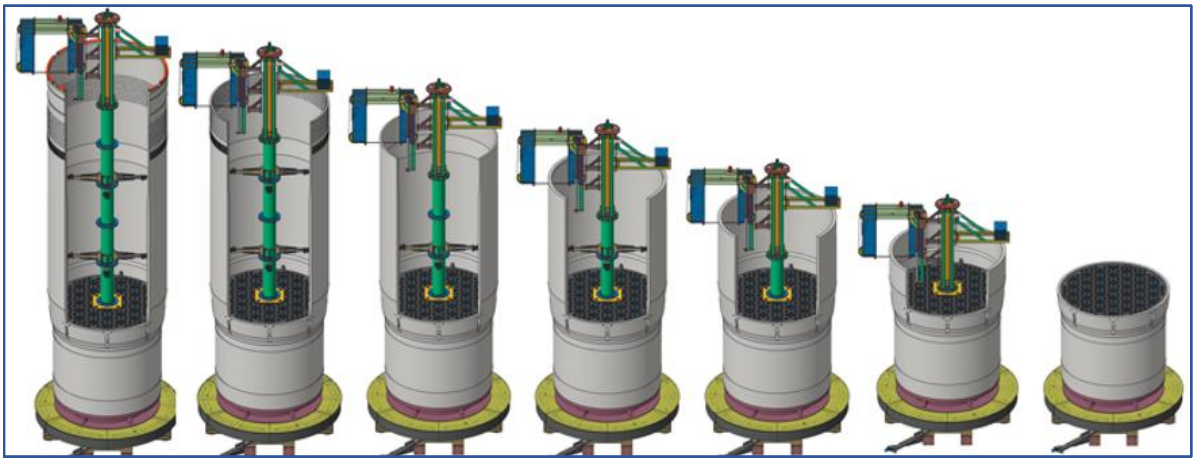


Figure 24. Bearing shell fragmentation process

When placed at the WCW´s cutting site, the bearing shell bottom remained in the RIS container, and the hanging pins did not slide out of the bearing shell bottom transport windows. Measures were taken to stabilise the bearing shell bottom through substitution, the cutting plan was changed, and the cutting schedule was modified. Verifying facts through inspection with a radiation camera and technical documentation was mandatory.

Removal of the side shell around the perimeter of the bearing shell bottom

The side shell, which surrounds the remaining lower part of the bearing shell bottom, was cut using multiple cuts of a disc saw. The cutting tool was clamped to the bearing shell bottom between the upper and lower guide plates and surrounding turntable supports. The cuts were made in horizontal and vertical orientations, resulting in large rectangles being cut off. A disc saw, fixed on the top plate, was used to cut the top plate of the bearing shell bottom, and the bottom plate cut was performed similarly (**Figure 25**). After cladding, only the top plate was removed; the bottom plate and all "protective" tubes remained.

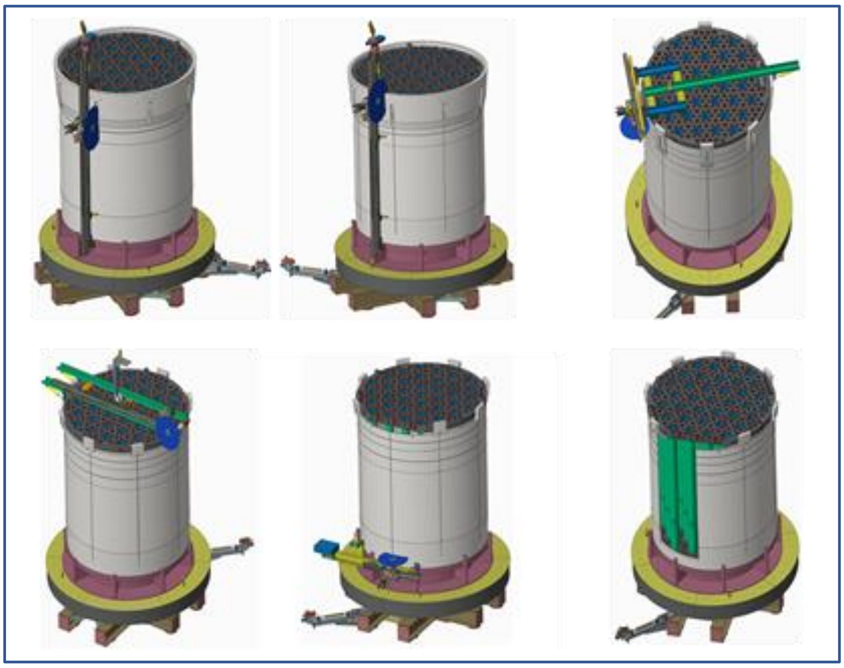


Figure 25. Bottom shell fragmentation

Cutting of tubes between the top and bottom plates

The tubes between the top and bottom plates of the bearing shell bottom were cut off similarly to the cutting of the protection tube units. A disc saw with a horizontal cutting blade was used to make three cuts on each tube by clamping the saw to the tube and making cuts along its length (**Figure 26**). The same tool was used to remove all the tubes, and the cut sections were removed from the cutting area using a handling tool. Before removing several tubes, the lifting tool was attached to secure the top plate.

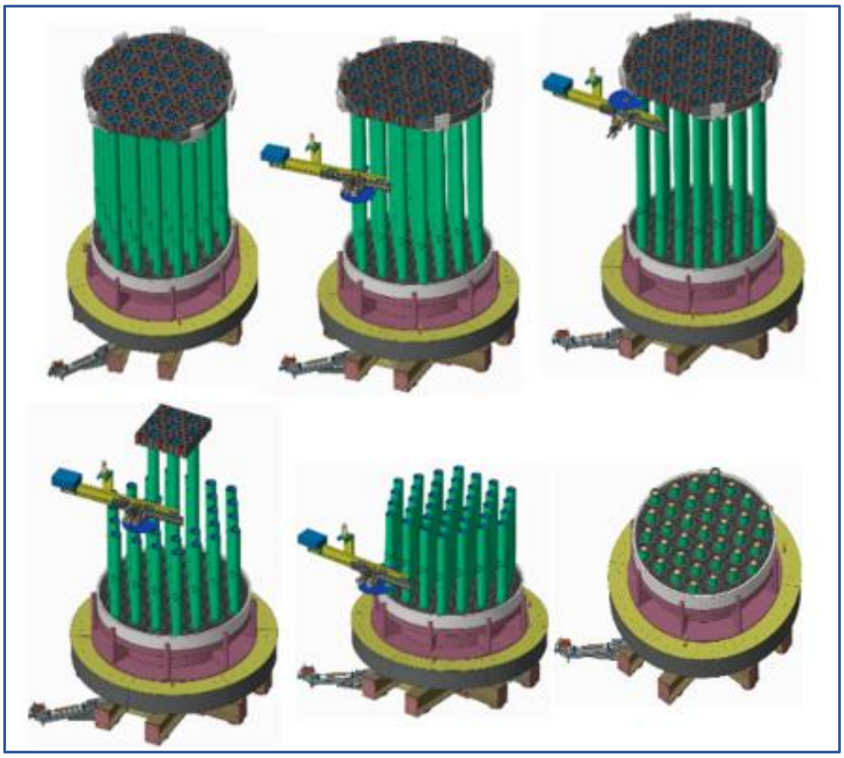


Figure 26. Cutting tubes between the bottom and top plate

Cutting of bottom/top plate

A disc saw tool is clamped on the bottom plate to cut the bottom plate of the bearing shell bottom into parts suitable for packaging (**Figure 27**).

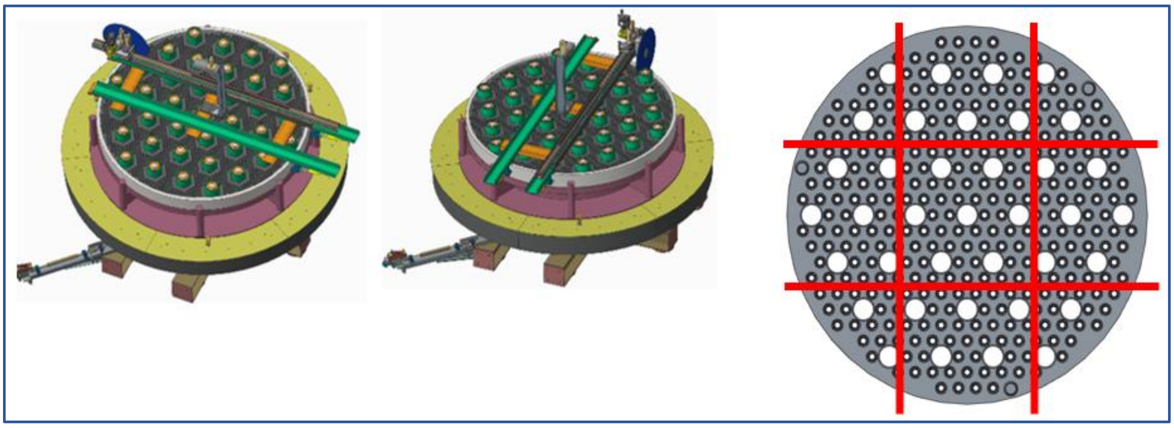


Figure 27. Cutting plan for the top and bottom plates of the bearing shell bottom

Cutting fragments management

Characterisation and packaging

After the cutting process, the fragments were characterised one by one based on their dose rate using a submersible gamma probe controlled from the working platform and weight using a dynamometer installed in the lifting hook. They were then loaded into FCC baskets in WCW-2 using clamping tools from the working platforms or a 5-tonne gantry crane.

Before removing FCC baskets from WCW-2, special equipment was used to characterise the full basket through their dose rate measured by a set of submersible gamma probes to verify that it was compatible with the operating specifications of the shielding bell and with the predefined type of package form (FCC, FCC + 80/150/210 mm shielding).

Finally, the baskets were removed from WCW-2 using a shielding basket. After being drained above the water surface, they were moved to the basket transfer station using a 250-tonne crane and placed in either FCC or FCC with external shielding for transport to storage outside the building.

5.4.3.2. Group 3: hexagonal inhomogeneous cross-section components

The next part of the case study describes the cutting procedure of the WWER-440/230 reactor´s shielding assembly under water.

Cutting planning and workplace layout

Fragmentation and packaging plan of the shielding assemblies

Each shielding assembly was cut into three parts, resulting in 216 pieces of fragments of the same length. The resulting fragments of shielding assemblies were placed in three baskets and then stored in the FCC with an external shielding of 210 mm.

Fragmentation workplace

The shielding assemblies were cut at the WCW-1, at the wet segmentation station 1B (WCW-1B). Spare parts and auxiliary equipment were stored close to WCW-1 (grey rectangles in **Figure 28**). A service area is required near each pool for equipment preparation and repair (green rectangles in **Figure 28**).

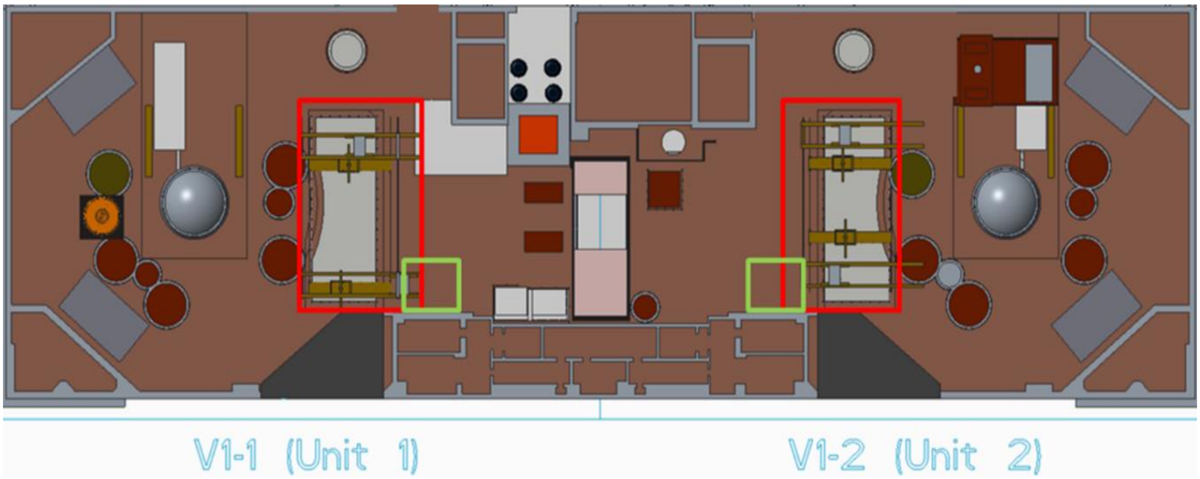


Figure 28. Place in WCW-1 designated for cutting off the shielding assemblies

Steps of the cutting process

Transport and handling

All the shielding assemblies were stored underwater on the spent fuel storage pool racks. The refuelling machine used in V1 NPP´s operation transported the shielding assemblies from the racks to the T12 internal storage cask—also from V1 NPP´s operation (or equivalent) of the C-30 container. The assemblies were transported in the C-30 container from the spent fuel storage pool to the WCW using a 250-tonne crane.

In the WCW, the shielding assemblies were temporarily stored in the internal T12 storage casks before fragmentation. **Figure 29**, **Figure 30**, and **Figure 31** show the original handling means for transporting the shielding assemblies.

Each shielding assembly was characterised before the segmentation. The dose rate was measured using a submersible gamma probe operated from the work platform, and the mass was measured using a dynamometer installed in the lifting hook.

Figure 29. T12 Storage cask for handling the reactor shielding assemblies

Figure 30. C-30 Container used to transport the shielding assemblies

Figure 31. Equipment used to handle shielding assemblies over the spent fuel storage pool

Fragmentation of the shielding assemblies

The shielding assemblies were cut underwater using mechanical cutting equipment (disc saw) as described in Section 5.4.1 (see **Figure 32**). The equipment was operated and controlled from the working platforms above the cutting pool in the reactor hall (WCW-1).

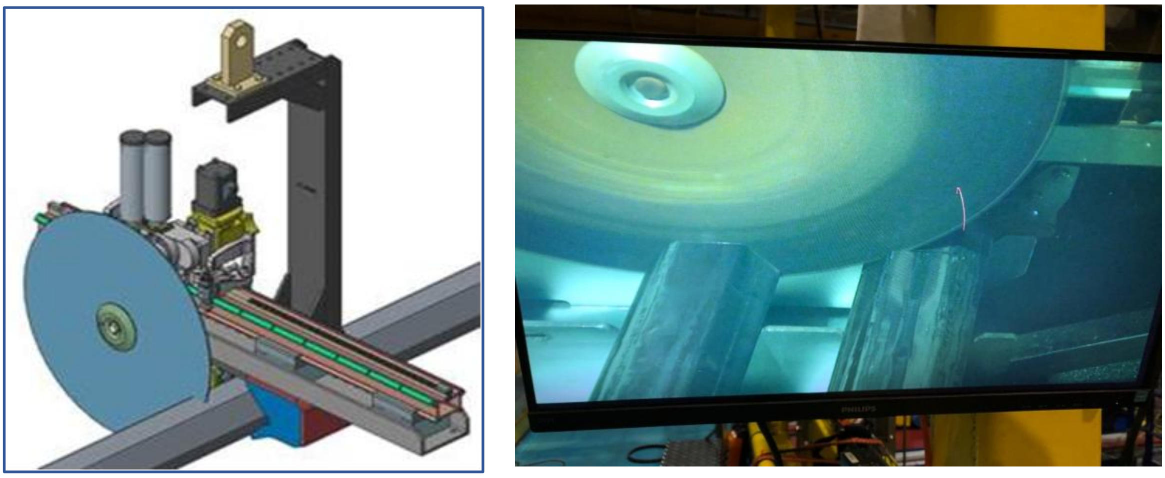


Figure 32. Disc saw used (left) and process video monitoring (right)

Cutting fragments management

Characterisation and packaging

After the fragmentation, the fragments were loaded into the FCC baskets at the bottom of WCW-1 by operating gripping tools from the working platforms.

Before removing the baskets from WCW-1, the loaded baskets were characterised by the dose rate measured by a set of immersion gamma probes to verify that they were compatible with the shielding bell's operating specifications and with the predefined type of package form (FCC+210 mm shielding).

Finally, the baskets were removed from WCW-1 using the shielding bell and, after drained above the water surface, moved to the packaging and transport station using a 250-tonne crane and placed in an FCC or an FCC with external shielding as the final configuration of the packaging set for transport to storage outside the reactor building.

5.5. Radioactive Waste Generated

Once the fragmentation of the activated parts of V1 NPP´s large components from the primary circuit and their subsequent final characterisation from 05/2020 to 03/2022 was complete, not all of the fragmented material was classified as ILW. The following primary and secondary RAW were produced.

Primary radioactive waste

The ILW stored in the ISF RAW is 264 tonnes (39%). After a certain time of artificial radionuclide decay, about 16 tonnes of this volume can be disposed of in the NRR in Mochovce. The more significant part of the volume, 418 tonnes (61%), was classified as LLW and disposed of at the NRR.

Table 2. Primary radioactive waste classification, in tonnes

Primary radioactive waste classification	Amount (t)
Low-level waste	418
Intermediate-level waste	264
Total primary radioactive waste	**682 t**

Secondary radioactive waste

The production of secondary RAW also accompanies decommissioning activities in the controlled area. Within the above-mentioned activities, secondary RAW consisted of:

- Cutting discs with 800/900 mm diameter were added to baskets and FCCs for further processing at the Radwaste Treatment Centre or Final Treatment of Liquid RAW Facility and disposed of at NRR.
- Abrasive and cutting material (saws, ropes, etc.) was added to 200L MEVA drums.
- Protective equipment, rags, and polyethene foils stored in TATRAFOL film bags. Low-level solid combustible RAW was also stored.
- Filters were added to baskets and FCCs for further processing at the Radwaste Treatment Centre or Final Treatment of Liquid RAW Facility and disposed of at NRR.

Table 3. Secondary radioactive waste classification, in tonnes

Secondary radioactive waste classification	Amount (t)
Cutting discs (800/900 mm)	11.2
Abrasive and cutting material	7.2
Protective equipment, rags, foils and low-level combustible RAW	6.1
Filters	1.02
Total secondary radioactive waste	**25.52 t**

5.6. Organisation and Human Aspects

Such a technically demanding project cannot be handled without good organisation and mutual understanding. Teams on both sides (client and contractor) must be prepared for complex and unexpected tasks that cannot be dealt with without mutual respect and compromise. Both crews had to overcome language and culture barriers. A well-managed organisation, sufficient human resources, and the ability to work together with respect are prerequisites for project teams to focus on the technical side of the project.

The preparatory phase for the client consists of preparing the technical specification, which is necessary based on international best practices. This requires studying the available information or personal meetings with people who have already implemented such a project. Using the experience of operations personnel who have worked on primary circuits before shutdowns and are familiar with the subject is a good idea. The preparatory phase must set the conditions that ensure the selection of an experienced implementer with key experts directly on site while the project is being performed.

On the client's side, the theoretical preparation of the project team is appropriate, as it, after substantial support in the licensing phase of the process, will be able to recognise possible process anomalies and manage risks. The project itself consists of a preparatory phase and an application phase. Ideally, both project steps should be executed by the same key experts.

The fragmentation team must be able to cover 8+8 hours of operation. Typically, these are two complete teams with a mechanical supervisor, management, and machine operators to operate the fragmentation workshops and to carry out RAW management.

On the client's side, operational radiation protection personnel were continuously involved, checking radiation protection conditions and regularly checking the dose rate at the control points. The objectives were achieved through daily brief coordination meetings with plant operations personnel and the supplier fragmentation crew.

Close cooperation between the cutting (specialist) contractor, operating personnel, dosimetry, and chemistry is a prerequisite for implementing systemic fragmentation of V1 NPP´s primary circuit-activated components.

Problems and risky operations were dealt with only during the day after the morning meetings of both teams.

5.7. Regulatory and Licensing Aspects

The following institutions were involved as main regulatory authorities in the preparation and implementation of V1 NPP´s primary circuit-activated component-cutting process:

- Nuclear Regulatory Authority of the Slovak Republic for supervision of **nuclear safety**,
- Public Health Authority of the Slovak Republic for supervision of **radiation protection**,
- Ministry of Environment of the Slovak Republic for environmental **impact assessment**.

These authorities issued permits for implementing relevant activities (a total of more than 30 decisions) and then supervised the fulfilment of the specified conditions.

Be prepared to provide additional analyses to support a positive regulatory opinion. From the point of view of obtaining the necessary permits, the open and transparent approach of the responsible employees to the regulatory authorities, including preliminary consultations and the joint search for optimal procedures, has been proven.

5.8. Quality Aspects

The quality assurance plan was developed at the beginning of the project implementation. The following contents of the quality assurance plan must be carefully addressed:

- Responsibilities and powers: The project's basic organisational structure, the project team members' competencies and responsibilities, and the workers' qualifications requirements.
- Method of communication: The project team's communication method. To ensure quality assurance in the project implementation process, the contractor prepared monthly progress reports and submitted them to the Client, which were discussed at regular monthly meetings.
- Document management is required as part of project implementation. The subject of the deliverables was also many documents that were subject to the approval of Slovak supervisory authorities. It was therefore important to work with the managed versions of the documents.
- Technical documentation developed during the project, which provide a description of the solution for the technical implementation of the project. It had to be developed on the basis of valid legislative standards and acts.
- Methods for monitoring and control of the project implementation were an integral part of it. The EARN VALUE MANAGEMENT (EVM) Methodology was used to measure the progress of the project.

The quality system addressed all contractual conditions and the Employer's requirements from the current situation during the project duration.

5.9. Benefits for other Operators and Organisations

Decommissioning and waste management operators and regulatory bodies will obtain insight to ensure proper planning, management, control, and decision-making processes when addressing the activated primary circuit WWER-440/230 components decommissioning management.

The volume and properties of primary circuits differ for each nuclear power plant decommissioning project. Every decommissioning project must carry out its characterisation, decision on the cutting method, etc. However, the information and lessons learned in this case study provide benchmark information, and the lessons learned provide a basis to avoid errors and save time for more demanding decommissioning activities.

Cutting V1 NPP´s activated primary circuit WWER-440/230 components case study provides the following insights.

Project preparation steps: Effectively setting the cutting project phases starts with project preparation, which includes creating technical specifications, defining the cutting scope, and procuring the cutting work executor.

Achieving project objectives: Definition of the necessary steps to achieve the project objectives from setting the realistic project objectives through the design phase, permitting process, verification of equipment parameters, how to evaluate fragmentation results, and achieving optimal results.

Direct control and safety: Good knowledge of the cutting processes, understanding of the risks, and lessons learned from other implementations will enable better direct control of the contractor and safe implementation of the processes.

Baseline for future projects: Being involved in the cutting processes and understanding the processes and results provided a good baseline for the following projects regarding the fragmentation of large primary circuit components.

Use of existing resources and structures: It is necessary to use technical means and building structures when fragmenting the large, activated components of the primary circuits, which were also used during their operation.

Overview of the fragmentation techniques: It is important to have an overview of current procedures and techniques for fragmenting large, activated components of the primary circuit.

Awareness of decommissioning risks: Be aware of the potential risks of implementing such demanding decommissioning activities.

RAW management considerations: The objectives of the project of handling large activated components from V1 NPP´s primary circuit depend on the available RAW management level. The effectiveness of the approach is not maximised if there is no disposal facility and is typically impossible without interim storage of solid RAW.

6. REFERENCES

[1] Programmes of work for activities related to the fragmentation of V1 NPP´s activated large components.

[2] Evaluations of the programmes of work for activities related to the fragmentation of the V1 NPP activated large components.

[3] Technical Specification of the BIDSF D4.2 Project.

[4] Photos and videos from the implementation of the V1 NPP large components fragmentation.

[5] Interviews with the Project Manager and members of the BIDSF D4.2 project team.