



DECONTAMINATION OF THE PRIMARY CIRCUIT OF UNITS 1 TO 4 OF KOZLODUY NPP

Case Study Kozloduy NPP

This is a knowledge product prepared by SERAW
for the JRC's Nuclear Decommissioning
Knowledge Management (NDKM) Initiative



Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation establishing a dedicated financial programme for decommissioning nuclear facilities and managing radioactive waste. 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 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 being implemented by the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which has become a knowledge generator extracting the knowledge from the ongoing decommissioning activities across the JRC's four different sites (Geel, Ispra, Karlsruhe, and Petten).

The JRC NDWMD has the goal to become a Centre of Excellence in nuclear decommissioning knowledge management and aims to develop a decommissioning knowledge platform which allows exchanging information and building on the best practices in the EU through executing the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project started in 2024 with the objectives 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, as well as to develop potential EU synergies.





Knowledge Product Information

Decontamination of the Primary Circuit of Units 1 to 4 of Kozloduy NPP

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EXECUTIVE SUMMARY

What, how, for whom



Overview

Objective

Target Users

Approach

Findings

Value



Target Users

- Nuclear decommissioning operators
- Regulatory authorities
- Waste management professionals
- Technical staff involved in decontamination and dismantling projects



Objective

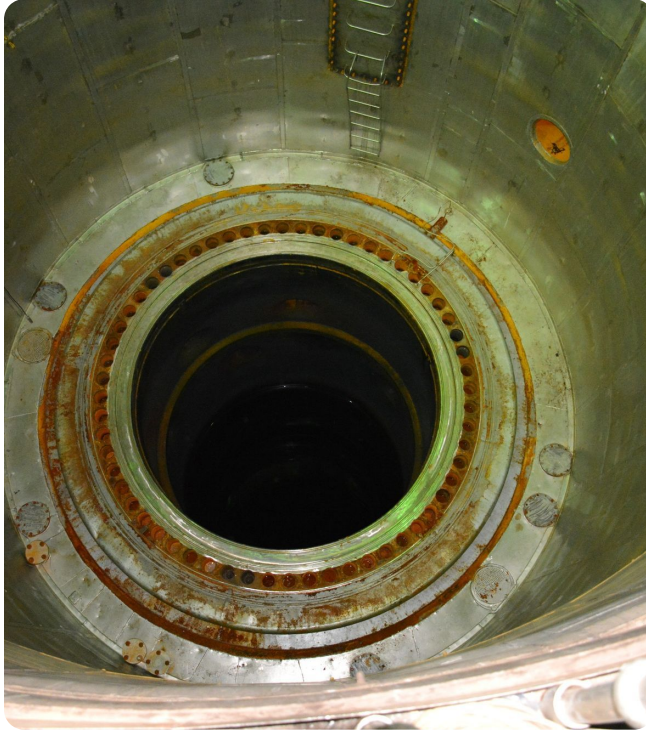
To add further value as an extension to the knowledge product KP-JAVYS-005 by integrating the results and lessons learnt from Project 55-3 at Kozloduy NPP. This further enhances and facilitates a shared understanding of safety, efficiency and radioactive waste management with respect to nuclear decommissioning processes within the EU.



Findings

- Significant reduction in surface contamination and radiation dose rates
- Improved operational safety and efficiency
- Lower volume of radioactive waste generated
- Effective knowledge transfer from Bohunice, avoiding previously encountered challenges
- Comprehensive documentation of experience
- Direct applicability to other VVER-440 units; partial applicability to other reactor types

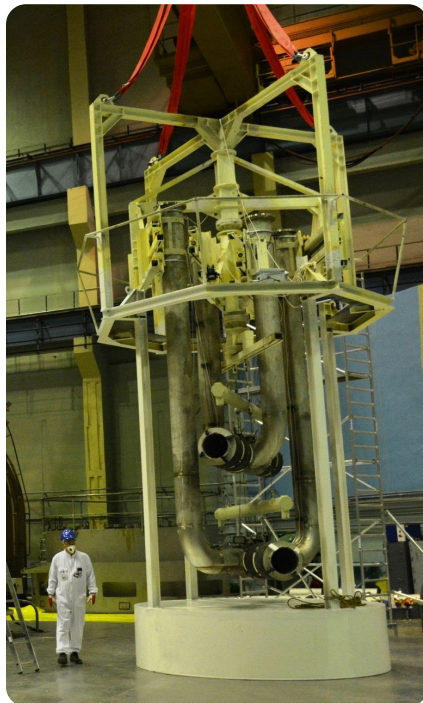




Approach

A controlled chemical decontamination process was applied to dissolve the surface metal layer where radionuclides had accumulated. The project followed Westinghouse's design and used similar equipment and expertise as was used in the Bohunice NPP case. All auxiliary tasks were performed by SERAW's specialised division, which enabled the successful decontamination of four units within six months.





Value

The lessons learnt shared by SERAW will inform other decommissioning operators about, and in some instances will help them to avoid, the main challenges and shortcomings encountered during the decontamination of primary circuits, in a similar manner as they benefitted previously through drawing on knowledge shared by experts at JAVYS in Slovakia.



Overview

This knowledge product documents the chemical decontamination of the primary circuit of units 1 to 4 at Kozloduy Nuclear Power Plant (VVER-440 type), conducted by SERAW under Project 55-3. The goal was to reduce radiation dose rates and to facilitate dismantling activities, building on prior experience from Bohunice NPP in Slovakia.

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The Context

Kozloduy NPP
Decommissioning



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The Project

Decontamination
of the Primary
Circuit



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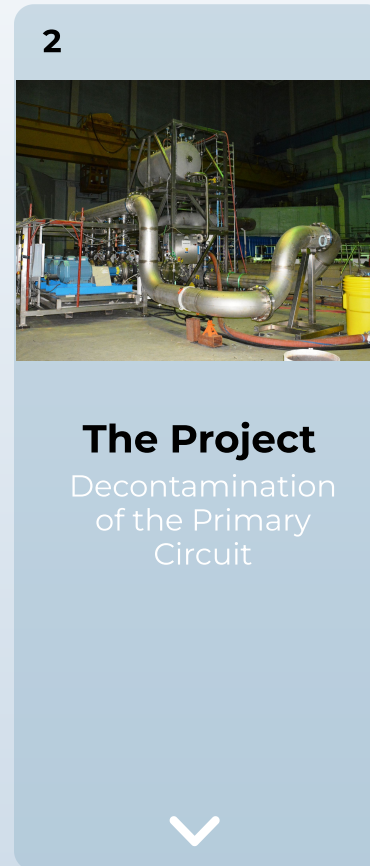
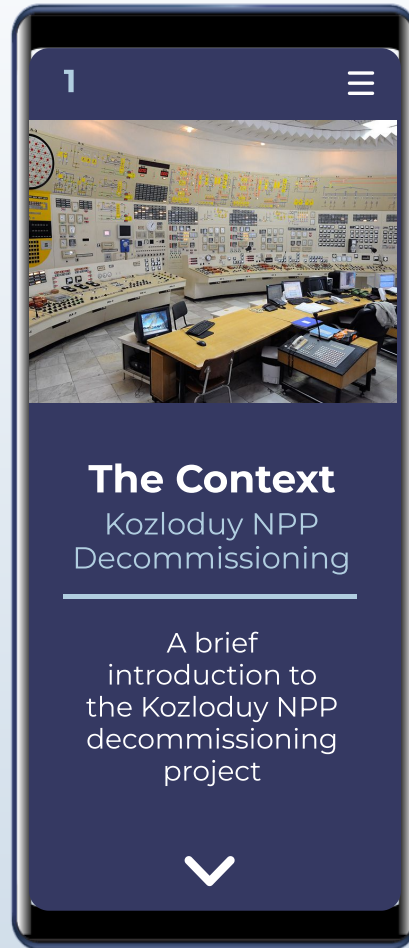


The Experience

Lessons Learnt
and Takeaways



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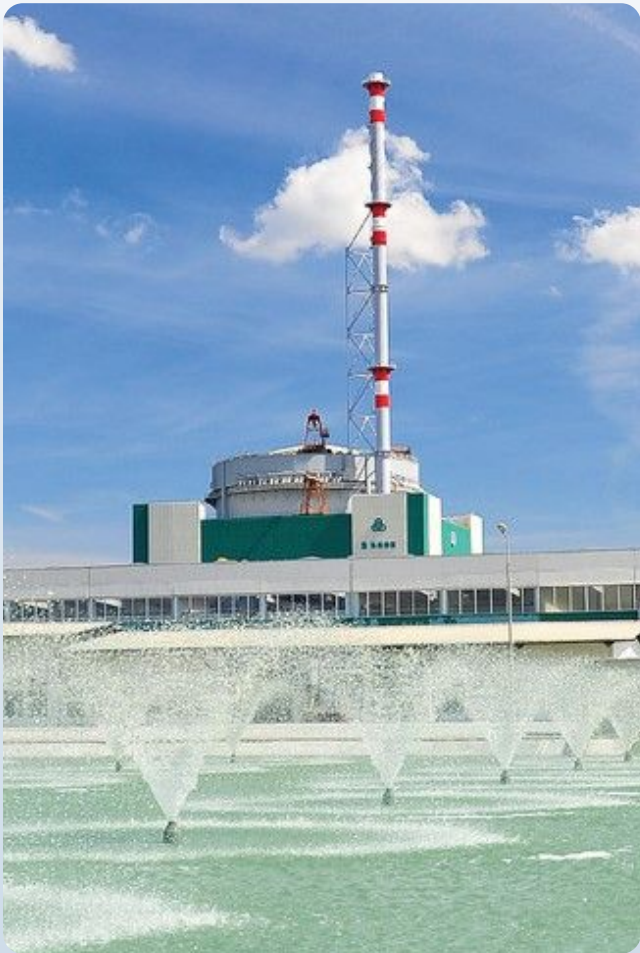
What was learnt by
the project team,
and how lessons
from previous
experiences were
applied





THE CONTEXT

Kozloduy NPP



Construction

The first nuclear power plant in Bulgaria

Construction of the Kozloduy NPP began in 1970. Units 1 to 4 have been permanently shut down, while Units 5 and 6 remain operational.

+ INFO

Design features

VVER-440 and VVER-1000 reactors

The plant includes pressurised water reactors designed by the Soviet Union. Units 1 to 4 were of the VVER-440 type, and Units 5 and 6 are VVER-1000.

+ INFO

Operation

Over 40 years of service

The active units have been operating since the 1980s. Kozloduy is one of the most significant nuclear facilities in southeastern Europe.

+ INFO

Decommissioning

Since 2002

Units 1 to 4 were shut down as part of Bulgaria's accession to the EU. Decommissioning is ongoing, with projects focused on waste management and environmental restoration.

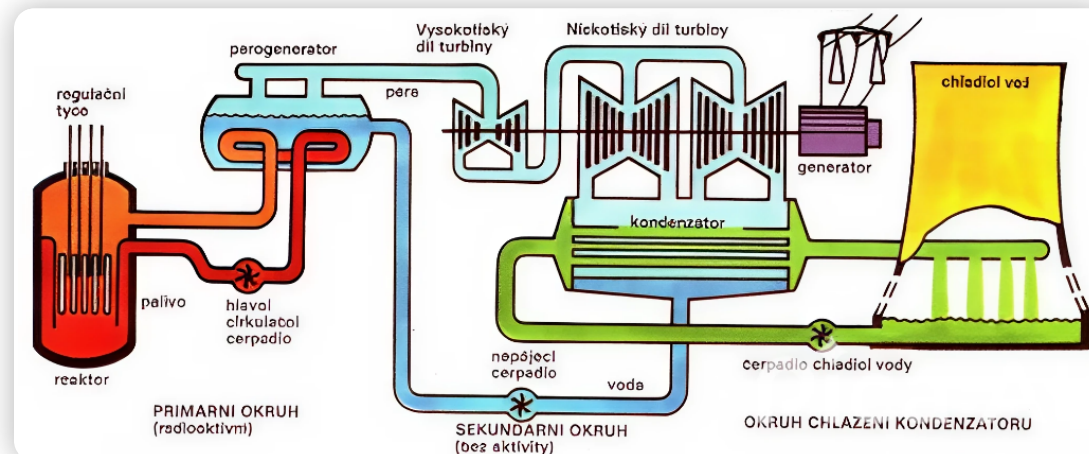
+ INFO



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Key Design Features

- Pressurised water reactor (PWR): VVER-type reactors are used at Kozloduy, which are PWRs with enhanced safety systems.
- Fuel: the reactors use enriched uranium dioxide fuel, housed in zirconium alloy cladding.
- Steam generation: unlike Western models, these steam generators feature a horizontal configuration, which influences both their structural design and operational characteristics.
- Reactor vessel: unlike RBMK reactors, VVER reactors use a single large pressure vessel, improving containment and safety.
- Safety systems: units 5 and 6 have undergone extensive modernisation to meet EU safety standards.





Social

The construction of Kozloduy NPP required extensive infrastructure development, including roads, railways, power lines, and water systems. The plant has been a major employer in the region for decades, supporting thousands of families and contributing to the local economy. It also led to the development of nearby towns and technical education programs.



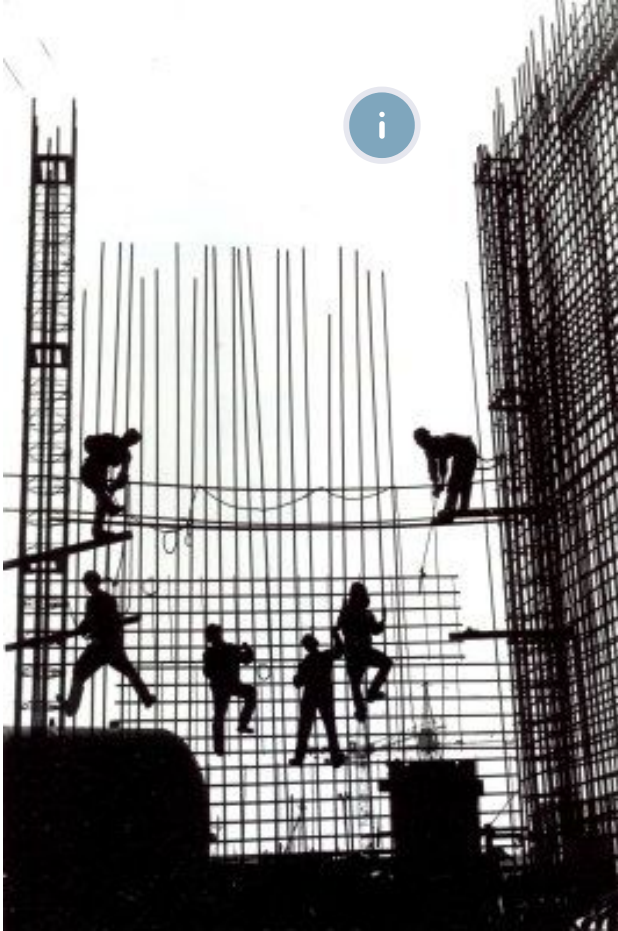
Clean

Over its operational lifetime, Kozloduy NPP has produced hundreds of billions of kWh in electricity, contributing to lower carbon emissions - The equivalent to powering a home for each person in Bulgaria for over 10 years / a national-scale renewable energy project.



Reliable

Kozloduy has consistently provided over one third of Bulgaria's electricity, making it a cornerstone of the national energy grid.



Kozloduy NPP

Originally, six reactors were planned and constructed at Kozloduy. Four VVER-440 reactors (units 1–4) were commissioned between 1974 and 1982, and two VVER-1000 reactors (units 5 and 6) were launched in 1987 and 1991 respectively. The VVER-1000 units are among the most powerful in the region, with a thermal capacity of 3 GW and an electrical output of 1 GW each. During peak construction periods, thousands of workers were employed, supported by multiple ministries and industrial partners across Bulgaria and the Soviet Union.



Decommissioning

Units 1 to 4 were shut down between 2002 and 2006 as part of Bulgaria's EU accession commitments. The decommissioning process is ongoing, focusing on safe dismantling, radioactive waste management and environmental restoration. The goal is to ensure that future generations are not burdened by legacy nuclear waste.

THE PROJECT

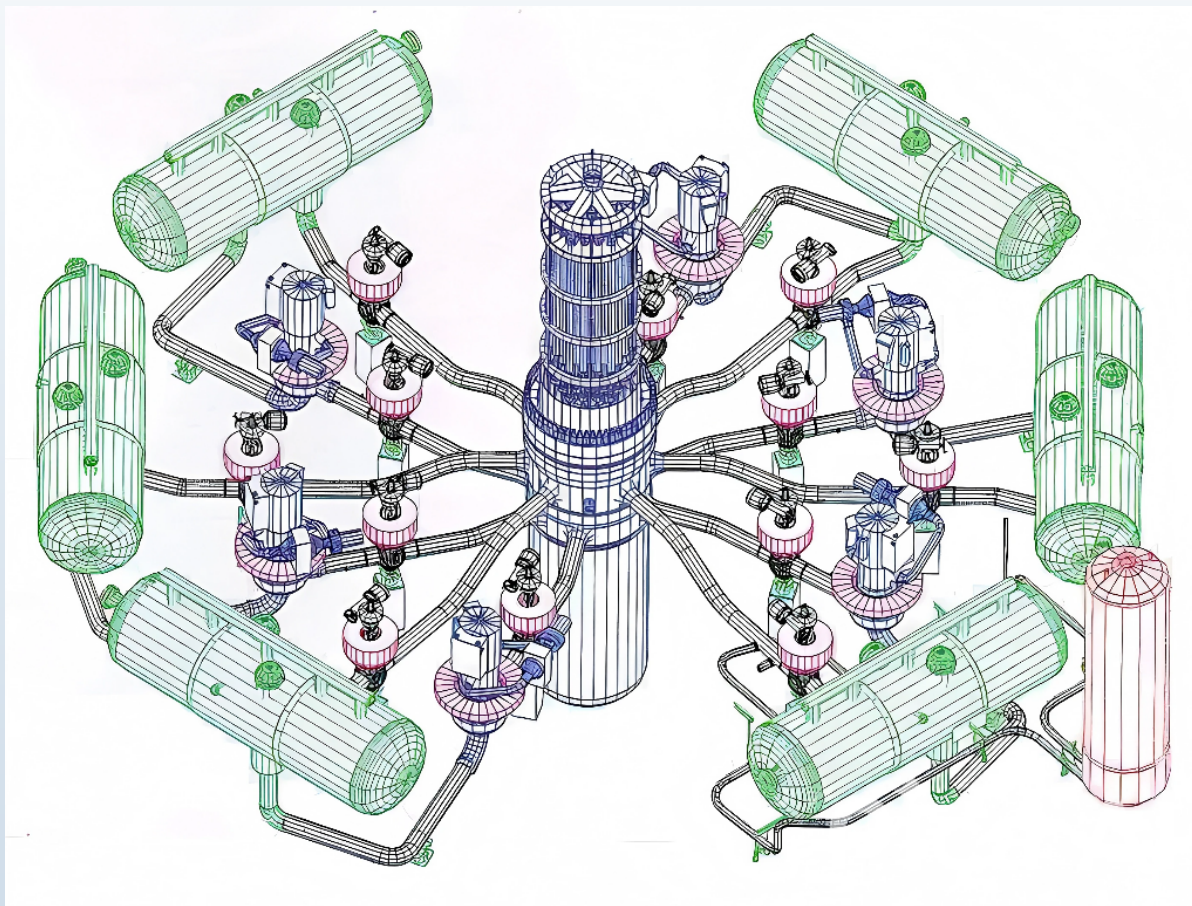
Decontamination of the Primary Circuit

Overview

The inner surfaces of the primary circuit loops were treated using chemical methods in order to remove the surface layer of radioactive contamination.

Several cycles of two different treatment processes, NITROX-E and DfD, were carried out.

This procedure greatly reduced the internal surface contamination and as a result significantly lowered the doses of radiological exposure to the workers during the dismantling activities.





Decontamination

**Primary piping
preparation**

Key metrics

THE PROJECT

Decontamination of the Primary Circuit





Key Performance Indicators (KPIs)

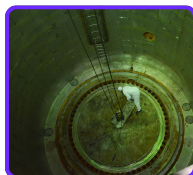
The main KPI for the decontamination process was the **Decontamination Factor (DF)**. It was obtained by dividing the initial dose rate by the final dose rate for each of the pre-selected locations at which it was measured.

Other important metrics included:

- **Quantity of ion-exchange resins used** (kg)
- **Amount of activity removed** (GBq)
- **Percentage of activity removed** (%)
- **Amount of metal removed** (kg)
- **Dose rate at defined points** ($\mu\text{Sv/h}$)

Conditioning of the primary circuits

Reactor vessel isolation process



Securing the safety cover

All the pipelines connected to the primary circuit, such as I&C piping, were isolated prior to the decontamination. This prevented any leakage outside of the working area.

Furthermore, the reactor pressure vessel was not part of the scope of the project, as the vessel and the reactor internals were activated equipment and not suitable for surface decontamination. Instead, the "spider" piping assembly was used to connect the vessel inlet and outlet connections, bypassing the vessel. It is designed to decontaminate a pair of loops at a time (yielding three applications per unit).

Additionally, the pressurisers were also isolated from the primary circuit piping, due to the low resulting decontamination factors for the pressurisers and the large volumes of secondary radioactive waste.



Chemical processes

The NITROX-E process consists of the cyclic application of oxidising and reducing chemicals, applied with the goal of dissolving the oxide film, and the associated radioactive material, deposited on the pipe walls.

The DfD process (acronym for “Decontamination for Decommissioning”), much more corrosive, is applied subsequently to further remove radioactivity from the surfaces of metallic components beyond the oxide film.

The primary circuits were decontaminated using up to six NITROX-E cycles, followed up by up to two DfD cycles on each of the cooling loops.





Key Performance Indicators

**Decontamination
Factor**
87.6



**Metal Mass
Removed**
76.5 kg



**Activity
Removed**
24.3 GBq



**Resin Volume
Generated**
18.6 m³

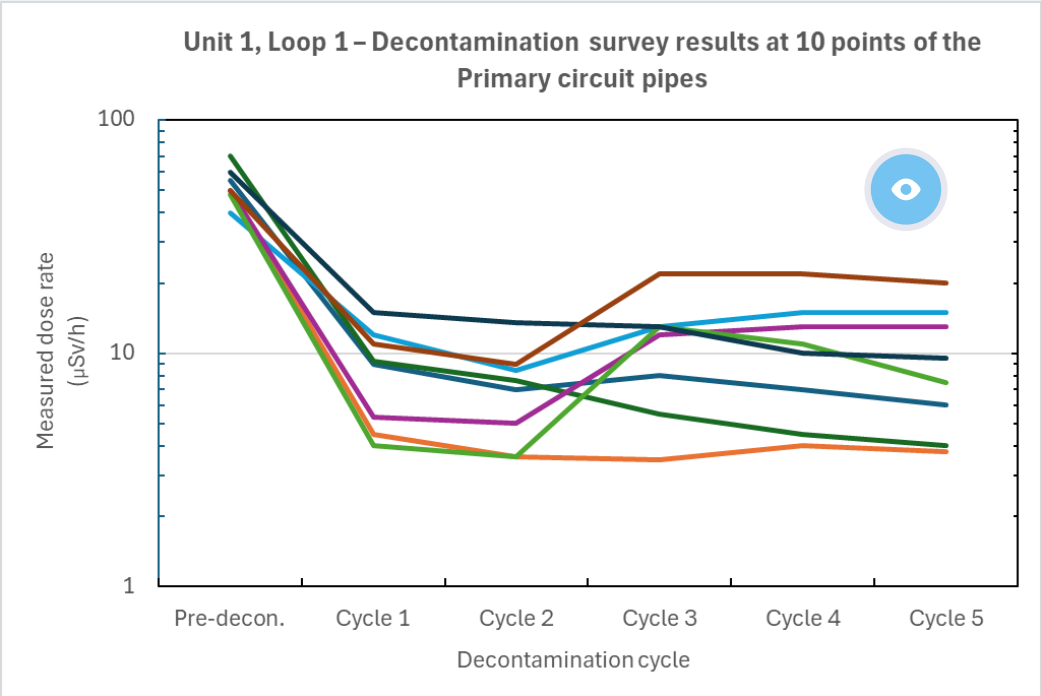
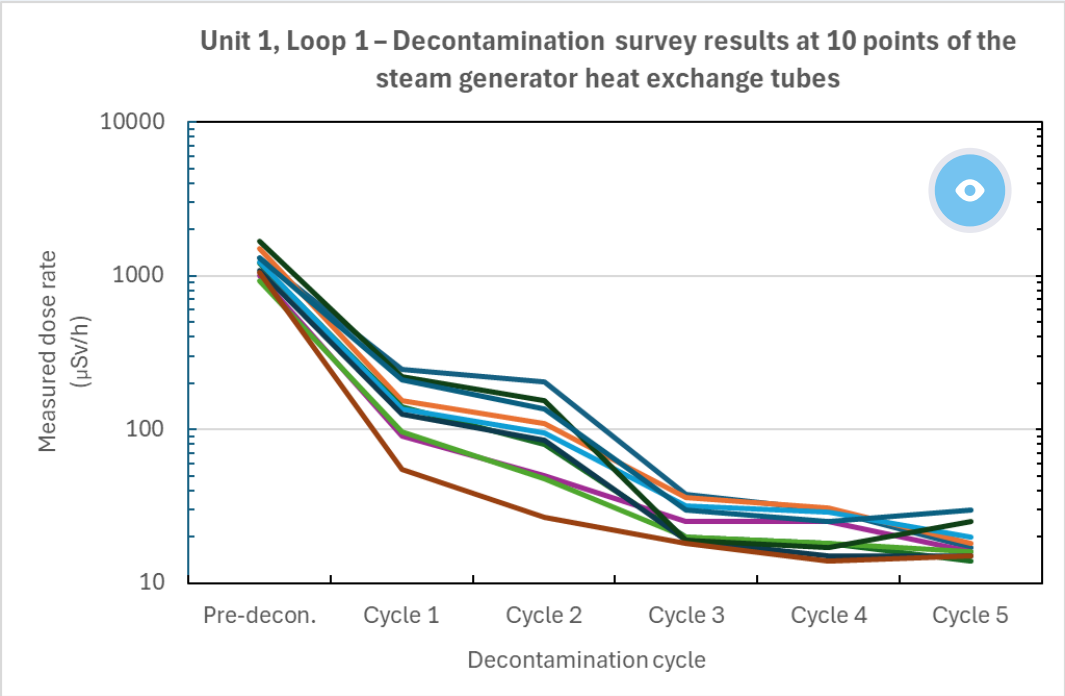




THE PROJECT

Results

Results - Decontamination overview





THE EXPERIENCE

Challenges and lessons

Challenges and lessons learnt

1 Modification of the
"spider" assembly

2 Optimisation of
the number of
decontamination
cycles

3 Ensuring uniform
conditions for
dose rate
measurements

4 Decontamination
of the pressurisers

5 Treatment and
sampling of spent
ion-exchange resins

6 Timing of the
decontamination
within the
decommissioning
process



Ensuring uniform conditions for dose rate measurements

Since it is a key indicator, it was important to ensure dose rates after every decontamination cycle were measured uniformly. To achieve this:

- Schematics with all the decontamination factor control points were prepared, and the dose rate before decontamination was measured.
- The control points were preliminarily marked.
- Personnel were trained on the procedures.





Decontamination of the pressurisers

One of the lessons learnt from the experience at Bohunice was that the dose reduction achieved from the pressurisers, when included within the overall primary circuit decontamination, resulted in only limited success and as such the advice given was to isolate the pressurisers from the primary circuit decontamination process.

A separate technical solution was developed to decontaminate each pressuriser individually, which consisted of successive acid and alkaline washes plus bubbling with compressed air.



Timing of the decontamination within the decommissioning process

It is most beneficial to carry out the decontamination as early as possible during a dismantling project. Doing so ensures, in addition to minimising the dose rates to which personnel are exposed, that problems with dismantled equipment are avoided.

As an example, for some of the other units (3 and 4) the I&C system pipelines had already been dismantled before the decontamination process started, making the pressuriser level gauge unavailable. In that case, a sampling pipeline was used for the purpose of level control.

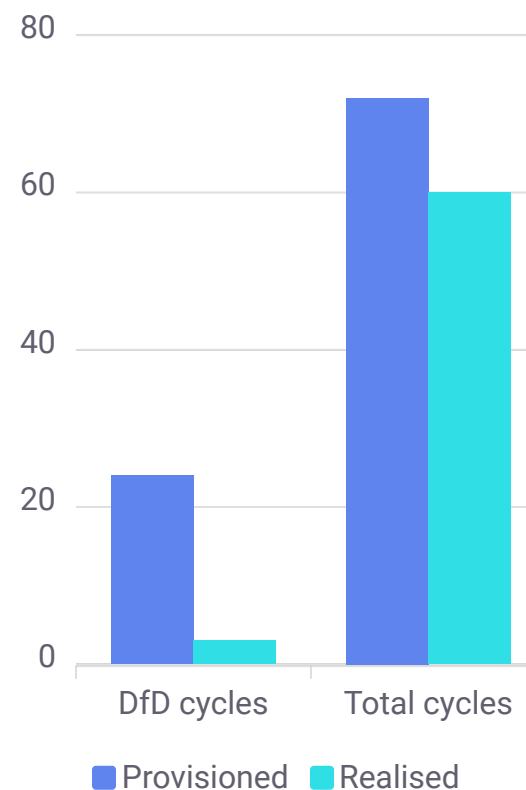


Optimising the number of decontamination cycles

Minimising the number of decontamination cycles while still achieving the desired Decontamination Factor minimises the volume of secondary radioactive waste generated.

Experience early in the process showed that the DfD decontamination process was much less effective than expected. The decision was taken thereby to undertake only a total of 3 DfD cycles across the 4 units, down from the 24 that were provisioned for (2 per pair of loops at each of the units).

This brought the total number of Nitrox-E and DfD decontamination cycles to 60, a reduction from the 72 that were initially planned, which provided a saving of approximately 12 working days on the programme.





Replacement and characterisation of spent ion exchange resins

The regeneration of saturated ion-exchange resins produces radioactive waste that is difficult to treat. The decision was made, therefore, to replace them instead, as that leads to waste that is easier to treat.

Furthermore, in order to take samples for characterisation, a special instrument was installed to take samples during the hydro discharging of the ion exchange resins.



Modification of the "spider" assembly

The piping assembly used to bypass the reactor vessel, known as the “spider”, was modified for use at Kozloduy based on lessons learnt at Bohunice.

Specifically, the connection points were made of a flexible nature, rather than the original rigid connections. This led to the transfer between the steam generators being more expedient, and yielding an estimate of 6 working days saved on the programme for the 4 units.