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At Bohunice V1, Westinghouse is working on the first VVER-440 units to be dismantled in Europe – the company's largest dismantling project to date
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Decommissioning

Determining the best approach at Bohunice V1

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Innovative D&D at Bohunice V1

Westinghouse has started a five-year project to dismantle the VVER-440 reactors at Slovakia's Bohunice V1 plant. **Joseph Boucau** and **Tomáš Klein** explain how 3D modelling helped determine the best strategy for cutting primary circuit components and dealing with radioactive waste

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ABOUT 2.5KM FROM THE VILLAGE of Jaslovské Bohunice in the Slovak Republic, at Bohunice V1, Westinghouse is working on the first VVER-440 units to be dismantled in Europe. It is the company's largest dismantling project to date.

Bohunice V1 has two V-230-type VVER-440 units (440MWe each). The first unit ceased operation on 31 December 2006, and the second on 31 December 2008, after 26 and 27 years of operation, respectively. In partnership with Slovak company VUJE, Westinghouse was awarded the dismantling contract in October 2017 by Jadrová a vyraďovacia spoločnosť, (JAVYS). It has begun work on dismantling the two reactor coolant systems.

In awarding the contract, JAVYS required bidders to have proven decontamination, dismantling and waste packaging expertise, and to be innovative in planning and meeting a very tight schedule – around five years – while meeting the highest safety standards. During this period Westinghouse and VUJE must conduct studies; design new tools, equipment and procedures; prepare the site; and decontaminate, dismantle, segment, package and manage the waste from 9500t of contaminated and activated components.

These components include the primary circuits (steam generators, main circulation pumps, main insulation valves, pressurisers, bubble tanks and primary piping), reactor vessel internals, reactor vessels, auxiliary equipment, plant systems and other elements such as the annular water tank. It also includes high-activated operational waste, which is stored in a dedicated location.

To meet such a stringent schedule for that quantity of work, the project team designed special technical strategies. These include creating space for, and building, two new pools where the underwater segmentation will be performed, and adapting and reclassifying the turbine building as a dry cutting workshop so that it can be used to segment six steam generators from each unit.

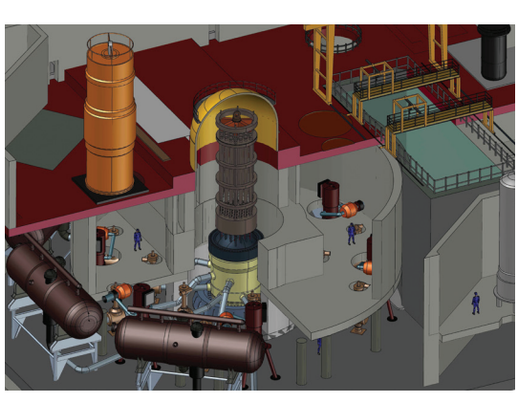
Before the onsite work began, JAVYS managed the previous dismantling and decontamination activities for Bohunice V1 to ensure that they were properly performed and that material logistics routes are available. This gave the project team the proper framework in which to begin onsite activities.

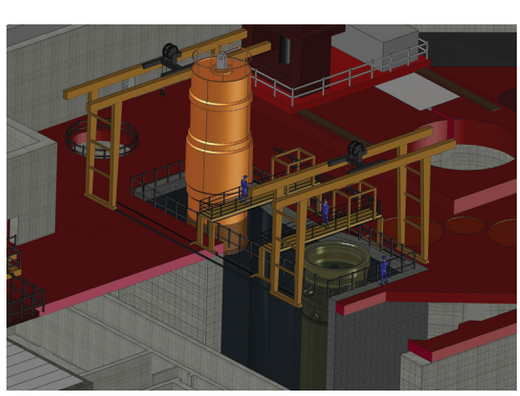
Planning and design work

In this complex project, all activities had to be thoroughly planned with the customer and all aspects of the interface between different workshops had to be well understood and communicated. Close collaboration has been imperative to successfully plan and design the tooling, equipment and procedures, based on detailed information on the radiation level of the internals and the specific requirements of the site work.

The first year of the project was largely spent on engineering studies, to define the best process and tooling for segmenting each of the components, and to design and manufacture the equipment. The project team also wrote procedures for dismantling each item. The equipment and procedures will be tested and personnel qualified before site work begins. Testing and qualification for the reactor internals and reactor vessel segmentation will take place in a specially designed Westinghouse test facility in Västerås, Sweden, before the equipment is sent to site.

At Bohunice, before beginning any dismantling activities,





Right: **Illustration of plan for installing the 12.20m deep and 18.30m long pool – also called the Wet Cutting Workshop – at Unit 1**

the project team conducted extensive tag-out and lock-out activities, asbestos removal, radiological characterisation, sampling and decontamination to ensure that operations could be conducted as safely as possible.

Design and cutting strategy

To design the advanced tooling for wet cutting activities, Westinghouse used detailed three-dimensional (3D) modelling. This allowed Westinghouse to decide the best strategy for cutting the components, and plan the most cost-effective approach to disposal, considering radiological and packaging constraints (in accordance with Slovak and European Union regulations).

Westinghouse chose mechanical cutting as the strategy for wet cutting because it does not produce gases, aerosols, turbulence or large quantities of secondary waste. The company has used mechanical cutting at a number of plants across Europe very successfully and can apply the lessons learned and efficiencies gained to segmenting and packaging components at Bohunice V1. Westinghouse will use remotely operated disc saws, band saws and shears as the main tools underwater.

To cut the primary circuit components, VUJE designed a dry cutting workshop and it will fragment some components in-situ. Conventional dry cutting techniques (diamond wire, thermal cutting tools and band saw) were designed that met specific requirements of the nuclear industry. Safety measures were also incorporated during the design phase to avoid spreading contamination to the working environment.

Dismantling strategy

Westinghouse will remotely segment and package, underwater, components with high radioactivity, for which conventional dry segmentation techniques are not deemed safe. This is a safety measure to shield operators from the high levels of radiation in accordance with as-low-as-reasonably achievable (ALARA) principles.

At Bohunice V1, components with high radioactivity include the reactor vessels and the reactor internals. The operational waste contained in the remote-handled waste storage area is also highly radioactive and will be cut underwater.

As part of a separate contract, Westinghouse has already performed a full system chemical decontamination of the primary circuits (excluding the reactor vessels and internals). That successful work reduced radioactivity of the decontaminated primary circuits to an acceptable level, enabling operators to use dry cutting methods and hands-on tooling safely.

Preparing for cutting

The project team devised an approach for wet and dry cutting that helps to meet the compressed schedule and ALARA requirements. Since the existing reactor hall pools are too small to segment the components and operational waste efficiently, or meet the ALARA requirements, the project team decided to remove the steam generators and create space in which to build two large pools called wet cutting workshops. This will allow the highly radioactive components and waste to be dismantled, segmented and packaged simultaneously and under a depth of water that shields workers from high levels of radiation.

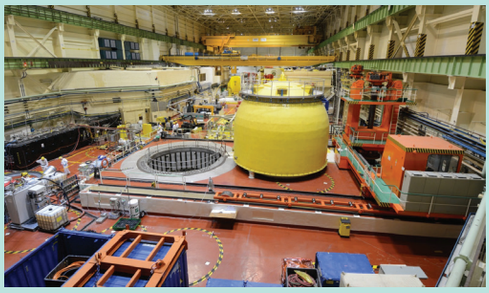
Each pool will be equipped with two working bridges, on which four crews of operators can work simultaneously. The operators will control the cutting and packaging remotely with cutting tool manipulation and handling systems. They can observe the remotely operated tools using underwater cameras from which live images will be projected to screens on the working bridges.

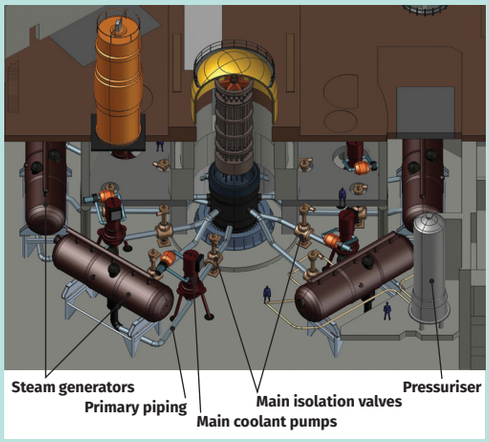
VUJE is also separating dry cutting activities to improve efficiency and speed up the process. For example, in addition to repurposing and taking advantage of the large space available in the turbine building to build a dry cutting workshop, two further dry cutting workshops will be installed, in the reactor building. These will be used to fragment the remaining large components of the primary circuit – the main coolant pumps, main isolation valves and primary coolant pipes – as well as auxiliary system components, including the cable trays, valves and coolers.

The other large components, such as the reactor shaft protection lids, reactor vessel upper blocks, pressuriser and bubble tanks, are being cut in-situ with dry cutting tools.

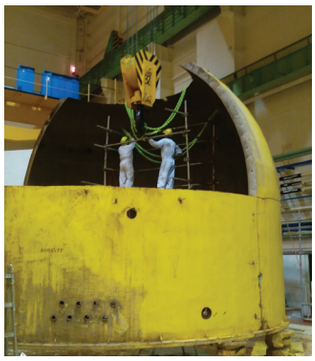
Bohunice V1: general plant lay-out

The primary system of each unit is located in an independent sealed compartment, also called a hermetic compartment. The distance between reactor axes is 84m. Each reactor unit consists of one reactor pressure vessel, six reactor coolant loops with two main gate valves per loop, one steam generator per loop, one main coolant pump per loop and one pressuriser.■





Top: **Bohunice V1 plant layout**
Source: Jadrová a vyraďovacia spoločnosť, a.s.
Bottom: **3D model of Unit 1 with components to be dismantled**



Above (from left to right): **Fragmentation of one of the reactor shaft protection lids** Source: Jadrová a vyraďovacia spoločnosť, a.s.

Preparing the turbine building for dismantling the steam generators

Turbine building model Source: Jadrová a vyraďovacia spoločnosť, a.s.

Ongoing preparatory activities

Onsite work began in July 2018, with preparatory activities for dismantling the main components started. At both units the project team has dismantled, fragmented and packaged the reactor shaft protection lids and upper blocks. The Unit 1 bubble tank has been dismantled and the first phase of the tag-out and lock-out activities completed. The team is currently working through dismantling the reactor vessel heads, removing the steam generators, fragmenting the primary circuit piping, constructing the workshop in the turbine building and manufacturing the workshops for the reactor building.

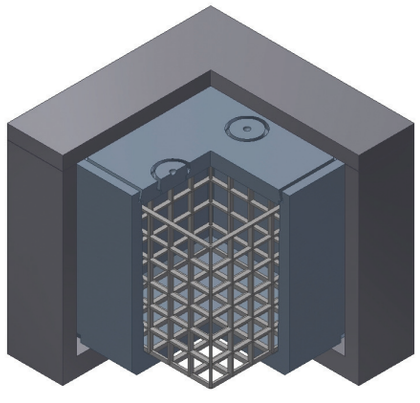
Removing the reactor shaft protection lids

The two reactor shaft protection lids are vertical, cylindrical and semi-spherical covers bolted to the concrete slab of the reactor hall. The first step in their removal was to disconnect from them all electrical cables and other auxiliary devices and systems and remove all the bolts that secured them to the concrete slab flanges. Once the reactor shaft protection lids were entirely disconnected, each was transported with a 250t reactor hall crane to their dismantling locations under large tents in the reactor hall. The protective tents were constructed to avoid dust being dispersed and portable filtration systems were used.

The reactor shaft protection lids have metallic liners; these were cut using oxy-acetylene. This severs or removes metal by the chemical reaction of oxygen with the metal at elevated temperatures. A flame of fuel gas burning in oxygen maintains the necessary temperature. Once the metallic liners were removed, the concrete covers of the lids were broken down with electromechanical hammers.

The lids are mostly non-contaminated, so waste disposal is not complicated. The materials are mainly metallic fragments and concrete debris, and a small quantity of secondary waste generated during dismantling, including plastic films. Most of the materials could be cleared for free release.

Right: **Example of dry packaging: Control rod drive mechanisms in box pallets** Source: Jadrová a vyraďovacia spoločnosť, a.s.



Right: **3D model of a fibre concrete container with basket and insert for solid and fixed low-level and very-low-level radioactive waste**

Waste management

The 3D modelling allowed the waste containers and segmenting processes to be planned, an essential step in a segmentation project, as the cut pieces must fit into specifically sized waste containers. At Bohunice V1, activated component fragments will be loaded, underwater, into metallic baskets with approximate internal dimensions of 1.3x1.3x1.3m³.

The basket size is compatible with the fibre concrete container licensed for transport and disposal at the National Radwaste Repository, located in Mochovce. The repository can accept solid and fixed low-level and very low-level radioactive waste for final disposal. When necessary, Westinghouse will add external shielding to the containers for intermediate level waste. Waste classified as intermediate will be stored at JAVYS' interim storage facility at Bohunice.

Westinghouse will perform this segmenting, and package the segments from the underwater cutting using the same handling tools that were used to segment the components underwater. The tools will be controlled from the main crane and the working bridge crane. The cranes are always used in parallel, one for tool handling and one for securing and lifting the cut pieces. Extension poles will be used to lower the tools down into the pool and into position. With the help of pan and tilt cameras and lighting positioned on the working bridges, all work can be supervised by the operators.

Fragments from the dry cutting operations will be packaged in box pallets, drums and large heavy-duty bags.

Continuous learning

Dismantling the reactor together with the rest of the reactor coolant system offers excellent synergies for accelerating the planning and reducing the cost of the Bohunice dismantling programme. The strategy of decoupling the dry from the wet cutting activities offers significant safety benefits and will continue to be applied at Bohunice. So will lessons learned and experience gained from dismantling projects in Sweden, Germany, Finland, Spain, France and the USA. The experience gained by the Westinghouse, VUJE and JAVYS teams in Slovakia will be invaluable in future dismantling projects as well. ■