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Decommissioning of Activated Reactor Components in Germany and Lessons Learned

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1. Introduction and Overview

On April 15th, 2024 the last three remaining German nuclear power plants have been shut down. Since that time the German nuclear power plant landscape has been entirely moved in the era of dismantling and decommissioning (D&D).

In Germany, the approach of immediate decommissioning was chosen and the radiological principle was followed to decommission activated reactor components and concrete structures from “hot” to “cold”.

This means that the decommissioning is carried out from the inside out, meaning the areas most heavily contaminated with radioactivity within the reactor containment (RC) – namely the reactor pressure vessel (RPV) and its internals (RPV-I) – are removed first. The RPV-I components, which were located in close proximity to the fuel assemblies during operation, are dismantled underwater into smaller, packageable parts and appropriately packaged. Whereas the RPV structures are cut e.g. by a band-saw in the unflooded storage pool (dry cutting). In this area, the GNS Group has been represented for several years through different projects and is the market leader in Germany.

As the decommissioning progresses, the dismantling of activated concrete structures within the RC begins, such as the biological shield, which was part of the barrier concept required in the nuclear power plant until then. These activated concrete structures must now also be properly dismantled and packaged. In pressurized water reactors, this mainly involves the Bioshield and support shield, while in boiling water reactors, it involves the Bioshield and associated stand frames.

This paper provides an overview of the activated structures decommissioned so far by the GNS Group [1] and the associated experiences considering

- the reactor pressure vessel internals,
- the reactor pressure vessel as well as
- the activated concrete structures such as the Bioshield.

2. German Decommissioning Projects

In this section, an overview is given of the projects carried out or initiated by the GNS Group and its partners such as the Reinwald GmbH [2] regarding the decommissioning of activated structures.

2.1 Reactor Pressure Vessel Internals

The ZerKon program of former utility PreussenElektra has already successfully served the sites Unterweser (KKU), Grafenrheinfeld (KKG) and Isar 1 (KKI-1), where it dismantled the reactor pressure vessel internals as well as the movable corescrap and packaged them for final disposal in Germany.

Thanks to the experience gained in the ZerKon pilot project KKU and the consistent implementation of “lessons learned” (cp. section 3.1), the follow-up plant KKG was completed in around two thirds of the initial time.

The RPV-Is of the only boiling water reactor in the PreussenElektra fleet at KKI-1 was also fully completed before the contractually agreed deadline. This was only possible thanks to the mutual support of the ZerKon consortium teams and advanced technologies in the dismantling of components (cp. Fig. 1).

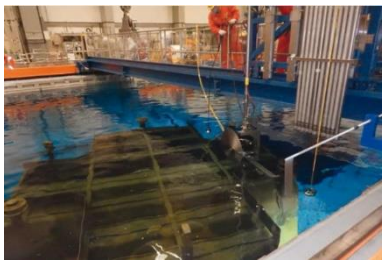

Fig. 1. First cut on the steam dryer in KKI-1.

The closely knit ZerKon project team is currently in the planning phase for two of the three remaining PEL plants Brokdorf (KBR) and Grohnde (KWG) at the same time. Here, too, the boundary conditions are being optimized as far as possible together with the customer’s

project management team so that the projects can run smoothly in the upcoming implementation phase. At Isar 2 (KKI-2), which is the last remaining PEL plant, the planning phase has just finished and the implementation phase started early this year.

Apart from that the planning team is facing completely new challenges at the KKI-2 site. Due to the only recent shutdown, radiology at this facility places particularly high demands on cutting and packaging planning. In addition, it is the only plant within ZerKon that will still have fuel assemblies in the pool during dismantling and packaging of the RPV internals. As these fuel elements are to be unloaded immediately after the ZerKon activities, a delay would have considerable consequences regarding the overall timeline for decommissioning of the whole nuclear power plant (NPP).

2.2 Reactor Pressure Vessel

Following on seamlessly from ZerKon, the ReaDi program of former utility PreussenEleketra, which takes care of dismantling and packaging of the RPVs, has already completed dismantling and packaging at the two sites KKU and KKG. The third of the six sites, KKI-1, also started on time.

Thanks to the extensive experience gained at the individual sites, the GNS Group was able to optimize the processes and massively reduce the implementation time already at the second site.

During D&D of the RPV, the RPV is lifted from the reactor pool into the storage pool (cp. Fig. 2) and disassembled there with a tailor-made bandsaw called “the Beast” (cp. Fig. 3). This approach was intentionally chosen to reduce activity release and to save on the associated enclosures that would have been necessary for thermal cutting. This kind of tailor-made equipment was the key of success in the ReaDi program.

The whole D&D process designed by the GNS Group can only be realized by outstanding specialists which are the particular strength of the group and fully aligned with GNS strategy ‘Excellence for Nuclear’. The waste management and dismantling specialists at GNS Group work together flexibly and in a results-oriented manner, always with a common goal in mind.

The GNS Group represents a perfect symbiosis between a container and cask manufacturer as well as a service provider for D&D. This enables a good cooperation within the group in such a way that clear standards can be set and cost-effective cutting as well as packing solutions can be found for the customer.

Thanks to all this experience and unique reference projects from dismantling in Germany, the GNS Group has already won several international dismantling and disposal projects such as an RPV dismantling in Switzerland.

Fig. 2. Lifting the RPV out of its installation position.

Fig. 3. “The Beast”, a bandsaw system working on RPV cylinder.

2.3 Activated concrete structures

The approach that has prevailed in the German and international market so far for the dismantling of activated concrete structures involves

- cutting them into individual segments using diamond wire-saws,
- lifting them out,
- possibly further disassembling them,
- and then packaging them as blocks in suitable containers.

The analysis by the GNS Group revealed that a significant improvement of this approach to support the overall D&D planning of the site is only possible through a completely different technological approach, which brings technical as well as economic advantages.

Therefore, the GNS Group, together with their partner Reinwald GmbH, developed a new technical concept for the dismantling and conditioning of activated concrete structures based on the use of milling technology (cp. Fig. 4). This technique, which removes the activated concrete surface, in combination with direct suction and filling of the resulting waste product (cp. Fig. 5), namely concrete debris with defined bulk density, into steel containers, offers significant time and economic advantages compared to conventional technologies.

Fig. 4. Concrete milling machine with dust protection cover.

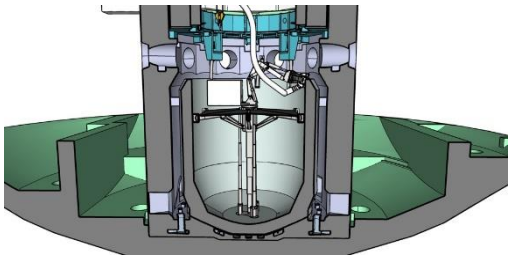

Fig. 5. Demolition of the Bioshield with the milling excavator.

The new approach offers the following key advantages for customers:

- Reduction of execution time through direct filling of steel containers, thereby minimizing transport and logistics operations.
- Reduction of total dose rate during execution through (semi-)automation of processes and control by personnel at the reactor pool floor level, where a low dose rate level prevails.
- Reduction of the required final disposal containers (steel containers) by utilizing the voids during filling.
- Remaining volumes of already loaded steel containers can be filled with concrete debris.
- The removal of the concrete surface can be carried out with centimeter precision, which, in combination with accompanying sampling and the associated determination of releasable structures, leads to a significant reduction in the volume of concrete waste to be disposed.
- The amount of concrete for free release is significantly increased.
- The reinforcing steel can be removed from the concrete and be recycled or disposed separately.

The competitiveness of the new technical concept has already been demonstrated by the fact that the new approach is already in the implementation phase at a power plant in Germany. For the GNS Group, this contract represents the entry into the "concrete age" of decommissioning and thus into a completely new market segment. Through the use of the new patented technology, a unique selling point has been created that can enable the acquisition of further projects of this kind in the near future.

3. Maintaining Expertise and Knowledge Transfer

In this section, the lessons learned during the ongoing D&D in Germany are outlined and it is shown how the transfer of knowledge within the GNS Group and beyond is ensured.

3.1 Lessons Learned

After each of the projects presented in this paper, a lessons learned workshop is conducted together with the customer in which all insights from the respective past project are compiled. Solutions are developed to enable future projects to be more time and cost-efficient.

The essential conclusions, which have also been implemented by the GNS Group in subsequent projects, were so far:

- All boundary conditions must be clearly documented in advance. This includes in particular, the radiological characterization related to activation and contamination, as well as the local conditions (ideally captured via a 3-D laser scan).
- Preparations can usually be parallelized to save time.
- Fleet approaches offer the possibility to transfer proven technologies to NPPS of the same or similar type.
- Loading and dismantling must be planned logistically so that they can take place in parallel. At the same time, the handling (task of GNS) and the removal of containers (task of the customer) must be logistically coordinated. Clear and good communication between both parties is crucial here.
- Ideally, the dismantler is also a composite supplier that designs and manufactures containers as well as casks for the transport, interim and final storage of radioactive waste. This allows the decommissioning concept and container design to be coordinated. A good example of this is the T-Box series delivered by GNS in Taiwan, which was specifically designed for the decommissioning of Taiwanese NPPs (see Fig. 6).

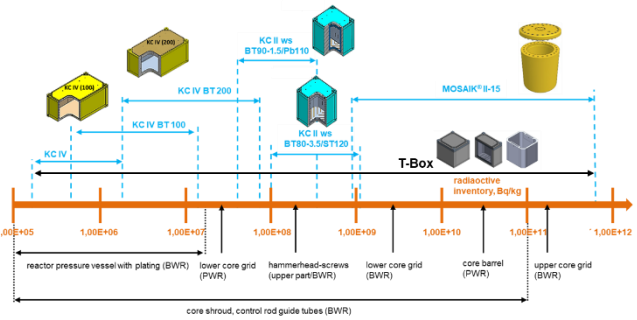

Fig. 6. Operational fields for GNS casks and containers.

3.2 Transfer of knowledge

Lessons learned are not only gained in a single project; they must also be made accessible to a broader audience through a know-how transfer. This transfer is offered by AiNT [3].

Since August 2024, AiNT has been part of the GNS Group. Even before its integration into the GNS Group, AiNT was known for conducting research and development, offering highly specialized training, and organizing the International Conference On Nuclear Decommissioning (ICOND) [4] in Aachen (Germany). AiNT continues to fulfill this role within the GNS Group.

Therefore, the comprehensive decommissioning knowledge of the GNS Group and its partners can also be offered to interested customers in training courses organized by AiNT. In the AiNT training courses, knowledge is presented not only from books but also "hands-on". For that purpose, project engineers dealing with specific D&D tasks are invited as speakers for the training courses. This approach leads to maintaining expertise in nuclear technology and is a unique selling point in the international market.

At the same time, the ICOND offers an opportunity for international as well as national participants to exchange knowledge and to extend their network.

4. Conclusions and Summary

Germany has entered a new era of nuclear power plant decommissioning following the shutdown of its last operational reactors. The decommissioning process involves dismantling activated reactor components and concrete structures, starting from the most radioactive areas. The GNS Group, a leading service provider in this field, has developed innovative techniques such as underwater dismantling and milling technology for concrete structures. These methods offer significant time and economic advantages, positioning the GNS Group as a market leader in Germany. The lessons learned from completed and ongoing projects are shared through workshops and training programs to enhance future decommissioning processes.

REFERENCES

[1] https://www.gns.de/

[2] https://www.reinwald.com/

[3] https://www.nuclear-training.de/

[4] https://www.icond.de/