Experience in Remote Demolition of the Activated Biological Shielding of the Multi Purpose Research Reactor (MZFR) on the German Karlsruhe Site – 12208

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ABSTRACT

In 2009, WAK Decommissioning and Waste Management GmbH (WAK) became owner and operator of the waste treatment facilities of Karlsruhe Institute of Technology (KIT) as well as of the prototype reactors, the Compact Sodium-Cooled Fast Reactor (KNK) and Multi-Purpose Reactor (MZFR), both being in an advanced stage of dismantling. Together with the dismantling and decontamination activities of the former WAK reprocessing facility since 1990, the envisaged demolishing of the R & D reactor FR2 and a hot cell facility, all governmentally funded nuclear decommissioning projects on the Karlsruhe site are concentrated under the WAK management [1].

INTRODUCTION

The Karlsruhe heavy water reactor facility MZFR (Multi-Purpose Research Reactor) of 57 MW electric power was constructed in the early 1960s. It was used as a prototype reactor for the development of reactor materials and the testing of fuel elements and heavy water systems, to mention a few of its purposes only. Due to its 19 years of operation at a high availability of about 80%, the MZFR also represented a reactor suitable for the demonstration of safe demolition of a highly activated nuclear power plant.

MZFR dismantling started in 1987 and has meanwhile reached a far advanced stage. This plant is dismantled in eight separate steps, which also refers to licensing. Since 2007, all licenses under the Atomic Energy Act required for MZFR decommissioning to the green field have been granted already.

All former nuclear circuits were disassembled and various buildings and building sections were emptied completely and decontaminated long ago. Remote dismantling of the reactor pressure vessel, including internals, was completed successfully under step seven in 2007. For this purpose, several, partly innovative dismantling techniques had been applied under remote handling conditions.

The last activated component to be dismantled was the inner activated part of the biological shield. Due to the radiological conditions, remote handling systems had to be applied. To the extent possible, work was carried out using industrial products. The scope of tools was complemented by special developments.

Today, this positive experience is used by other decommissioning projects for the safe and economically efficient demolition of the plants.

REMOTE DISMANTLING OF THE ACTIVATED BIOLOGICAL SHIELD

Dismantling Concept

The dismantling concept was divided into the following phases. Mostly, the steps were not independent:

- Qualification and testing of the dismantling and packaging facilities.
- Removal of the vertical wall ducts (former measurement tubes) in the biological shield.
- Installation of the activated concrete packaging station.
- Installation of the dismantling facilities in the reactor building.
- Remote-controlled dismantling of the steel liner.
- Remote-controlled dismantling and packaging of the activated concrete.
- Sampling campaigns to determine the required removal depths.

Initial Situation and Boundary Conditions

After the complete dismantling of the reactor, the following boundary conditions for the dismantling of the bioshield prevailed:

- Removal depth of the cylindrical area of 0.6 m to about 1 m.
- Static removal limit in the cylindrical area without static replacement measures: About 1 m.
- Calculated max. dose rate in the dismantling area: About 7 mSv / h.
- New installation of a packaging station for activated concrete below the biological shield.
- Further use of existing facilities of the dismantling step before, the RC dismantling of the RPV and internals, partly after modification:
    - Packaging station for metallic residues.
    - Dismantling crane.
    - Additional ventilation and filter system.
    - Enclosure of the reactor room.
    - Turning and support ring of the dismantling step before.
- Use of the existing additional ventilation enclosure (pressure grading).
- Extension of the ventilation systems by removal and prefiltration of the aerosol- and dust-containing air produced during concrete demolition.

Maintenance and Repair Concept

In the case of trouble with the electrohydraulic excavator, there were two possibilities to remove the excavator from the dismantling area. The first possibility was to attach it directly to a special transport traverse hanging on the crane to lift it off. The second possibility was to remove the rack together with the excavator and lift it off to the repair and tool area close to the dismantling area for the repair work.

If the excavator hydraulic system fails in a difficult kinematic situation, a redundant hydraulic system with the control panel in the control room can be used to move the excavator arm to a transportable kinematic constellation.

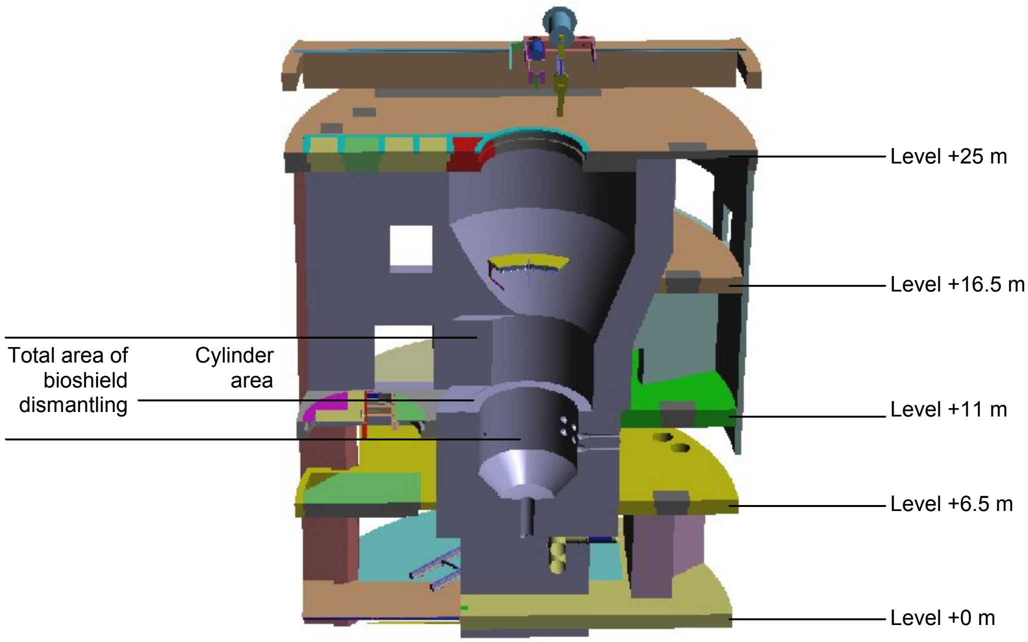


Fig. 1: Longitudinal section of the reactor building from level +0 m up to level +25 m with the biological shield

Dismantling and Packaging Systems

Due to the boundary conditions outlined above, a modified electrohydraulic demolition excavator was chosen to be used as a tool carrier system for remote dismantling, see Figs. 3, 8, and 9. This excavator was mounted on a special working platform that was inserted into the existing turning and support ring such that it could be rotated.

For the different dismantling tasks, various tools were connected and disconnected remotely to/from the arm of the excavator via a rapid-exchange coupling. Among these tools were a universal cutter ("saw" for the liner, concrete, and reinforcement), a hydraulic chisel¸ a concrete mill, a crusher, a scrap cutter, and a hoe dipper.

The dismantled concrete was removed via a central opening in the floor of the biological shield to a concrete packaging station with a jaw crusher installed below (s. Fig. 2). Removal, crushing, and packaging of the concrete were accomplished remotely due to its activation.

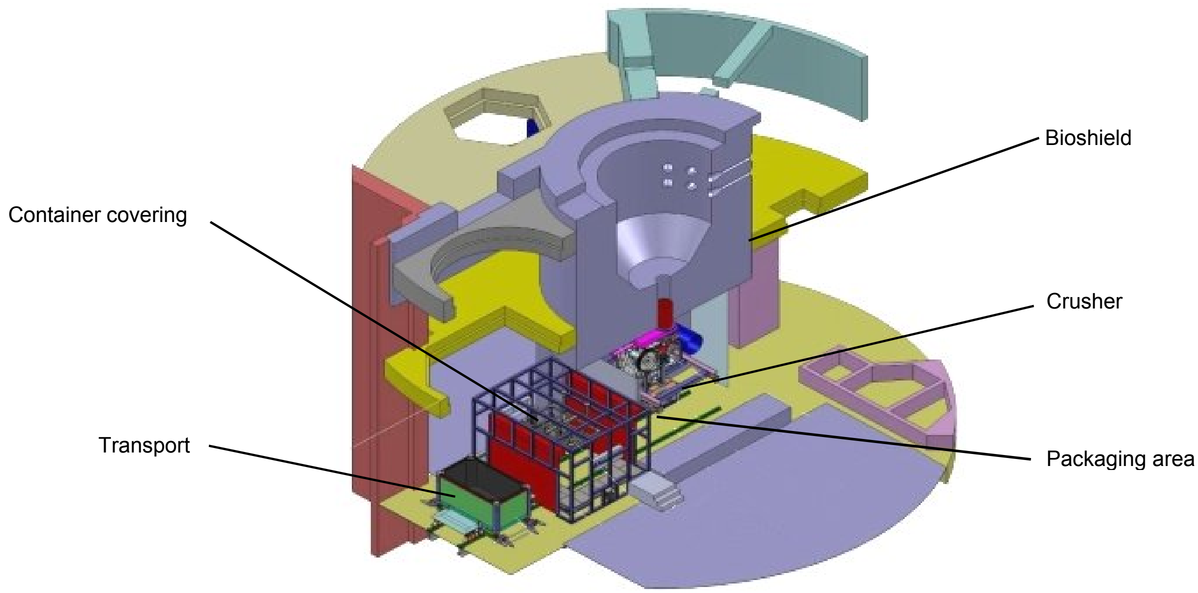


Fig. 2: Concrete packaging station

Qualification and Testing of the Dismantling and Packaging Facilities

The facilities to be used for dismantling the activated part of the biological shield in step eight were installed, qualified, and tested in the former turbine hall of the MZFR (Fig. 3) that served as a test rig. Due to its size, the existing infrastructure, and in particular due to its conventional status, the turbine hall was ideally suited for this purpose.
To create close-to-reality conditions, the dismantling area of the reactor was modelled in the test rig. In addition, a concrete dummy of a representative section of the biological shield was installed.

In the test rig, all dismantling, cutting, and auxiliary facilities for the segmentation of the steel liner – the former dead sheathing for concreting the biological shield – and activated concrete removal under remote handling conditions were tested in detail and optimized. An electrohydraulic demolition excavator was modified to a tool carrier system and installed in a rotatable scaffolding.

In parallel, the concrete packaging station was assembled and tested on the open area of the test rig of Karlsruhe Institute of Technology (KIT), close to the MZFR Plant.

In the test rig already were the operators of the facilities familiarized with their setup and trained extensively.

Fig. 3: The cold test rig (left) in the emptied MZFR turbine hall (right)

Packaging Concept

Two residue flows were implemented for the separate packaging of the activated residue sorts. All metal parts were packaged at the already existing packaging station on level +11 m. Packaging of the activated concrete required the new installation of another packaging station. It was installed below the biological shield on level +0 m.

Use of the Existing Packaging Station for Metallic Residues

The packaging station on level +11 m remaining from the previous reactor dismantling step was used for packaging steel parts, sheet metal liners, and reinforcing steel into containers. For transporting the steel parts from the dismantling area, various grippers were designed and applied.
The liner parts and the metallic components were packaged according to the acceptance conditions of the Central Decontamination Department, HDB, into containers PSC type II, transport casks TB-2000, or 200 l drums.

Installation of the Packaging Station for Activated Concrete

Via a newly drilled borehole in the reactor pit, the demolished concrete was transported to the concrete packaging station (Fig. 4) in a controlled manner. By means of specially developed and tested concrete crushing and filling facilities, the concrete was loaded into type IV containers. The packaging station was equipped with various conveyor systems and concrete rubble distribution systems that could be lowered into the containers. Radiological mixed samples were taken.

Fig. 4 Installation (left) of the packaging facilities for activated concrete on level +0 m. The right figure shows the complete installation of the packaging facilities with open gates and a container in the background from the perspective of the material lock

Introduction and Installation of Dismantling Facilities

After the successful qualification, testing, and acceptance of both the individual components and the complete system for about a duration of 13 months, the dismantling and handling facilities were disassembled and installed in the dismantling area of the reactor building.

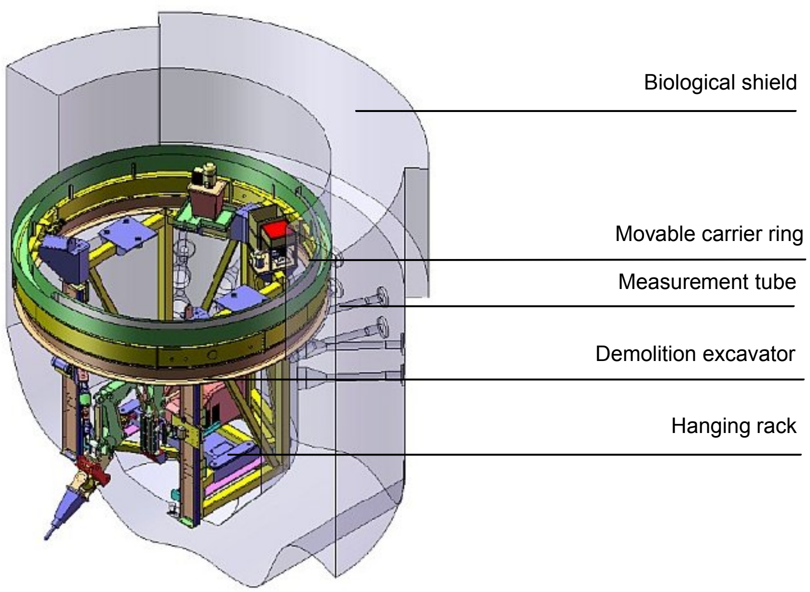


Fig. 5: Installed dismantling facilities with excavator and rotating scaffolding in suspended position (schematic representation)

Remote-controlled Dismantling of the Activated Steel Liner

To cut the 10 mm thick steel liner (Fig. 6) of the activated part of the biological shield, which originally had been used as dead sheathing, a universal cutter was applied. This device similar to a wall saw was developed to cut the steel liner and the first reinforcing layer behind in one cutting process (Fig. 7). In this way, subsequent concrete removal was facilitated considerably. Via a rapid-exchange coupling attached to the demolition excavator, the cutter was fixed remotely. The excavator was positioned in a special working platform mounted to a rotating ring (Fig. 5).
The about 72 m² of sheet metal liner (Fig. 6) were cut within a period of about three months from March to June 2010 (Fig. 7), removed from the former reactor shaft, and packaged.

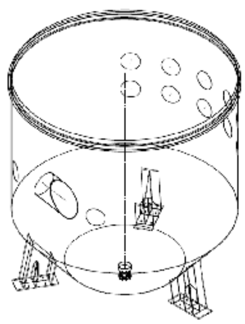


Fig. 6: Steel liner

Fig. 7: Segmenting of the liner by means of the universal cutter

Remote-controlled Dismantling of the Activated Concrete

The activated part of the biological shield was dismantled efficiently by means of the remotely controlled demolition excavator that was positioned in the biological shield via a special working platform (see figures 5 and 8).

Following the dismantling of the liner, concrete removal was accomplished in two areas that were dismantled successively:

Area 1: From about +10 m to about +6 m (round floor of RPV pit) and
Area 2: From about +11.4 m to about +10 m.

Fig. 8: Excavator in working platform during tool transfer

Area 1, from About +10 m to About +6 m:

The excavator was located in the suspended working platform. This platform was mounted in the rotating carrier and transfer ring. Using the attached tools, a chisel (Fig. 9) and a concrete mill, the concrete was removed and subsequently crushed by a grinder in the RPV pit. Metallic components existing in the concrete rubble were removed, crushed, if necessary, and packed separately. Then, the concrete rubble was transferred to the packaging station, crushed further by a jaw crusher, and filled into containers.

Concrete was removed from the top to the bottom, i.e. in the cylindrical part first, then in the cone section, and finally in the area of the round floor.

First, the higher activated, inner concrete layers were removed remotely down to a depth of about 0.3 m using the excavator and the chisel and concrete mill.

The following, lower activated layers were dismantled by means of the same technique, supported by manual demolition work (cutting of steel internals). In parallel, samples were taken to determine the specific activity of the remaining standing building structure. In the cylindrical section, maximum removal depth may be 1 m without static replacement measures.

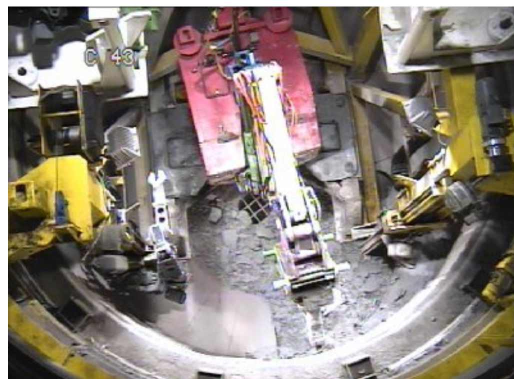


Fig. 9: Concrete removal using a rock chisel

The cut concrete was crushed in the reactor pit using the crusher fixed to the excavator and transferred to the packaging station by the crusher or hoe dipper (Fig. 10). There, the cut concrete was crushed again and filled into the containers.

Metallic components (reinforcing iron, shield cooling lines, supports, etc.) in the concrete rubble were removed by a magnetic gripper or manually and disposed of separately via the packaging station for metals. Further cutting of the metallic components, if necessary, was accomplished in the RPV pit by the excavator and scrap cutter or manually using hydraulic cutters or a saw in the RPV pit or alternatively at the secondary cutting station on level +11 m. As an alternative, angular grinders with cutting disks or autogenous cutters could have been used.

When the activity values were below the release limits, dismantling of area 1 was completed in February 2011. Then, the ambient dose rate in the RPV pit was below 10 µSv/h.

The removal depths were about 95 cm in the cylindrical section, 70 cm in the cone section, and about 30 cm in the area of the round floor.

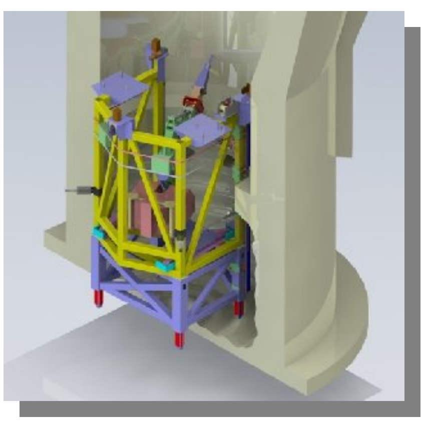
Fig. 10: Transfer of the concrete rubble to the packaging station via the vertical borehole

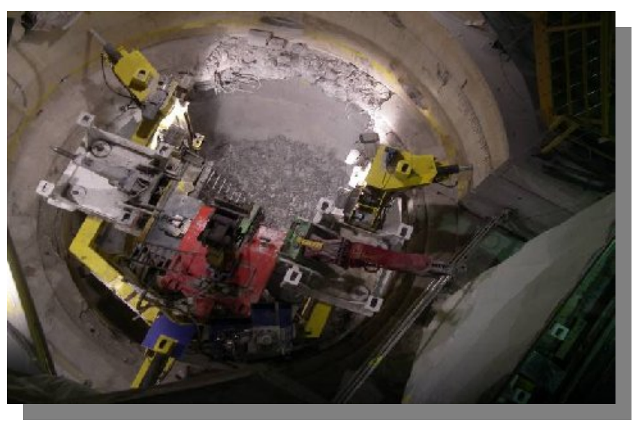
Dismantling of Area 2, from About +11.4 m to About +10 m:

Upon the completion of dismantling in area 1, reconstruction of the working platform was required.

For this purpose, the demolition excavator was lifted out. The rotating ring was no longer needed and was dismantled and disposed of. Then, the so far suspended scaffolding was mounted onto a standing scaffolding, placed in the RPV pit, and secured. From this position, the ring remaining on the level from about +10 m to about +11.40 m was dismantled. This ring had served as static support of the working platform.

Using the tools attached to the excavator mounted on the scaffolding, the remaining part of the liner had been dismantled first before the activated concrete was removed. The concrete rubble was handled in analogy to dismantling in area 1.





Figs. 11 and 12: Dismantling Area 2

Dismantling of the biological shield was completed on August 12, 2011. The dismantled concrete mass was 364 tons, packed into about 40 type- IV containers.
In total, approx. 10 tons of steel were dismantled and packed into 3 type II containers.

The removal depths were about 95 cm in this section, too.

OUTLOOK

Now, all activated components have been dismantled and packaged, such that MZFR can concentrate on:

- the simplification and successive dismantling of the remaining operation systems,
- the decontamination of the building surfaces, and on
- the clearance measurement of the complete facility.

SUMMARY

The small space typical of prototype research reactors represented a challenge also during the last phase of activated dismantling, dismantling of the activated biological shield of the MZFR. Successful demolition of the biological shield required detailed planning and extensive testing in the years before.

In view of the limited space and the ambient dose rate that was too high for manual work, it was required to find a tool carrier system to take up and control various demolition and dismantling tools in a remote manner. The strategy formulated in the concept of dismantling the biological shield by means of a modified electrohydraulic demolition excavator in an adaptable working scaffolding turned out to be feasible. The following boundary conditions were essential:

- Remote exchange of the dismantling and removal tools in smallest space (see Fig. 8).
- Positioning of various supply facilities on the working platform (Figs. 3 and 8).
- Avoiding of interfering edges.
- Optimization of mass flow (removal of the dismantled mass from the working area, see Fig. 2).
- Maintenance in the surroundings of the dismantling area (in the controlled area).
- Testing and qualification of the facilities and training of the staff.

Both the dismantling technique chosen and the proceeding selected proved to be successful. Using various designs of universal cutters developed on the basis of wall saws, both the activated steel liner and the inner reinforcing layer were cut remotely in one process. This allowed for the efficient execution of the following remote concrete removal steps using mining techniques.

The electrohydraulic demolition excavator that was purchased and then modified turned out to be an ideal tool carrier system with rapid-exchange coupling. Due to the high availability, no major delays occurred. This also was a result of the consistently implemented maintenance and repair concept.
With the excavator installed in a modifiable scaffolding suspended from a rotating carrier ring, all dismantling areas could be reached and treated in spite of the small space.

Thanks to an optimum organization of workflows, routine change of dismantling work, and maintenance or repair, the iterative radiological measurement campaigns could be integrated in the whole activity without the dismantling work being disturbed significantly.
The ventilation system with pressure grading and prefiltration units ensured a low contamination level in the dismantling area. It was also possible to manage the dust formed by the milling of concrete surfaces.

As it was possible to further cut metal parts and crushed concrete later on, residue flows were optimized.
The planned overall period for testing, dismantling the bioshield and removing the equipment was 36 months. The final duration was 39 months.

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