Testing and Commissioning of a Multifunctional Tool for the Dismantling of the Activated Internals of the KNK Reactor Shaft – 13524

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ABSTRACT

The Compact Sodium Cooled Reactor Facility Karlsruhe (KNK), a prototype reactor to demonstrate the Fast Breeder Reactor Technology in Germany, was in operation from 1971 to 1991. The dismantling activities started in 1991. The project aim is the green field in 2020. Most of the reactor internals as well as the primary and secondary cooling loops are already dismantled. The total contaminated sodium inventory has already been disposed of. Only the high activated reactor vessel shielding structures are remaining. Due to the high dose rates these structures must be dismantled remotely. For the dismantling of the primary shielding of the reactor vessel, 12 stacked cast iron blocks with a total mass of 90 Mg and single masses up to 15.5 Mg, a remote-controlled multifunctional dismantling device (HWZ) was designed, manufactured and tested in a mock-up. After successful approval of the test sequences by the authorities, the HWZ was implemented into the reactor building containment for final assembling of the auxiliary equipment and subsequent hot commissioning in 2012. Dismantling of the primary shielding blocks is scheduled for early 2013.

INTRODUCTION

The Compact Sodium Cooled Reactor Facility Karlsruhe (KNK) was an experimental nuclear power station with 20 MW of electrical power output [1]. Initially, between 1971 and 1974, the plant was operated with a thermal core and referred to as KNKI. Between 1977 and 1991, it was run with a fast core as KNKII.

The reactor is currently being completely decommissioned and will be dismantled down to green field conditions in ten partial licensing steps according to the German Atomic Energy Act. Under the regulations of the 9th licensing step dismantling of the thermal isolation, removal and cutting of the primary shielding and dismantling the activated parts of the biological shield are being carried out. In a last step all remaining installations such as supply systems, ventilation systems and electrical components will be executed. This removal is necessary for the subsequent release measurement procedure and release from the Atomic Energy Act at the end of the dismantling project. Finally the demolition of the buildings is foreseen.

The current status of the KNK decommissioning project in 2012 is that the total sodium inventory has been removed from the reactor [2]. Therefore the subsequent work can be done under normal dismantling conditions without any inertization of the reactor building. This means, that only the activity and the related dose rates as well as the building conditions need to be taken into consideration. Due to the activation during operation the existing dose rates demand a remote-controlled dismantling of the remaining activated part of the primary and biological shielding. (Fig. 1)

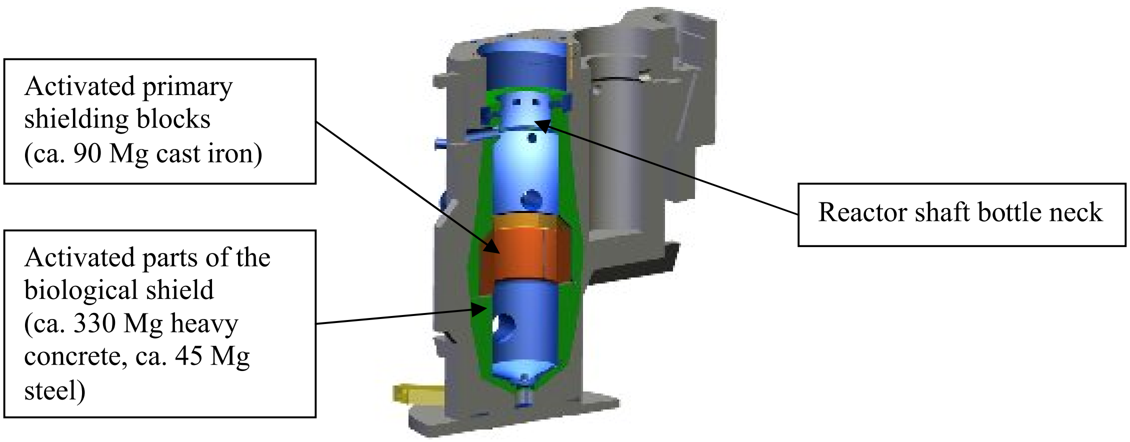

Fig. 1 Setup of the reactor shaft internals with activated parts of primary and biological shielding

The Co-60 activity of the primary shielding blocks is about 1.3 E 13 Bq, respectively 330 mSv/h. Apart from the dose rate the lack of space further complicates the dismantling process. Due to these conditions, it is necessary to develop special machines for the individual dismantling steps to meet the system-dependent requirements. A multifunctional tool, the HWZ, has been designed for the remote-controlled dismantling of the primary shielding.

REMOTE DISMANTLING OF THE KNK PRIMARY SHIELDING BLOCKS

Special Technical Features of the KNK Primary Shielding Blocks

The primary shielding of the KNK reactor shaft consists of 12 modularized cast iron blocks (Fig. 2) with a total mass of 90 Mg and single masses up to 15.5 Mg. The segments are arranged in a niche that is on a level with the former reactor core. (Fig. 1) The 12 blocks are stacked together and interconnected by means of tongue and groove joints to avoid gaps and therefore

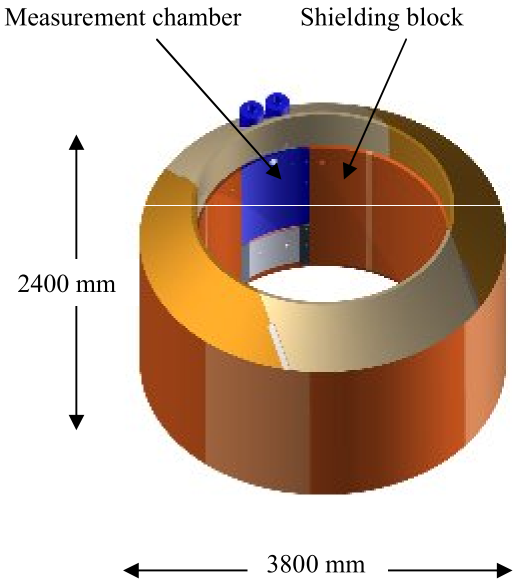

Fig. 2 Principle layout of the primary shielding blocks

direct radiation. Thus this configuration requires a certain dismantling sequence. One segment contains a measurement chamber filled with lead and a filling piece below the chamber.

The shielding blocks do not provide any options for lifting and hook on procedures and are located significantly out of the potential main crane centerline. All blocks have to be maneuvered through a narrow opening on to top of the reactor shaft (bottle neck) with a maximum diameter of 2100 mm.(Fig. 1) Some shielding blocks must rotate up to 90° to allow the lifting through the bottle neck within a clearance of 40 mm.

KNK Primary Shielding Block Processing after Remote Dismantling

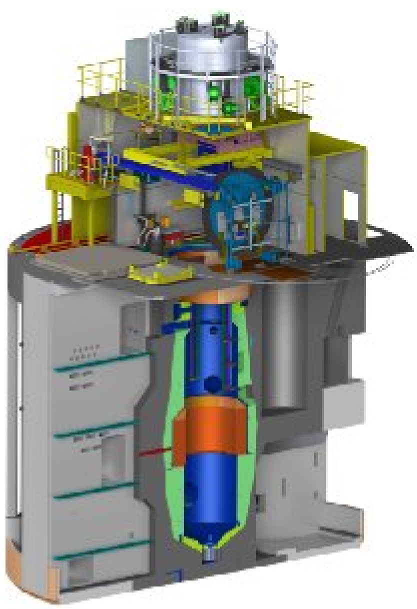

Fig. 3 Shielding block disassembly caisson and transfer lock

After remote dismantling of the shielding blocks, the blocks will be cut with a remote-controlled band saw to fit into special shielding and transfer casks to meet the German repository requirements. For that purpose the blocks will be vertically transferred to the reactor shaft center line and subsequent into the shielding caisson with cask transfer lock. (Fig. 3) The caisson is positioned above the reactor shaft on the level of the former refueling floor and has already been used for the removal of the thermal isolation. The caisson is heavy shielded and airflow controlled to protect the staff against airborne contamination and radiation impact. Within the caisson the reactor shaft is covered with a remote-controlled reactor shaft cover for ventilation control and radiation shielding from the reactor shaft to protect the staff during eventually needed manual maintenance activities and trouble shooting on the caisson utilities (e.g. cranes, HWZ, band saw, lighting).

THE KNK MULTIFUNCTIONAL SHIELDING BLOCK DISMANTLING DEVICE (HWZ)

General Technical and Functional Requirements

The KNK HWZ must meet the following requirements:

- High availability
- No planned maintenance and in-service inspection
- Technical features for salvage operation
- Actuator redundancy
- Max. payload 16 Mg
- Construction weight limited to 9 Mg with respect to the KNK polar crane payload of 25 Mg
- Construction size (OD) limited to 2100 mm with respect to the reactor shaft bottle neck
- With respect to the functionality nine degrees of freedom like a 9-axis machine tool
- High repeating and drive up accuracy of all axis under maximum payload
- Automatic and individual remote control of all axis
- Indirect visual control by Closed Circuit Television (CCTV)

Technical Description of the KNK HWZ

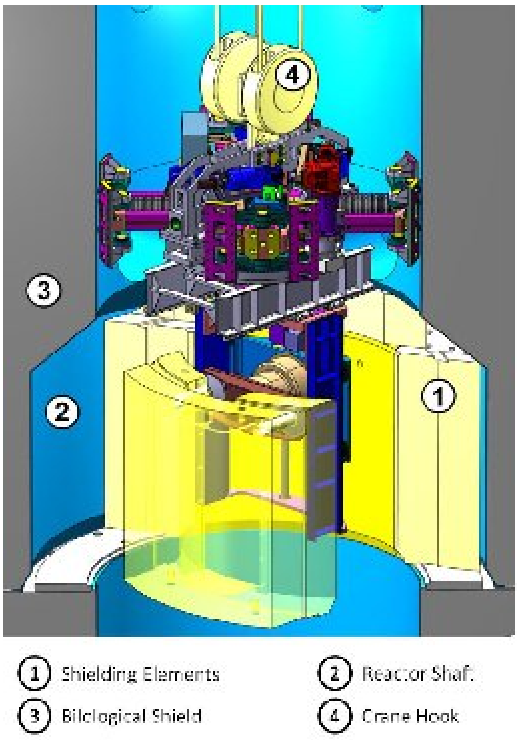

Fig. 4 Hoisting of the HWZ

According to the dismantling concept, the components of the primary shielding shall be lifted out of the reactor shaft one by one. To realize this procedure multiple tasks have to be performed by the HWZ. As a result of the limited space in the reactor shaft many technical items had to be designed especially for this application, thus satisfying the static and spatial requirements. The HWZ is handled within the caisson and reactor shaft with the existing KNK polar crane. (Fig. 4) The HWZ consists of a heavy steel framework with all systems and actuators being integrated. The HWZ conducts the following moving axis (Fig. 5):

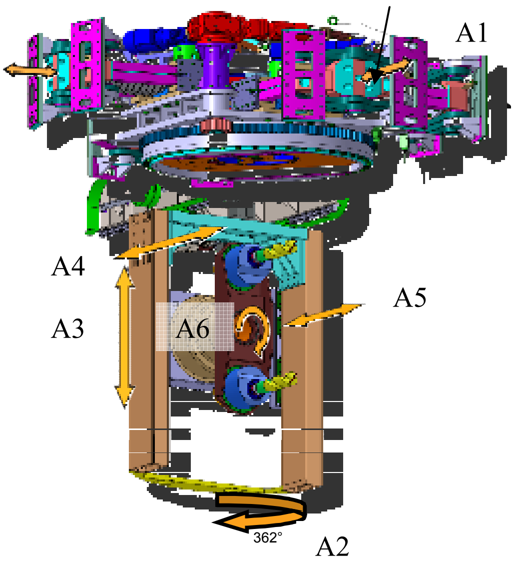

Fig. 5 Axis of the HWZ

- A1 In order to fix the HWZ into the reactor shaft the “clamping unit”, positioned on the top of the HWZ, is endowed with four outriggers that can be tightened against the reactor shaft liner. (Fig. 4.)
- A2 Axis for complete horizontal orientation of the tool support
- A3 Axis for vertical orientation of the tool support
- A4 Axis for linear horizontal orientation of the tool support
- A5 Axis for tool support feed (milling, drilling)
- A6 Axis for rotating of dismantled blocks to fit through the rector shaft bottle neck

The axis are driven by electric motors. Each electric motor is equipped with a parallel connected hydraulic motor as redundancy in case of malfunction of the electric unit. To lift the cast iron shielding blocks two horizontal core holes (Ø 110 mm, depth 320 mm) have to be drilled into each block. A specially developed drilling system was designed to set the two holes in just one cycle without changing the tool, thus reducing the need of manual interaction. (Fig. 6, 7)

Fig. 6 Drill rod Ø 110 mm

Fig. 7 HWZ drill rod during mock-up tests

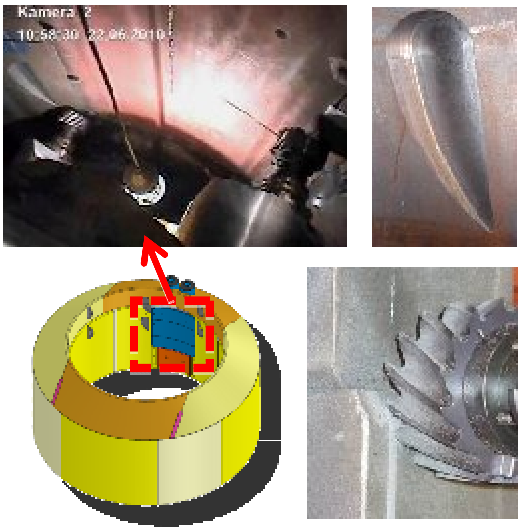

Fig. 8 Shielding block milling during mock-up tests

To place the core holes into the cast iron shielding blocks, it was necessary for drill technology reasons to break the very hard cast iron skin and to manufacture a butting face to the concave shielding block surface by milling. (Fig. 7, 8) The two milling cutters have been placed in the same way as the two drill rods. For visual control of the milling, drilling and clamping process the HWZ is equipped with nine CCTV units.

After placing the lifting holes into the shielding blocks, the drill rods will be exchanged manually in the caisson against so called “clamping mandrels”. The two clamping mandrels will be remotely inserted into the core holes to achieve a firm connection between shielding block and HWZ. (Fig. 9) The clamping mandrels are spring loaded and hydraulically activated. After fixing the clamping mandrels to the shielding block, the shielding block can be lifted up by the interaction of the axis A3, A4, A5 and A6 to transfer the shielding block to the centerline of the reactor shaft and into a position to fit trough the reactor shaft bottle neck. (Fig. 10)

Fig. 9 Shielding block clamping mandrel

Fig. 10 HWZ with a typical 3 Mg shielding block during mock-up testing

MOCK-UP TEST OF THE HWZ

Due to the complexity of the HWZ and the requirement of the authorities an extensive test program and staff training was planned and successfully executed in the years 2011-2012 in a mock-up test facility. (Fig. 10, 11, 12) The mock-up is a full-scale model of the former reactor shaft with its relevant geometry. This includes the reactor shaft bottle neck, the niche for the primary shielding blocks as well as five different sizes of shielding blocks and the necessary measurement chamber with filling piece. During the training program the staff was first trained in operation of the HWZ for the remote-controlled dismantling of the shielding blocks under CCTV operation. Subject of the test program was the demonstration of the functionality concerning the geometrical, kinematical and static features of the HWZ and all necessary tasks, such as:

- Milling and drilling holes into the blocks, wear characteristics of the tools
- Clamping the blocks and lifting them up to the caisson through the bottle neck
- Separate removal of the measurement chamber
- Proving of the salvage operation
- Verification of the arrangements of the CCTV units

Fig. 11 HWZ during cold tests at mock-up

Fig. 12 HWZ during cold tests at mock-up

During the mock-up tests, it has been shown, that some features needed to be modified and optimized, e.g. for the dismantling of the measurement chamber additional tools have to be developed. Finally it was proven that all tasks can be performed safely as specified before. Additionally important key figures and characteristics were recorded which are necessary for estimation of the total duration of dismantling the primary shielding. At the end the authorities confirmed the tests as an important precondition before beginning the installation activities of the HWZ in July 2012. In total 4600 man-hours were spent for the cold tests and staff training.

NEXT STEPS AND CONCLUSIONS

After finalization of the cold acceptance tests in July 2012, the HWZ was dismantled at the mock-up (Fig. 13) including its utilities

- hydraulic and electric supplies
- hydraulic and electric spools
- switchgears and control units
- CCTV systems

and shipped to the KNK reactor building (Fig. 14) and preassembled in the caisson. (Fig. 15) In December 2012 the HWZ will be final assembled with all its utilities and supplies in the caisson. Hot commissioning of the HZW under supervision of the authorities is scheduled February 2013. Hot dismantling of the shielding blocks is expected starting March 2013.

Fig. 13 HWZ dismantling in mock-up

Fig. 14. HWZ transferred to the reactor building

Fig. 15. Preassembling HWZ in the caisson

In summary, it becomes apparent, that despite the various challenges, a highly complex and individually constructed machine like the KNK HWZ, is a reasonable solution for ambitious deconstruction measures.

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