Decommissioning of German Research Reactors Under the Governance of the Federal Ministry of Education and Research − 12154

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ABSTRACT

Since 1956, nuclear research and development (R&D) in Germany has been supported by the Federal Government. The goal was to help German industry to become competitive in all fields of nuclear technology. National research centers were established and demonstration plants were built. In the meantime, all these facilities were shut down and are now in a state of decommissioning and dismantling (D&D).

Meanwhile, Germany is one of the leading countries in the world in the field of D&D. Two big demonstration plants, the Niederaichbach Nuclear Power Plant (KKN) a heavy-water cooled pressure tube reactor with carbon-dioxide cooling and the Karlstein Superheated Steam Reactor (HDR) a boiling light water reactor with a thermal power of 100 MW, are totally dismantled and "green field" is reached. Another big project was finished in 2008. The Forschungs-Reaktor Jülich 1 (FRJ1), a research reactor with a thermal power of 10 MW was completely dismantled and in September 2008 an oak tree was planted on a green field at the site, where the FRJ1 was standing before. This is another example for German success in the field of D&D.

Within these projects a lot of new solutions and innovative techniques were tested, which were developed at German universities and in small and medium sized companies mostly funded by the Federal Ministry of Education and Research (BMBF). Some examples are underwater-cutting technologies like plasma arc cutting and contact arc metal cutting. This clearly shows that research on the field of D&D is important for the future. Moreover, these research activities are important to save the know-how in nuclear engineering in Germany and will enable enterprises to compete on the increasing market of D&D services.

INDRODUCTION

Nuclear R&D in Germany has been supported by the Federal Government for a long period of time. Several national nuclear research centers were established, especially to perform research on all fields of nuclear technology. The two most important are the Forschungszentrum Karlsruhe (FZK) and the Forschungszentrum Jülich (FZJ). Since the beginning of the eighties, the focus of research activities of FZK and FZJ has shifted more and more from the nuclear topics to different new research areas. Some of these are e.g. nanotechnologies, technologies for production of renewable energies, as well as information and communication technologies. Meanwhile, all research reactors and demonstration plants operated by these research centers were shut down.

For decommissioning of nuclear facilities in Germany responsibility is three-fold: Firstly, the electric utility companies are responsible for the nuclear power plants. Secondly, as laid down in the German Reunification Treaty, the Federal Ministry of Economics and technology (BMWi) is in charge of the decommissioning projects in the former German Democratic Republic (e.g., the Greifswald and the Rheinsberg power plants). Finally, there are the facilities within the responsibility of the BMBF, i.e. eight reactors, the Karlsruhe reprocessing plant (WAK) and several hot cells and laboratories located at the sites of the national research centers.

BMBF's decommissioning strategy is in many cases a quick return to "green field" sites. The rationale behind this approach is based on the following concerns: public acceptance, costs and to avoid losses of knowledge during a safe enclosure, because especially for research reactors with their individual design only the present personnel is familiar with all details.

Cost reductions have to be pursued without compromising safety and environmental standards. In many cases comparison between safe enclosure and total dismantling of reactors reveals about equal costs. Still, this result cannot totally be generalized as there is a clear dependence on the structure of direct and indirect costs.

COSTS OF DECOMMISSIONING PROJECTS

Concerning the decommissioning projects under BMBF's responsibility, the costs are about 160 Millions € per year. Till 2035, the total amount will be about 5 billion € [1]. Besides this, private industry has to pay additional money for some of these projects. Table I shows details about the costs for decommissioning projects at different research reactors sites, which are actually in progress and of some already completed decommissioning and dismantling projects. Future projects for example the decommissioning of the Forschungs-Reaktor Geesthacht (FRG-1) are not included here.

Table I. BMBF's Decommissioning Projects

Location	Facility	Decommissioning operation time and goal	Total cost	
			Million €	**% of Total**
Niederaichbach	KKN reactor	Completed in 1996, green field	130	100
Karlstein	HDR reactor	Completed in 1996, green field	40	100
Kalkar	SNR-300 reactor	Completed in 2006, among others fuel removal	238	~ 25[1]
Heidelberg, DKFZ	TRIGA II	Totally removed in 2006	2	90[3]
Juelich	Merlin (FRJ1)	Completed in 2008, green field	31	90[3]
Hamm-Uentrop	THTR-300 reactor	safe enclosure in 1997, 1997-2009 safe storage (continued), new contract under preparation	~ 95 (cost for safe storage)	33[2]
Karlsruhe	KNK reactor	1992-2019, green field,	378	90[3]

Karlsruhe	MZFR reactor	1985-2015, gray field, place is foreseen for new research facility	351	100
Juelich, AVR GmbH	AVR reactor	1987-2015, safe enclosure of reactor vessel, total removal of the building,	444	70[3]

[1]co-financed by industry (Rheinisch-Westfälische Elektrizitätswerks Aktiengesellschaft, (RWE AG)), [2]co-financed by federal state and industry, [3]co-financed by Federal State,

PROJECT STATUS AT THE DIFFERENT SITES

Demonstration Plants

FZK operated two demonstration nuclear power plants outside the research center. One was the Karlstein Superheated Steam Reactor (HDR), it was located in Karlstein at the Main river in the north-west of Bavaria. The other the KKN was operated in Niederaichbach in Bavaria, this is located about 70 kilometers in the north-west of Munich.

The **Karlstein Superheated Steam Reactor (HDR)** started operation in October 1969. It was a boiling light water reactor with a thermal power of 100 MW. The failures of the special fuel element concept of the HDR were the reason for its final shutdown in 1971. Afterwards the HDR was converted into a test facility. From 1974 until the end of 1991, reactor safety experiments were performed there. Decommissioning and dismantling started in 1994. The HDR was dismantled completely and green field was reached in 1998. Details about the D&D of the HDR were reported in [2].

The **Niederaichbach Nuclear Power Plant (KKN)** was a heavy-water moderated pressure tube reactor with carbon-dioxide cooling. It was in operation from 1972-1974. It was shut down, because this reactor was not longer promising and BWR and PWR reactors were already established in Germany. After some years of safe storage, decommissioning started in 1987 and remote-controlled decommissioning of activated parts were done from 1990 to 1993.

This project should serve as an example for feasibility of a return of a nuclear reactor site to a green field with the former natural vegetation. During this project a lot of technologies were established with are now state of the art in Germany. For the FZK it was a kind of pilot project with regard to later decommissioning projects at the area of the research center in Karlsruhe. This project was a big success and it was the first decommissioning project that reached “green field”. It ended with replanting of the former reactor site in late 1995. More detailed information about this D&D project is found in [2].

Prototype Reactors

The **SNR-300** was a sodium-cooled fast breeder reactor. It was completed in 1985, but never took up operation. The entire project came to an end in 1991 and the property was sold to a private investor in 1995. The 205 fuel assemblies were stored in Hanau till 2005. By the end of 2005, the storage facility in Hanau was closed and the fuel assemblies were shipped to France and will be used for the production of MOX fuel.

The **“Thorium-Hochtemperaturreaktor” (THTR)** was gas cooled high temperature reactor. The purpose of this 300 MWe prototype reactor was to demonstrate the viability of pebble bed technology with special spherical graphite fuel elements containing coated fuel particles. The THTR was shut down in 1989, because despite three years of operation with satisfactory performance, the competent authority of the State (Northrhine-Westfalia) refused to renew the operation license. Another reason might have been that many BWR and PWR reactors were running successfully in Germany and both the public financiers and the private industry were not interested to spend more money for the operation of this prototype reactor. Decision for safe enclosure was made in late 1989. Safe enclosure was reached in 1997 and will be followed by up to thirty years of operating of the safe enclosed plant. The next decision about the on-going of the safe enclose was planned for 2009, but the new contract is not finished, so up now the project is financed by the remaining money from the first period of safe storage. A detailed description of this decommissioning project is found in [3].

Experimental Reactors

Before reporting about these projects, a change in the organization structure of BMBF projects must be mentioned. In Karlsruhe the responsibility for the D&D projects changed. Since the 1 July 2009 all projects are operated by the WAK GmbH (“Reprocessing plant Karlsruhe Dismantling and Disposal Corparation”). Three month later the Forschungszentrum Karlsruhe (FZK) and the University Karlsruhe merged to the Karlsruhe Institute of Technology (KIT).

The **Compact Sodium-cooled Nuclear Reactor Facility (KNK)** at the side of the former Forschungszentrum Karlsruhe was an experimental power plant with electric power of 20 MW. The KNK reactor was run with two reactor cores. From 1971 to 1974, the plant was operated with a thermal core as KNK I. From 1977 to 1991, it was run with a fast core as fast breeder power plant KNK II. The operation of this second core was conceived to pave the way for the SNR-300.The reactor was shut down in 1991.

After the shutdown, the sodium and the fuel assemblies were removed quickly in order to make use of CEA’s fuel reprocessing service at Marcoule. The contaminated sodium has been treated in a joint effort with UKAEA. The KNK decommissioning project is very special due to the special requirements from the sodium. The use of wet or thermal cutting methods is not possible. Another special circumstance is that from the fast neutrons during operation as fast breeder (KNK II) the biological shield is activated deeply. Due to the resulting high radiation, the reactor tank, the primary shield (60 cm cast iron) and major parts of the biological shield have to be handled with remote controlled devices.

Dismantling of the KNK is planned in 10 steps, each step needs a separate decommissioning licenses. The goal is a complete dismantling to a green field. Of these 10 steps, the first 8 have already been completed. One part of the 9th step is the remotely controlled dismantling of the thermal insulation and primary shielding and the dismantling of the activated part of the biological shield.

The dismantling of the thermal insulation and the packaging of the residues has to be performed in a remote-controlled manner. In addition, work is complicated due to the very small space available in the reactor shaft and the enclosure above. The upper section of the thermal insulation consists of a 160 mm thick refractory brick lining and a mineral wool mat of 90 mm thickness behind. The lower part of the thermal insulation is made of a 250 mm thick refractory lining. Behind this lining, a sheet metal liner of 0.5 mm in thickness is arranged over the complete height. Using stud bolts as spacers, it is fixed to the sheathing tank and primary shielding. The total mass is about 11 Mg. The individual components of the thermal insulation are loosened, collected, and packed into packaging drums. A tool carrier system has been developed specifically for the dismantling of the thermal insulation and packaging of the residues. The tool carrier system is equipped with a hydraulic manipulator system, a telescopic drum beam with a rack for packaging drums, cameras, and a microphone are arranged on this plate. For remotely controlled operation, conventional tools, such as drilling hammers or cut-off grinders, were equipped with manipulator-suited adaptersand plugs.

The tool carrier system and the dismantling of the thermal insulation were tested and optimized in a mock-up, a 1:1 model of the KNK reactor sheathing tank. After the handling units of the enclosure had been adapted to the dismantling of the thermal insulation and subsequent commissioning together with the tool carrier system in the presence of an inspector, dismantling of the thermal insulation started in September 2010. To dismantle the thermal insulation, the tool carrier system is lowered into the reactor shaft by the cell crane and fixed there. Inevitably, work starts with the refractory lining. Then, it is preceded with the mineral wool, sheet metal liner, and the stud bolts. By the middle of 2011 the dismantling of the thermal isolation was completed. The next step will be the dismantling of the primary shielding.

The dismantling work showed good progress over the last years, so that according to present planning “green field” should be reached by the end of 2019.

The **Multi-purpose Research Reactor (MZFR)** at the side of the former Forschungszentrum Karlsruhe was a pressurized water reactor, cooled and moderated with heavy water. It was operated with slightly enriched uranium fuel. The MZFR went critical for the first time in 1965. At that time, the MZFR was the world largest heavy water cooled nuclear reactor in the world, with a thermal output of 200 MW and an electrical output of 57 MW. It served, among other things, as a prototype for the 340-MWe Atucha power plant in Argentina. MZFR was operated very successfully for nearly 20 years until final shutdown in 1984.

After shutdown, safe enclose of the reactor was planned first. In 1989, the decision was changed in favor of a complete dismantling of the plant. The reactor is dismantled in eight separate steps, beginning from the top to the bottom and then from inside to outside. Each step needs to be licensed. Since 2007, all licenses under the Atomic Energy Act required for MZFR decommissioning to the green field have been granted already.

MZFR dismantling has reached a far advanced stage. All former nuclear circuits were disassembled; various buildings and building sections were emptied completely and decontaminated. Remote dismantling of the reactor pressure vessel, including internals, was completed successfully in 2007. For this purpose, several, partly innovative dismantling techniques had been applied under remote handling conditions. One of these was the underwater contact-arc-metal-cutting, a new cutting technology that has been developed and adapted for dismantling of nuclear facilities in the frame of a research project founded by the Federal Ministry of Education and Research, only a few years before.

Since March 2010, the activated concrete structures of the biological shield have been dismantled. The activated part of the biological shield was dismantled efficiently by means of a remotely controlled demolition excavator, which was positioned in the biological shield via a special working platform. Following the dismantling of the liner, concrete removal was accomplished in two areas that are dismantled successively. 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 and a concrete mill, the concrete was removed. Metallic components existing in the concrete rubble are 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. 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. Metallic components in the concrete rubble were removed by a magnetic gripper or manually and disposed of separately via the packaging station for metals. The complete dismantling of the activated part of the biological shield is planned for the end of 2011.

The decommissioning and dismantling of the MZFR showed good progress over the last years and it is planned to be finish the project in 2015. It is discussed to use the area later for a new research facility for nuclear fusion research.

The "**Versuchsatomkraftwerk Jülich"(AVR)** at the Forschungszentrum Jülich was the experimental facility that preceded the THTR-300. It was operated from 1967 to 1988. After a successful operation time for more than 20 years, its final shutdown was in 1988. In 2003 the AVR GmbH, which was responsible for the decommissioning of the AVR, was taken over by the Energiewerke Nord (EWN) GmbH. EWN is following a new decommissioning strategy, instead of a safe enclosure the reactor will be dismantled, after the reactor vessel will be taken out as one piece. The reactor vessel will be filled with lightweight concrete and transported to a new storing facility close to the reactor site for an intermediate storage.

RESEARCH ON TECHNOLOGIES FOR DECOMMISSIONING AND DISMANTLING NUCLEAR FACILITIES

In addition to these large scale decommissioning projects BMBF founded a lot of R&D on this field. During the last five years it allocated an average of 5 Million € per year. About this research program is reported half-yearly, in a publication issued by the Project Management Agency Karlsruhe (PTKA-WTE). These publications are found on the website of the KIT (www.kit.edu).

The founded research projects are related to e.g. dismantling techniques, especially cutting techniques and measurement for free release. As mentioned above some of these cutting technologies were used to solve very challenging cutting task connected with the safe dismantling of the moderator tank and the thermal shield of the MZFR. Other examples from the on-going research program are the development of remote-controlled techniques for the decontamination of concrete surfaces and development of a mechanical cutting tool which is able to cut both concrete and metallic components.

CONCLUSION

The author assumes that an efficient decommissioning of nuclear installations will help stabilize the credibility of nuclear energy. Some critics of nuclear energy are insisting that a return to “green field sites” is not possible. The successful completion of two big D&D projects (HDR and KKN), which reached green field conditions, are showing quite the contrary.

Moreover, research on D&D technologies offers the possibility to educate students on a field of nuclear technology, which will be very important in the future. In these days D&D companies are seeking for a lot of young engineers and this will not change in the coming years.

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