Decommissioning of German Nuclear Research Facilities under the Governance of the Federal Ministry of Education and Research - 8059

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ABSTRACT

Since the announcement of the first nuclear program in 1956, nuclear R&D in Germany has been supported by the Federal Government under four nuclear programs and later on under more general energy R&D programs. The original goal was to help German industry to achieve safe, low-cost generation of energy and self-sufficiency in the various branches of nuclear technology, including the fast breeder reactor and the fuel cycle. Several national research centers were established to host or operate experimental and demonstration plants. These are mainly located at the sites of the national research centers at Juelich and Karlsruhe. In the meantime, all these facilities were shut down and most of them 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. For two other projects the return to “green field” sites will be reached by the end of this decade. These are the dismantling of the Multi-Purpose Research Reactor (MZFR) and the Compact Sodium Cooled Reactor (KNK) both located at the Forschungszentrum Karlsruhe.

Within these projects a lot of new solutions und 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). For example, high performance underwater cutting technologies like plasma arc cutting and contact arc metal cutting.

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. Two of them, the Forschungszentrum Karlsruhe (FZK) and the Forschungszentrum Jülich (FZJ), celebrated their 50 years anniversary in 2006. Since the beginning of the eighties, the focus of research activities of FZKa and FZJ has shifted more an 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. The last one was the FRJ-2 reactor at FZJ. This reactor, of the DIDO class, was closed in May 2006, after almost 44 years of operation.

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), the Asse research mine 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 FRJ-2 are not included here. Since 2002 cost for some of these project increased significantly as you can see comparing this table with one presented by my former co-worker R. Papp on the WM symposia 2002 [2].

Table I. BMBF's Decommissioning Projects

Location	**Facility**	**Decommissioning operation time and goal**	**Total cost**	**BMBF Funding**	
			Million €	**Mill. €/a**	**% 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]
Hamm-Uentrop	THTR-300 reactor	safe enclosure in 1997, 1997-2009 first safe storage period	~ 95 (cost for safe storage)	2.5	33[2]
Karlsruhe research center	KNK reactor	1992-2011, green field,	301	~ 15	90[3]
Karlsruhe research center	MZFR reactor	1985-2009, gray field, place is foreseen for new research facility	298	10-12	100

Juelich research center	Merlin (FRJ-1)	1995-2007, total removal,	2	30	90[1]
Juelich, AVR GmbH	AVR reactor	1987-2012, safe enclosure of reactor vessel, total removal of the building,	398	~ 15	70[1]
Heidelberg, DKFZ	TRIGA II	2002-2006, total removal	2	11	90[1]

[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 very close to Landshut city and two of the most efficient nuclear power plants in the world, the ISAR-1 and ISAR-2 reactors.

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 aim was a complete dismantling of the facility to green field conditions. The project was carried out in three steps. Due to the small ambient dose rates, resulting from a very short operation time of the reactor, all rooms of the plant could be accessed. Therefore, remote-controlled methods and tools were not required. First, all experimental equipment from the safety research program was removed. The second step was the dismantling and removal of reactor equipment and machines including the reactor pressure vessel. The reactor pressure vessel with only a small activity was dismantled by means of a propane cutting system. The third step was the removal of the concrete structures inside the reactor containment. Radial activation of the biological shield above the release limit extended down to a depth of about 50 cm. Finally, the clearance measurement and declassification of the controlled areas as well as the clearance measurements of the external facilities followed. The entire reactor building was closed off and made ready for the conventional demolition. The HDR was dismantled completely and green field was reached in 1998.

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 [3].

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 will be made in 2009. A detailed description of this decommissioning project is found in [4].

Experimental Reactors

From the beginning of advanced reactor development in Germany, responsibility for the accompanying R&D was split among the national research centers. FZJ focused on the high-temperature, gas-cooled pebble bed reactor line, FZK focused its research activities on fast breeder technologies.

The **Compact Sodium-cooled Nuclear Reactor Facility (KNK)** at the 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 devises. The dismantling work showed good progress over the last years and according to present planning "green field" should be reached by the end of 2011.

The **Multi-purpose Research Reactor (MZFR)** at the 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. As the reactor is embedded in a biological shield, dismantling is done step by step, beginning from the top to the bottom and then from inside to outside. For this purpose, the dismantling area was equipped with a remote handling system. The highest activated inner components, such as the moderator tank, had to be dismantled in the reactor pressure vessel under water. For the remote controlled cutting of the thermal shield, underwater plasma cutting technique and underwater contact-arc-metal-cutting were used. These innovative cutting technologies has been developed and adapted for dismantling of nuclear facilities in research projects founded by the Federal Ministry of Education and Research, only a few years before.

The decommissioning and dismantling of the MZFR is planned to be finished in 2009.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 4 Million € per year. About this research program is reported half-yearly, in a publication issued by the Project Management Agency Forschungszentrum Karlsruhe (PTKA-WTE). These publications are found on the website of the FZK (www.fzk.de).

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. Another very successful example is the development of a technique for the decontamination of concrete surfaces using Laser ablation and simultaneously conditioning of the ablated material. Up to now, three patents were applied for this technique and a technical application of this method is the goal for the near future.

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 day D&D companies are seeking for a lot of young engineers and this will not change in the coming years.

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