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DISMANTLING THE REACTOR VESSEL OF THE COMPACT SODIUM-COOLED NUCLEAR REACTOR FACILITY (KNK) UNDER CONSIDERATION OF RADIATION PROTECTION ASPECTS

W. Pfeifer[a], I. Hillebrand[a], C. Dominke[a], J. Benkert[b]

[a]Forschungszentrum Karlsruhe, Germany

[b]Westinghouse Reactor
Mannheim, Germany

INTRODUCTION

The Compact Sodium-cooled Nuclear Reactor Facility (KNK) was an experimental nuclear power plant of 20 MW electric power erected on the premises of the Karlsruhe Research Center. The plant was initially run as KNK I with a thermal core between 1971 and 1974 and then, between 1977 and 1991, with a fast core as the KNK II fast breeder plant.

The reactor core of KNK was arranged in an unpressurized, thin-walled reactor vessel roughly in the middle of the containment (Fig. 1). Sodium was used as the coolant.

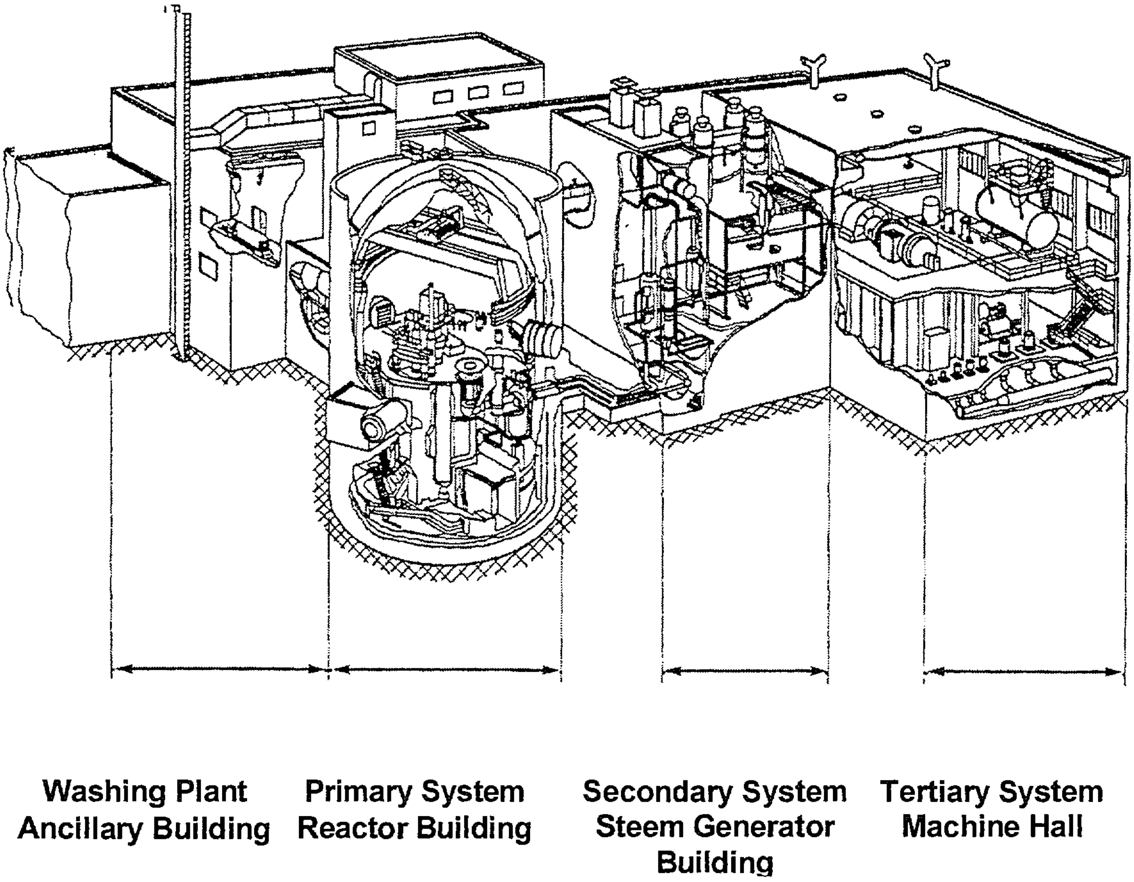

Fig. 1 KNK systems and buildings

The entire nuclear fuel and all movable core internals have already been disposed of. The sodium coolant has been removed except for some residues clinging to inner surfaces and in inaccessible locations. The tertiary systems (water-steam loop with the turbine) and the secondary sodium systems, including the associated auxiliary systems and buildings, have been taken out and demolished, respectively. The ventilation system, the electricity supply facilities, and the reactor entrance and exit lock have been adapted to the requirements of the decommissioning steps to follow. The primary system including the primary sodium dump tank, the fuel element store and the rotating reactor top shield of the reactor vessel were dismantled. The work conducted so far has been based on eight decommissioning permits.

All activated and/or contaminated materials are transferred to the Central Decontamination Operation Department (HDB) of the Karlsruhe Research Center, which processes them under consideration of the final disposal requirements, and stores them in interim storage.

Under the 9th Decommissioning Permit, the reactor vessel with its internals, the primary shield, and the biological shield are to be dismantled. A European wide limited tendering procedure was first run for these activities, and at last the contract was made with Westinghouse Reaktor Germany.

The difficulty involved especially in dismantling KNK, on the one hand, is posed by the residual sodium in the plant. This determines the choice of techniques to be used in disassembly and, in addition, the material must either be removed or converted by chemical means after component disassembly, as components bearing sodium metal cannot be delivered to HDB or stored in a repository.

Another difficulty is caused by the depth of activation by fast neutrons, as a result of which not only the reactor vessel proper, but also the entire primary shield (60 cm of grey cast iron) and large parts of the biological shield must be disassembled and disposed of under remote control.

PERMITS AND DEADLINES

Under the decommissioning concept, the plant is to be decommissioned completely to green field conditions in ten steps, i.e. under the corresponding ten decommissioning permits. To this day, nine decommissioning permits have been issued, the first one in 1993 and the most recent one, number nine, in 2001.

The decommissioning and demolition activities covered by decommissioning permits 1 to 7 have been completed. Under the 8th Decommissioning Permit, the components of the primary system and the rotating reactor top shield are to be removed by June 2002.

The 9th Decommissioning Permit covering disassembly of the reactor vessel and the biological shield was submitted in July 1999 and, with a final amendment, again in March 2000. The expert opinion covering these activities has been available since December 2000, and the permit was issued in March 2001. The period between March 2001 and December 2002 has been reserved for planning and preparing for the disassembly of the reactor vessel. From January 2003 on, the reactor vessel with its internals is to be disassembled and disposed of, and from mid-2003 on, the primary shield and the biological shield are to be disassembled and disposed of.

Under the 10th and last Decommissioning Permit, the remaining auxiliary systems (sodium washing plant, ventilation plant, liquid effluent system, gaseous effluent system, etc.) are to be dismantled and any buildings remaining are to be decontaminated, measured for clearance, and then demolished, if necessary. Then the site is to be recultivated. The work is to be finished probably at the end of 2005.

DISMANTLING THE REACTOR VESSELS

Initial Condition

After completion of the first eight decommissioning permits, the only remnants of the plant still in existence are the reactor vessel with its internals installed in the primary shield and the biological shield. These components are located in the middle of the containment in the reactor building (see Fig. 2). The reactor vessel is inerted with nitrogen and closed with a lid. Other installations still in place are the ancillary plants building, the control room building, and a storage facility. The reactor building and the ancillary plants building are part of the controlled area. They contain some systems important in the decommissioning process, namely the ventilation system, the washing system for components wetted with sodium, and the moderator store, which must be converted into a buffer store.

The residual sodium volume in the reactor vessel was estimated to amount to approximately 30 l. The maximum Co-60 activation is on the order of 10^7 - 10^8 Bq/g; the maximum dose rate in the middle of the vessel was measured in April 1997 to be 55 Sv/h.

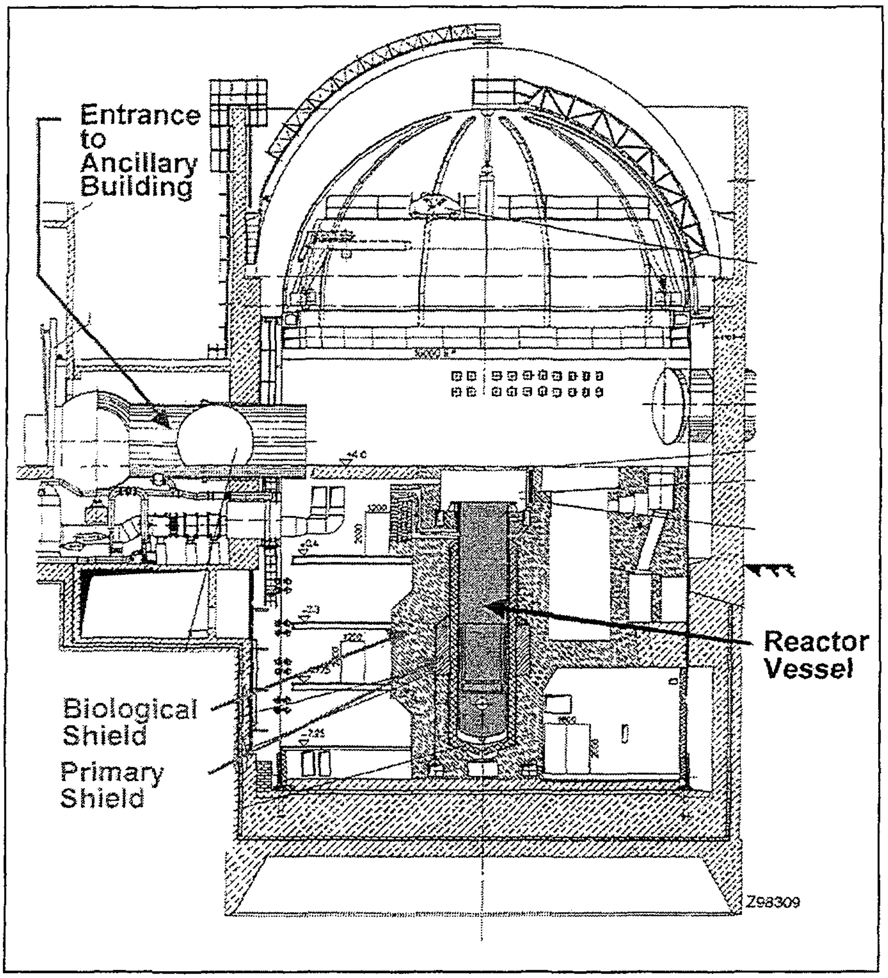

Fig. 2:Cross section through the KNK containment after completion of the 8th Decommissioning Permit

Demolition Concept

Before dismantling of the reactor vessel is begun, the gas room inside of the vessel is treated with a wet gas. For this purpose, the nitrogen is added humidity with water so that any particulate sodium deposits can be immobilized. Then the vessel is dried.

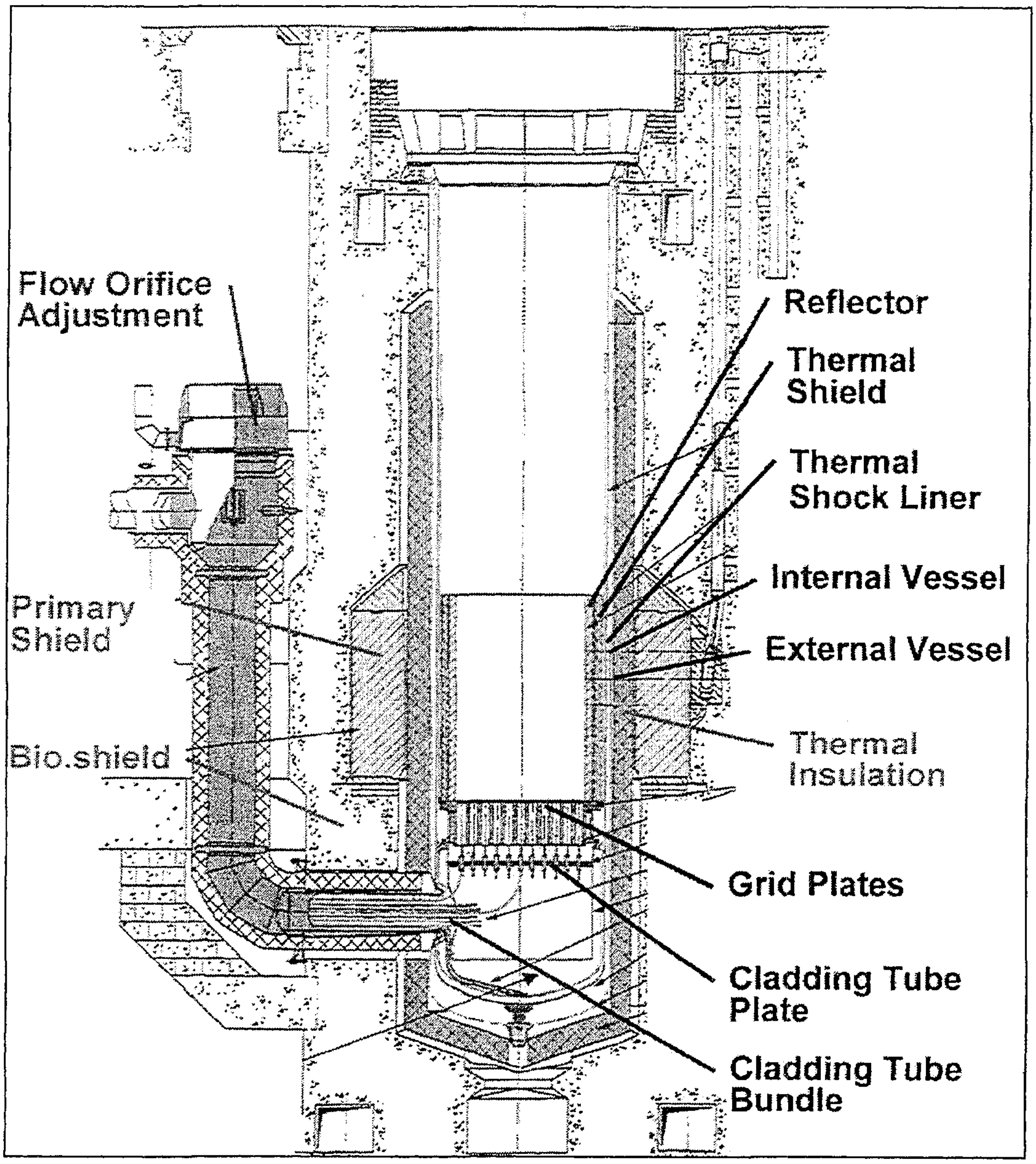

Fig. 3: Reactor vessel with internals

The reactor vessel with its internals (Fig. 3) are to be disassembled within the existing shielding, i.e. the biological shield, for radiological reasons. The internals of the reactor vessel are to be demolished inside out. The internal vessel and the external vessel must be demolished from bottom to top because they are suspended from an upper flange.

Because of the hazard of sodium fires, only mechanical cutting techniques, such as sawing, milling, drilling, or cutting, may be used to dismantle the reactor vessel and its internals.

For the purpose of dismantling the reactor vessel within the existing shield, a shielding enclosure (Fig.

4) will be erected at the working level above the reactor vessel. The enclosure must have a shielding of 35 cm of steel required for radiological reasons and has to ensure separation from the containment in terms of ventilation. It will be equipped with a handling cell, an intervention cell, a double-lid lock and a transfer lock for building rubbish, and all the necessary auxiliary systems (lifting gear, rails, lead glass windows, manipulators).

On the top of the enclosure a shielding bell will be positioned for transportation of the sodium wetted components to the washing plant and the buffer store in the ancillary building. At the bottom of the enclosure a container will be positioned under the double lid lock for transportation of the 200 l drums to the waste facilities at HDB. The shielding bell and the containers are also made of a shielding of 35 cm of steel.

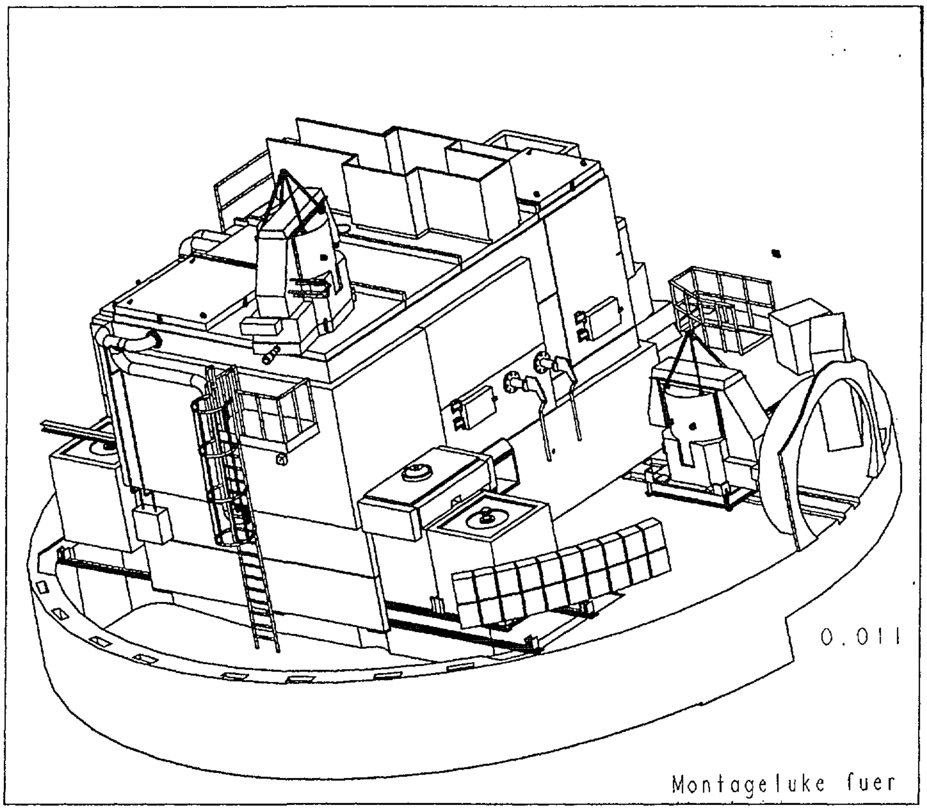

Fig. 4: *Hot cell enclosure*

For the calculation of the shielding it was assumed that a piece of the reflector with maximum Co-60 activation of 3.1 E+7 Bq/g was placed in an unshielded 200 l drum directly behind the shielding wall. For this arrangement the dose rate in the distance of 50 cm of the wall is about 3 μSv/h and in the distance of 2 m about 1 μSv/h. Because all other activation is smaller compared to the activation from the reflector, the shielding of 35 cm is a conservative assumption.

To minimize the exposure dose and for saving dose the radioactive components will not be moved to the HDB in larger sections. All cuts must be made so that the parts can be packaged in 150 l drums or baskets. In disassembly, special attention must be paid to the cladding tube plate with the stellite bushings and to the double-walled pipe joints cut out of the reactor vessel. The number of packages produced is to be optimized in order to save cost of interim storage and final storage.

For cutting the components to the right dimensions, a manipulator is to be inserted into the reactor vessel. It can be positioned in a variety of locations and will achieve self-bracing at the level of the cutting position. The manipulator must be designed so that it can handle, by means of a carrier system, all tools needed to disassemble all internals and the vessel proper. The necessary support systems and devices/auxiliary tools are to be harmonized and, as a consequence, minimized in number.

The table below provides data about the geometry, mass, and activity of components:

Component	**Height** (mm)	**Thickness/ diameter** (mm)	**Mass** (Mg)	**Max. Co-60 activation on Jan. 1, 2001** (Bq/g)
Reflector	2310	70-170	11.8	3.1 E+7
Thermal shield	2310	80	7.8	4.8 E+6
Thermal shock liner	6500	12	3.8	4.2 E+6
Other internals	-	-	2.8	1.2 E+9
Internal vessel	10500	16	11.8	4.0 E+6
External vessel	9500	12	4.8	2.2 E+6
		Total	**42.8**	

As a rule, the activation was calculated on the basis of a cobalt content of the steel of 200 ppm.

HANDLING THE WASTE

By dismantling the reactor vessel, approximate 43 Mg of steel with a total Co-60 activity of 1.7 E+14 Bq are accrued. The packages to be used for nearly all metal components are 150 l drums or, for components wetted with sodium, the corresponding 150 l baskets, which will be transported to the washing plant in a shielding bell to be cleared of sodium. The 150 l drums or baskets are packed into 200 l drums through a double-lid system and placed in shielded casks for the transport to HDB. The shielded casks for transport have the same calculation for shielding as the hot cell enclosure.

At HDB the 200 l drums are unloaded from the cask, then opened and cemented with concrete. After that they will be measured and declared in accordance with the final disposal requirements.

The drums will be stored unshielded in an intermediate level waste storage facility. After some decay of cobalt and packaging the drums into special containers, it will fullfill the KONRAD repository requirements.