CONCEPT FOR DISMANTLING THE REACTOR VESSEL AND THE BIOLOGICAL SHIELD OF THE COMPACT SODIUM-COOLED NUCLEAR REACTOR FACILITY (KNK)

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ABSTRACT

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.

Under the decommissioning concept, the plant is to be decommissioned completely to green field conditions at the end of 2005 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 late 2001. Under the 9th Decommissioning Permit, the reactor vessel with its internals, the primary shield, and the biological shield are to be dismantled.

The residual sodium volume in the reactor vessel was estimated to amount to approx. 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.

The difficulty involved especially in dismantling KNK, on the one hand, is posed by the residual sodium in the plant, which determines the choice of neither wet nor thermical techniques to be used in disassembly. 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.

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.

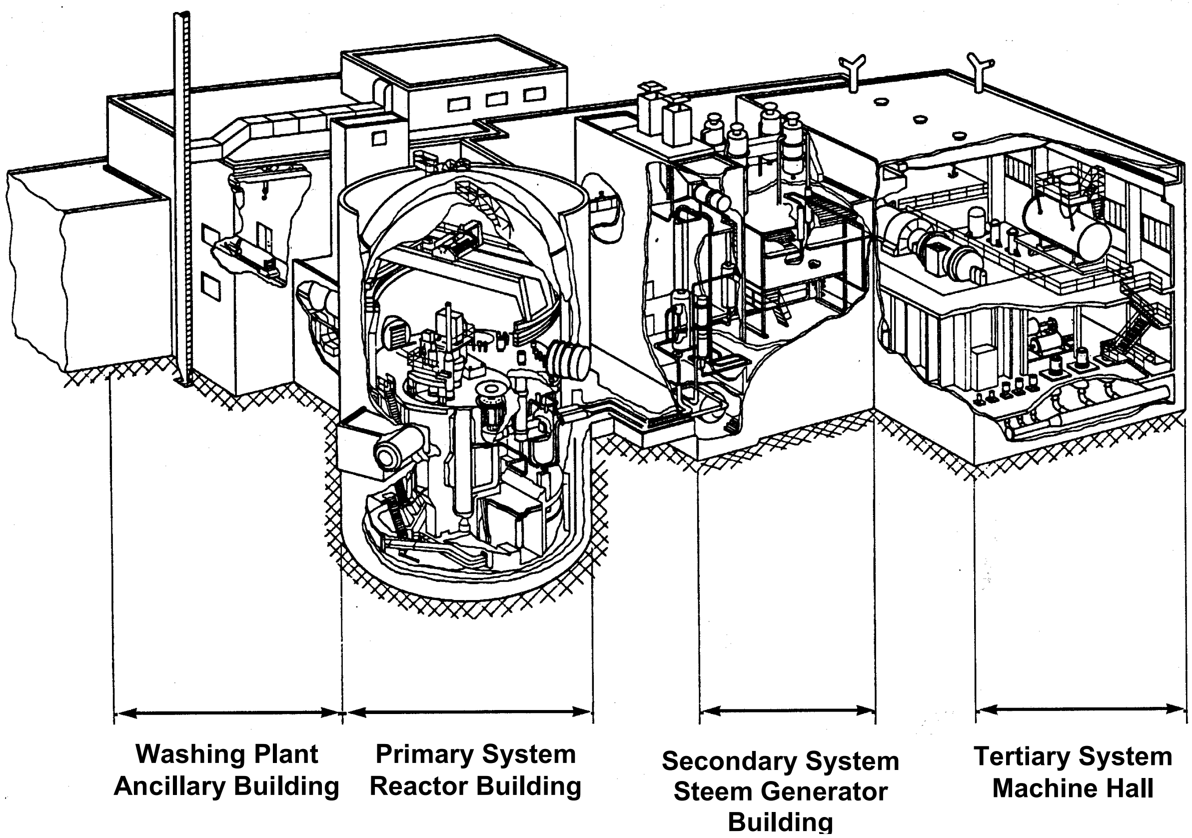

Fig.1: KNK systems and buildings

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 and 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 Department (HDB) of the Karlsruhe Research Center, which processes them in line with its permit under the Atomic Energy Act, and holds them in temporary storage.

Under the 9th Decommissioning Permit, the reactor vessel with its internals, the primary shield, and the biological shield are to be dismantled. A Europeanwide 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 late 2001.

The 9th Decommissioning Permit covering disassembly of the reactor vessel and the biological shield was filed for 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 2001 and mid-2002 has been reserved for planning and preparing disassembly of the reactor vessel. From September 2002 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 safety report on which the application for the 10th Decommissioning Permit is based is being completed and was submitted to the authority in June 2001. The work is to be finished probably at the end of 2005.

DISMANTLING THE REACTOR VESSEL AND THE BIOLOGICAL SHIELD

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. 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 reactor building and the ancillary plants building are part of the controlled area.

The residual sodium volume in the reactor vessel was estimated to amount to approx. 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.

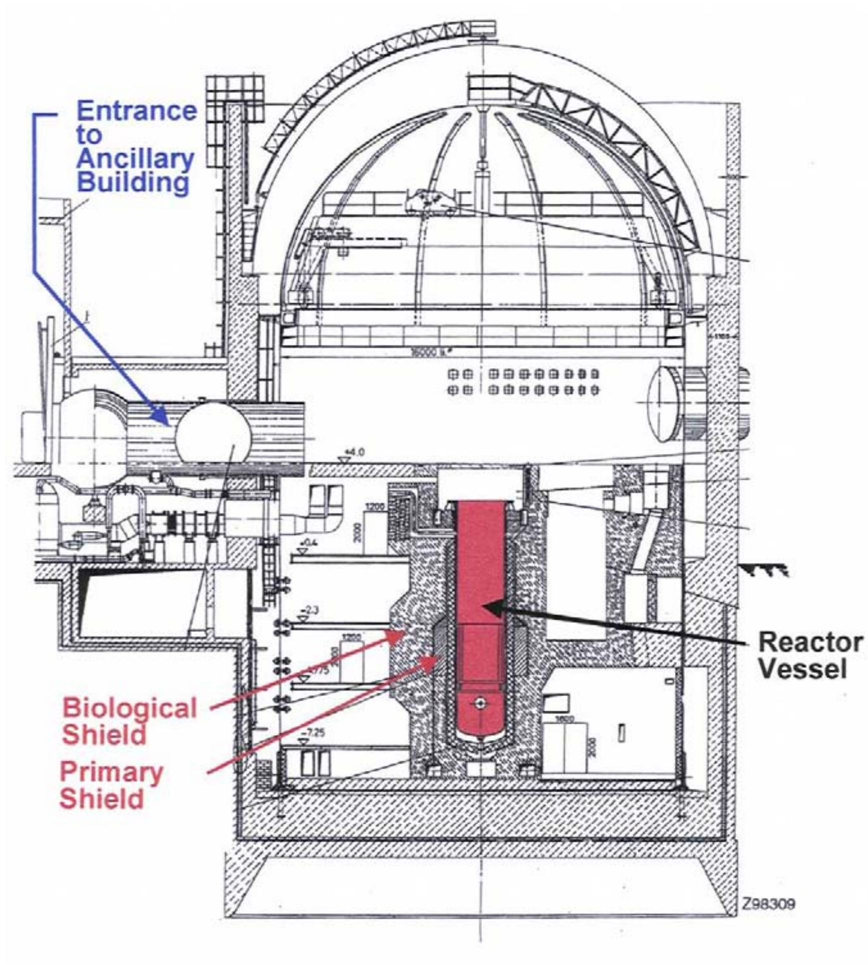

Fig. 2: Cross section through the KNK containment after completion of the 8th Decommissioning Permit

Demolition Concept

Before dismantling of the reactor vessel is begun, the interior space of the vessel is treated with a wet gas. For this purpose, the nitrogen is added humidity so that any particulate sodium deposits can be immobilized. Then the vessel is dried. The dismantling work of possibly sodium covered components is to be carried out under a nitrogen atmosphere.

The reactor vessel with its internals, and the primary shield, are to be disassembled within the existing shielding, i.e. the biological shield. For this purpose, a shielding enclosure will be erected at runway level above the reactor vessel, which 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). The enclosure must have a shielding of 35 cm of steel required for radiological reasons, on the one hand, and ensure separation from the containment in terms of ventilation, on the other hand.

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. Abrasive cutting and thermal cutting techniques may be used only with components free from sodium, such as the primary shield, or the reinforcement in the biological shield. The machines required for dismantling are to be mounted on a carrier which can be positioned variably inside the vessel and the biological shield, respectively. The necessary support systems and devices/auxiliary tools are to be harmonized and, as a consequence, minimized in number.

To minimize the exposure dose to the personnel disassembling these systems, and to minimize the number of transports, the radioactive components to be demolished will not be moved to HDB in larger sections. 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 packed in 200 l drums through a double-lid system and placed in shielded casks for transport to HDB. The components wetted with sodium must be transported first to the washing plant in a shielding bell to be cleared of sodium before they can be packed in 200 l drums. Shielded type-II KONRAD containers will be used for the concrete rubbish. The number of packages produced is to be optimized in order to save costs of interim storage and final storage.

Disassembly of the Reactor Vessel

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

Table I. Data on the geometry, mass, and activity of components.

Component	**Height (mm)**	**Thickness/ diameter (mm)**	**Mass (Mg)**	**Max. 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. The stellite bushings of the cladding tube plate, have a much more high cobalt content, so they show a maximum activation of 10^9 Bq/g.

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. The design of the reactor vessel can be seen from Fig. 3.

A central mast manipulator is to be introduced into the reactor vessel for disassembly purposes; 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. 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.

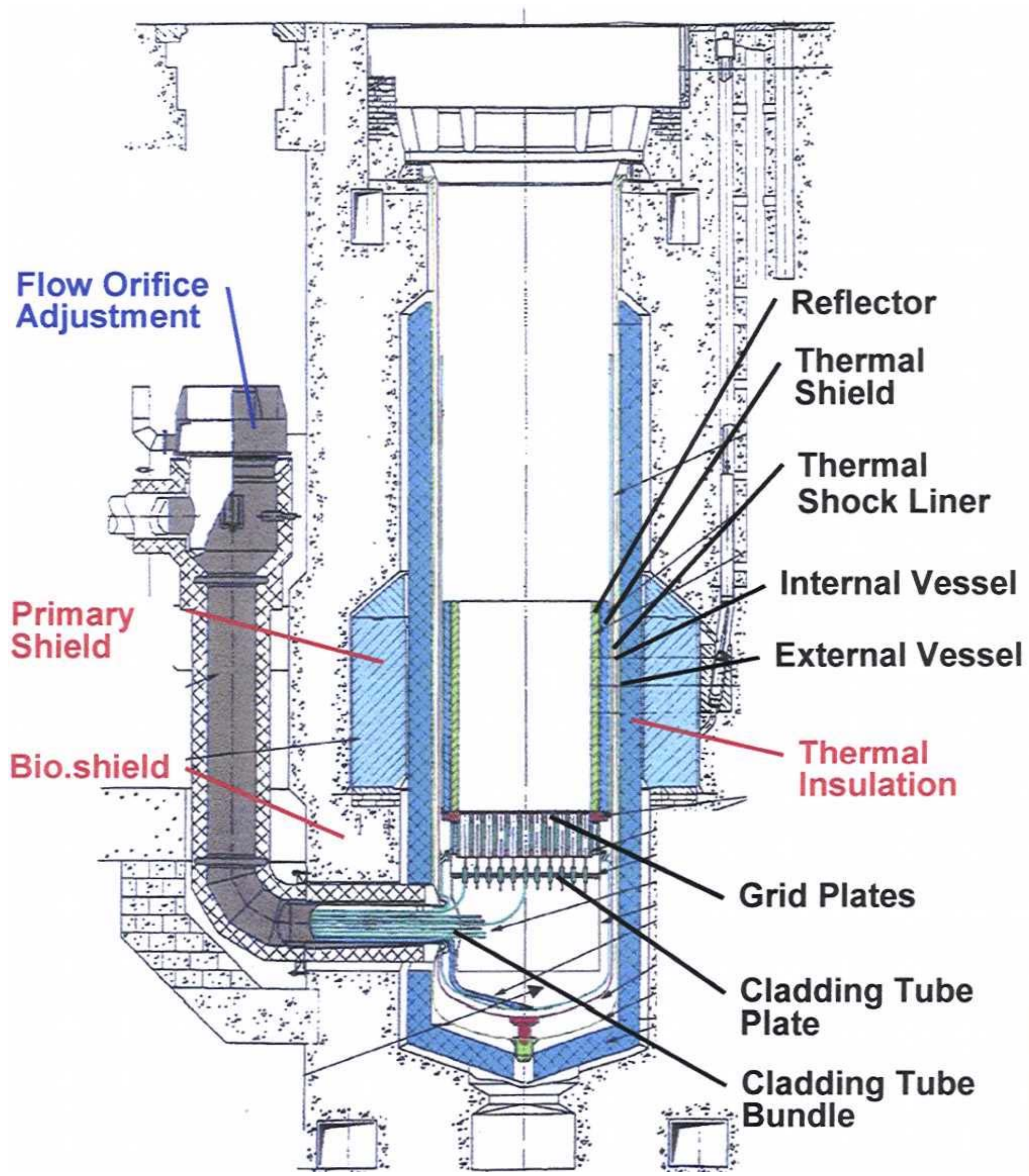

Fig. 3: Reactor vessel with internals

After disassembly of the metal components, the thermal insulation made of fireclay around the reactor vessel must be removed. This can be achieved either by cutting, as mentioned above, or by chipping, as in the later demolition of the biological shield.

Disassembly of the Primary Shield

At the level of the reactor core, the primary shield made of cast iron with lamellar graphite, GG-20, is situated in a niche of the biological shield outside the thermal insulation (see Fig. 3).

The total mass of the primary shield is approx. 90.5 Mg. Of this, 9.2 Mg is due to the conical part, whose four segments are approximately equal in weight. The triangular segments of the cylindrical section each have a mass of approx. 3.7 Mg, while the square ones have a mass of approx. 16.6 Mg. The maximum activation is 1.55×10^6 Bq/g.

Perhaps it will be necessary, prior to demolition of the primary shield, to remove parts of the biological shield above the primary shield as far as the outside diameter of the primary shield. This makes the primary shield freely accessible from the top and from the inside.

The primary shield is demolished by remote operation from the enclosure. The planning is to install a platform below the primary shield in the reactor cavity on which parts of the primary shield can be deposited. The parts of the primary shield are then disassembled by means of a saw which can be carried by the crane; it is applied to the component, braced, and thus allows horizontal and vertical cutting.

The parts cut off are attached to the crane by means of force-locking mechanical grabs, and are lifted to the runway level. The parts are filled into 200 l drums through the double-lid lock, and are then taken to HDB in shielded shipping casks.

Disassembly of the Biological Shield

The reactor core is surrounded by a block of concrete of very high density (density 4.14 g/cm^3), the biological shield, which was also activated by the neutron radiation emanating from the reactor core (see Fig. 3). The specific Co-60 activity of the concrete achieves a maximum of 8×10^5 Bq/g, which means that most of the disassembly work must be carried out remotely.

The depth of demolition of the biological shield is determined by the depth of activation of the concrete. According to the new German Radiation Protection Ordinance, a clearance level for Co-60 of 0.09 Bq/g must be observed for the unrestricted clearance of building rubbish. Probably, a total of 330 Mg of very-high-density concrete must be disposed of as radioactive waste.

Chipping will be the method of demolition (Fig. 4). For this purpose, an auxiliary platform variable in height is to be positioned in the reactor cavity, on which a small excavator will be placed. The concrete rubbish is to be sucked through a hose right into the type-II KONRAD container set up at the building rubbish transfer lock of the containment.

The reinforcement bars in the concrete must be cut mechanically or thermally at the same time and disposed of in 200 l drums through the double-lid lock.

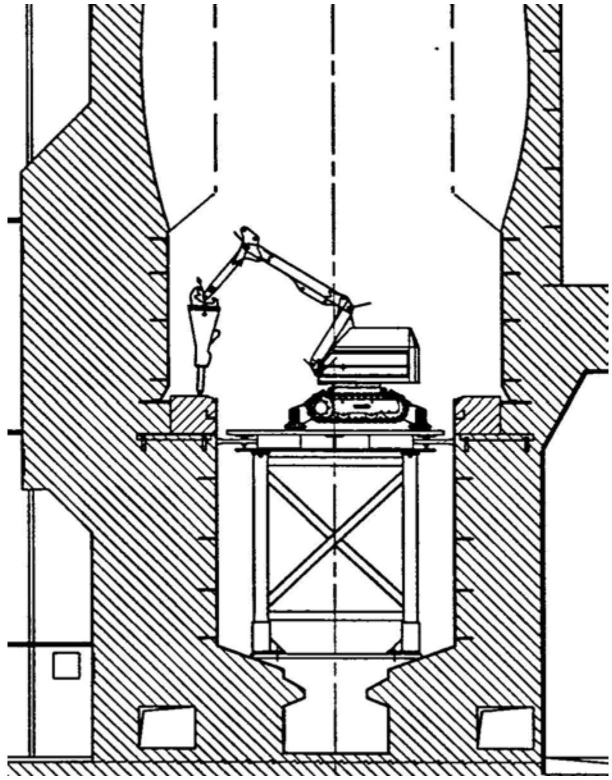

Fig. 4: Demolition of the biological shield

BALANCE OF THE RADIOACTIVE WASTE

Table II. Data on the geometry, mass, and activity of residues.

Type of residue	Mass (Mg)	Max. activation on Jan. 1, 2001 (Bq/g)	Total activity Co-60 (Bq)
Steel	approx. 43	3 E+07	1,7 E+14
Fireclay	approx. 28	9 E+04	-
Grey cast iron	approx. 90	1 E+06	2,5 E+13
Very-high-density concrete	approx. 330	7 E+05	6,2 E+12

The residues steel and grey cast iron will be packaged into 200 l-drums and stored in the HDB interim storage for ILW-Waste. After some halflifetimes of cobalt and packaging the drums into a shielded container, the waste fullfill the KONRAD repository requirements.

The residues fireclay and concrete will be directly packaged into shielded KONRAD containers and stored in the HDB interim storage for LLW-Waste, ready for final disposal.