Forschungszentrum Karlsruhe

Technik und Umwelt

Wissenschaftliche Berichte

FZKA 6510e

Radiation Exposure of the Personnel During Dismantling and Cutting of the Primary System of the Karlsruhe Multi-purpose Research Reactor (MZFR)

H. Hesse, W. Demant, A. Reichert, F. Willmann

Projekt Stilllegung Mehrzweckforschungsreaktor Karlsruhe

Hauptabteilung Sicherheit

Hauptabteilung Dekontaminationsbetriebe

Forschungszentrum Karlsruhe GmbH, Karlsruhe

2000

Abstract

The heavy water (D_2O) cooled and moderated pressurized water reactor MZFR with a thermal power of 200 MW will be dismantled step-by-step within the framework of sectional decommissioning licenses. The past decommissioning step (6th sectional license) in general covered the removal of the primary systems and of all reactor support systems inside the reactor building.

The measures for radiation protection during dismantling and handling of the large components of the primary system, such as the fuel element loading machine, fuel element transfer system, steam generator and pressurizer shall be pointed out. The measures taken for the reduction of the dose rate during dismantling and cutting of the components for the purpose of conditioning or unrestricted reuse at the Central Decontamination Department (HDB) shall be described.

Chemical decontamination of the primary circuit and its components, which had to be executed in order to reduce the dose rates for subsequent manual dismantling, shall be presented.

The efforts undertaken for the protection of individuals in view of the difficult radiological boundary conditions (high concentrations of tritium in all systems as well as very high alpha contamination) will be explained. Moreover, dose-minimizing measures during cutting of the primary circuit and its components at HDB shall be described by the example of the cutting of a steam generator.

It shall be demonstrated that cutting and dismantling of highly contaminated and activated parts with high dose rates can be executed safely in terms of both the radiation exposure of the personnel and the technical, financial and time expenditure.

Strahlenexposition des Personals während Abbau und Zerlegung des Primärsystems des Mehrzweckforschungsreaktors (MZFR)

Zusammenfassung

Der mit Schwerwasser (D_2O) gekühlte und moderierte Druckwasserreaktor MZFR (200 $MW_{th.}$) wird in mehreren Teilschritten zerlegt und abgebaut. In der zurückliegenden Stilllegungsphase wurden unter anderem die Primärkreisläufe dekontaminiert und abgebaut.

Es wird der prinzipielle Ablauf der Demontagen sowie die Handhabung von Großkomponenten des Primärkreislaufes, wie beispielsweise Dampferzeuger, Brennelementlademaschine und Druckhalter unter Strahlenschutzgesichtspunkten aufgezeigt. Maßnahmen zur Reduktion der Dosisbelastung vor und während der Demontagemaßnahmen sowie bei der Zerlegung der Komponenten zum Zwecke der Konditionierung bzw. Freigabe zur schadlosen Wiederverwertung werden näher erläutert.

Die Maßnahmen zum Personenschutz im Hinblick auf die schwierigen radiologischen Randbedingungen (Tritium sowie sehr hohe Alpha-Kontaminationen) werden beleuchtet. Erläutert werden im weiteren dosisminimierende Maßnahmen bei der manuellen Verarbeitung der Primärkreiskomponenten durch die Hauptabteilung Dekontaminationsbetriebe (HDB) am Beispiel der Zerlegung eines Dampferzeugers

Die Dosisbelastung des Personals während der Demontage und Handhabung am MZFR wird der Dosisbelastung bei der anschließenden Weiterverarbeitung bei HDB gegenübergestellt und diskutiert.

Zusammenfassend wird dargestellt, dass die Demontage und die Zerlegung hochbelasteter Primärkreiskomponenten eines Druckwasserreaktors mit vorausgehenden Dekontaminationsmaßnahmen und entsprechenden Planungsleistungen sowohl hinsichtlich der Strahlenexposition für das Personal, als auch unter technischen, wirtschaftlichen und zeitlichen Randbedingungen sicher durchgeführt werden kann.

LIST OF CONTENT PAGE

1.0 Introduction 5

2.0 Prerequisites for Manual Dismantling of the Primary System 5

2.1 General 5
2.2 Decontamination Methods 5
2.3 Removal of Residual Water of the Components for Later Dismantling 7

3.0 Dismantling of the Primary System under Radiation Protection Aspects 8

3.1 Protection Measures for Preventing Incorporation 8
3.2 Protection Measures for Dose Reduction when Dismantling Components of the Fuel Element Transfer System 10
3.3 Removal and Transportation of the Primary System Components 11
3.3.1 Overview 11
3.3.2 Removal of the Components As Illustrated by the Example of a Steam Generator 12

4.0 Processing of Large Components at HDB as Illustrated by the Example of the Steam Generator 14

4.1 Facilities at HDB 15
4.2 Processing of Steam Generator II 15
4.2.1 Protection Measures for Dose Minimization 15
4.2.2 Conditioning 15

5.0 Radiation Exposure of the Personnel 17

5.1 Radiation Exposure of the Personnel During MZFR Dismantling 17
5.2 Dose Exposure During Conditioning at HDB 18

6.0 Conclusions / Outlook 18

References 19

INDEX OF CHARTS

Chart 1: Chemical Decontamination of Primary Systems and Sub-Systems
General Data

Chart 2: Survey of the Removed Primary System Components

Chart 3: Collective Doses resulting from the Individual Processing Steps at HDB

Chart 4: Comparison of the Planned and actually reached Collective Doses, MZFR

Chart 5: Collective Doses Resulting from the Conditioning of the Large Components at HDB

INDEX OF FIGURES

Fig. 1: Chemical Decontamination of the Primary Systems and Sub-Systems
Principle Flowchart of the AMDA-Cycle

Fig. 2: Principle Representation of the Drilling Device for the Draining of D_2O-contaminated Components

Fig. 3: Schematic Representation of the Steam Generator Removal

Fig. 4: Section of the Equipment Decontamination Plant, HDB

Fig. 5: Dose Rate Profile of the Steam Generator Primary and Secondary Systems
All Data is given in µSv/h

Fig. 6: Collective Dose resulting from the Preparation for Dismantling, Removal and Processing of the Primary Circuit Components (in mSv)

1.0 Introduction

The Multi-purpose Research Reactor (MZFR) was a pressurized water reactor using heavy water as a coolant and moderator. It was constructed from 1961 to 1966 and went critical for the first time on September 29, 1965. After approximately 19 years of successful operation, the reactor was shut down on May 3, 1984. The reactor had a thermal power of 200 MW and an electrical output of 50 MW.

Whereas in the first concept safe enclosure of the plant was envisaged, it was then decided in favor of a step-by-step complete dismantling due to its significant advantages. The entire decommissioning program for achieving green-field conditions is divided into 8 steps. Prior to the approval and granting of sectional licenses by the licensing authority, documents describing all the work to be done have to be prepared for each decommissioning step
During dismantling, about 72000 Mg of concrete and 7200 Mg of metal will have to be disposed of. About 1000 Mg of concrete (600 Mg biological shield) and 1680 Mg of metal will have to be classified as radioactive waste.

2.0 Prerequisites für Manual Dismantling of the Primary System

2.1 General

Prior to the dismantling of plant components under the 6th sectional license for decommissioning, the primary and auxiliary systems (except for the reactor pressure vessel) of the MZFR were subjected to chemical decontamination. Thus, the dose rate at the measurement points selected on the primary system components to be dismantled could be reduced by a factor of 15 on an average. Chemical decontamination allowed the later dismantling work on the primary system to be carried out manually.

2.2 Decontamination Methods

Decontamination of the systems took about five months. The "automatic mobile decontamination facility" (AMDA) and the decontamination method "CORD/UV®" (chemical oxidation reduction decontamination) developed by Siemens AG / KWU were applied.
The CORD/UV® method represents a multi-cyclic "soft" decontamination method. The concentration of chemicals does not exceed 2000 mg/kg. The treatment temperature is ≤ 95 °C. The corrosion products dissolved in the process and the activity are bound on spherical ion-exchange resins during decontamination already.

A CORD/UV® cycle consists of several interlinked steps that are performed with a single filling of demineralized water only. The following major process steps are distinguished:

- **Preliminary oxidation**
  By using a diluted permanganic acid solution ($HMnO_4$), chromium(III) existing in the oxide layer is oxidized to readily soluble chromate(IV).
- **Reduction**
  During reduction, the chromate generated and the excessive $HMnO_4$ from preliminary oxidation are reduced with a stoichiometric volume of oxalic acid.
- **Decontamination**
  During the decontamination step, the oxide layers existing on the surfaces are dissolved and the metal ions are kept in solution as complexes. The corrosion products and the dissolved activity are continuously fixed on ion-exchange resins.
- **Decomposition**

The chemicals used are decomposed completely into CO_2 and water by photocatalytic wet oxidation. In parallel, cleaning by means of ion exchangers is continued.

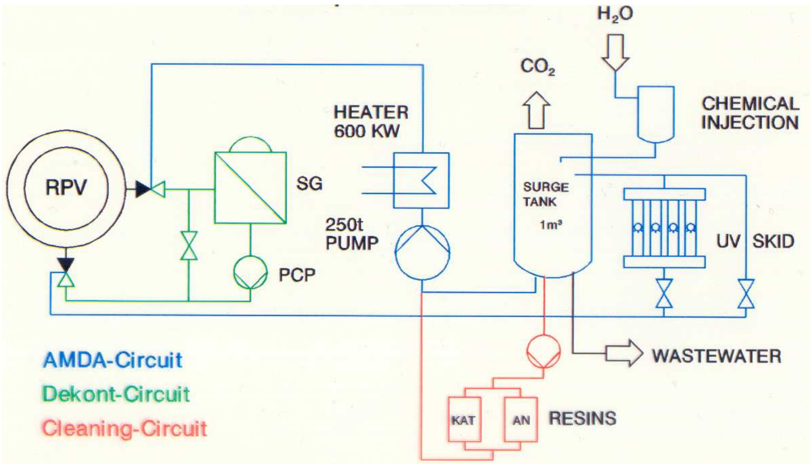


Fig. 1: Chemical Decontamination fo the Primary Systems and Sub-Systems Principle Flowchart of the AMDA-Cycle

The advantages of this procedure included:

- Constant regeneration of the decontamination solution.
- Permanent supply of fresh solution to the surfaces to be decontaminated.
- Recontamination is excluded by permanent cleaning.

The technical data of the chemical decontamination of the MZFR primary system are given below:

– Waste Volumes	
• Resins	3 m^3
• H_2O	100 m^3
• Removed Metal from Inner Surfaces	72 kg
– Decontaminated Surfaces	4000 m^2
– Decontaminated Mass	400 Mg
– Removed Activity (Cation Discharge)	1.7 E+12 Bq
– Average Decontamination Factor	15
– Collective Dose Rate	130 mSv

Chart 1: Chemical Decontamination of Primary Systems and Sub-Systems General data

2.3 Removal of Residual Water of the Components for Later Dismantling

A major prerequisite for dismantling the components of the primary circuit in terms of personnel radiation protection and removal progress was the removal of D_2O-containing residual water. Therefore, a system had to be developed for the draining of system components and pipelines without tritium being released into the ambient air of the surrounding areas.

The so-called "IFM-drilling device" designed for this purpose allowed to draw off the D_2O leakage water arising under directed flow conditions. The leakage water was then collected in a movable draining unit (TEWE). The TEWE is a tested and approved pressure vessel, which is installed on a running gear and equipped with all necessary devices (level meter, pressure meter, and shut-off valves) (cf. Fig. 2).
Using this method, all components were checked for D_2O-containing residual waters. After this, they were connected to a leak-tested drying system prior to their delivery to the Central Decontamination Department (HDB).

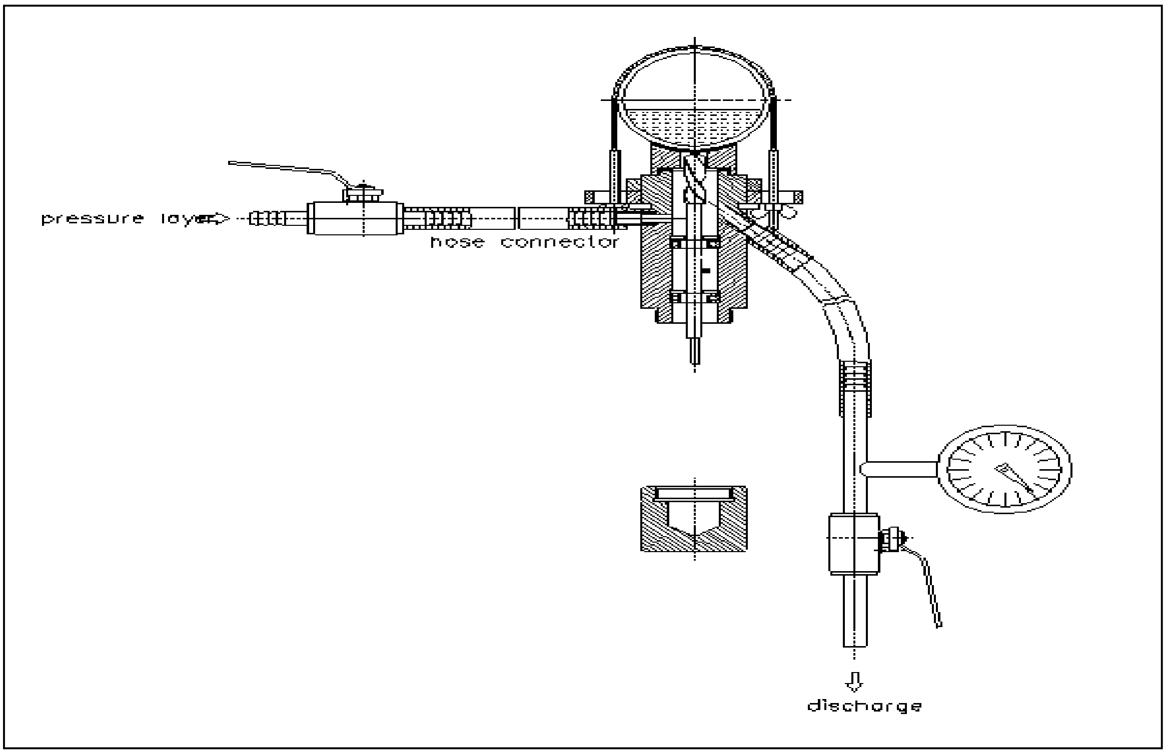


Fig. 2: Principle Representation of the Drilling Device for the Draining of D_2O-contaminated Components

3.0 Dismantling of the Primary System under Radiation Protection Aspects

3.1 Protection Measures for Preventing Incorporation

During reactor operation and in particular in heavy water-moderated nuclear power plants, tritium (mainly as DTO) is generated by the activation of the coolant. With an increasing operation time, the tritium activity rises as well. It approaches an equilibrium state which mainly depends on the extent of water exchange in the cooling circuits.
Intake of tritium in the form of steam does not only take place by inhalation, but also via the pores of the skin (about 50%). Hence, personnel protection measures are of crucial importance when handling this nuclide. Depending on the tritium concentration prevailing, a reliable protection as regards inhalation and skin resorption is only ensured by wearing a protective suit with an integrated breathing system.

In the MZFR, ambient air is subjected to routine monitoring via several fixed measurements stations. While dismantling the previously D_2O-bearing systems, additional mobile measurement stations, i.e. direct-reading devices with flow-type proportional counters, are applied. Their detection sensitivity is about 4 E+04 Bq/m³ H-3.

At the MZFR, incorporation monitoring is generally accomplished in accordance with the "regulation of physical radiation protection monitoring to determine the body dose" and the "regulation for determining the body dose in case of internal radiation exposure".
According to these regulations, regular incorporation monitoring is required, if more than one tenth of the annual intake limits given in the Radiation Protection Ordinance, Annex IV, Table IV.1, may be incorporated in one calendar year. As far as the MZFR dismantling activities were concerned, this could be excluded neither for the tritium nuclide nor for the group of transuranium nuclides. Hence, incorporation monitoring was arranged to be performed on the basis of excretion analyses and ambient air monitoring.

In accordance with the "regulation of physical radiation protection monitoring to determine the body dose," one urine test per month is required for incorporation monitoring with regard to tritium. Regular incorporation monitoring is necessary, if the mean tritium activity concentration of the ambient air at the working place exceeds 1 E+05 Bq/m^3.

Contamination measurements on dismantled pipelines and components of the primary system yielded an α contamination of some 10^2 - 10^3 Bq/cm^2.
According to the valid regulation, incorporation monitoring with regard to transuranium nuclides requires a regular control of the activity concentration in the ambient air at the working place as well as a determination of the activity in the excretions every six months. Regular incorporation monitoring is required, if the mean annual artificial α activity concentration of the ambient air at the working place exceeds 4.2 mBq/m^3.
The activity concentration of transuranium elements is measured at each working place using stationary air dust collectors. Based on the values measured, the mean monthly activity intake of the personnel working there is estimated as a function of the daily working time.

One of the requirements made by the radiation protection staff was to wear protective suits with integrated breathing systems when dismantling the previously D_2O-bearing systems. This also ensured full personnel protection with regard to the group of transuranium nuclides. For this reason, incorporation over the entire duration of the dismantling work resulted in a very small effective dose for the personnel.

3.2 Protection Measures for Dose Reduction when Dismantling Components of the Fuel Element Transfer System

Prior to the dismantling of the transfer system components, such as the winch, shut-off valve, and box of the tilting device, extensive dose rate measurements were undertaken. A maximum value of 500 mSv/h was measured at the winch. This high dose rate necessitated the remote dismantling of the winch in the first instance, followed by the dismantling of the shut-off valve and the box. Extensive preparatory work was necessary, i.e. positioning of a mobile shielding unit and a manipulator, installation of a lifting device, and erection of a tent around the dismantling area, which was kept under depression by a ventilation system.

Before two cuts were done remotely to allow the removal of the winch, holes were drilled into the transfer tube and the cutting region was filled with foam to fix the contamination inside the tube.

Further dose rate measurements showed a hot spot of 850 mSv/h at the spindle housing of the shut-off valve. For further dismantling work, lead shielding had to be applied to reduce the dose rate in the working area.

As a result of shielding, the dose rates were reduced to a level which allowed the dismantling of the shut-off valve and the box of the tilting device to be done hands-on.

In parallel, another point-like emitter of 355 mSv/h at the lower part of the tilting device had to be shielded in the area of the bottom slide in order to be able to perform the necessary dismantling work. After removing the tilting device from the housing, the shielding container was fixed to the lower part of the tilting device which was then transferred to HDB for further processing.

3.3 Removal and Transportation of the Primary System Components

3.3.1 Overview

Upon removal of the connected pipeline systems, all components were dismantled, the openings were sealed, and components of more than 6 m in length (except for the accumulator) were removed from the plant area as a whole. In accordance with the transport regulations of the Karlsruhe Research Center, the components were transported to the HDB for further processing (cf. Sec. 4).

This procedure was considered necessary and advantageous for the following reasons:

- On-the-spot dismantling in the MZFR would have been very difficult due to technical reasons and the space available. This would have resulted in the prolongation of the project by at least another year and costs incurred of at least 5 million DM.
- Following the removal and transportation of the components to the HDB, the ambient dose rate was reduced in the plant areas. This allowed further dismantling work to be performed in the MZFR at a reduced radiation exposure.
- HDB possesses special facilities for efficient dismantling at a low collective dose.

A survey of the primary system components that have been transported to HDB as a whole is given below.

Number	Component	Dimension [m]	Mass [Mg]
2	Steam generators	∅ 2.5 x 10.4	55
2	Main coolant pumps	∅ 1.2 x 3.9	12.6
2	Moderator coolers	∅ 1.0 x 9.2	17
1	Loading machine	∅ 0.4 x 8.0	25
1	Transfer machine	∅ 0.65 x 2.7	1.2
1	Tilting device	∅ 0.2 x 7.0	22
2	Moderator pumps	∅ 0.7 x 2.1	1.2
1	Accumulator	∅ 1.6 x 11.5	20

Chart 2: Survey of the Removed Primary System Components

The mass of the entire primary system amounts to about 600 Mg in total. Removal of this mass resulted in a collective dose of about 210 mSv. About 400 Mg of the total mass was subjected to prior chemical decontamination. The resultant collective dose amounted to about 130 mSv. The large components with a mass of about 230 Mg were subjected to processing and conditioning at the HDB. Up to now, the resultant collective dose has reached about 180 mSv. The pipelines make up about 370 Mg of the total mass.

The costs arising are as follows:

Chemical decontamination primary system (planning / performance):	about	5,400 TDM
Management and disposal of the materials at HDB:	about	26,000 TDM
Removal of the primary system (planning and performance):	about	5,800 TDM
Management and disposal of the materials at HDB (until end of 98):	about	12,000 TDM

3.3.2 Removal of the Components As Illustrated by the Example of a Steam Generator

According to the activity plan, the steam generator was disconnected first. All connecting pipelines and nozzles were dismantled. The then open nozzles were sealed using conventional sealing plugs and subjected to a leakage test. Some plugs were provided with units for the later connection of draining or drying systems.

For transportation within the building, a platform for heavy loads was constructed on the 0 m level. In addition, a rail system was installed. Upon the completion of this reconstruction work, a tilting and prism wagon was put on the rails for transportation of the large components.

At first, the earthquake supports at the top and bottom of the steam generator were dismantled. The 110 Mg polar crane with a specially designed traverse was positioned above the steam generator and attached to the posts of the steam generator. The traverse was prestressed, the supports at the bottom of the steam generator were removed, and the screw connections were disconnected and partially dismantled. The steam generator was moved above the assembly lock. By lowering the crane and simultaneous moving of the tilting wagon, the steam generator was tilted into horizontal position and laid down on the prism wagon (cf. Fig. 3).

Upon draining, drying, and decontamination, the lock was opened on both sides. The trailer with the platform was moved below the load. The component was put down, enclosed by a foil, and fixed on the platform of the trailer. Upon clearance by the radiation protection staff, the steam generator was transferred to HDB as a "special transport".

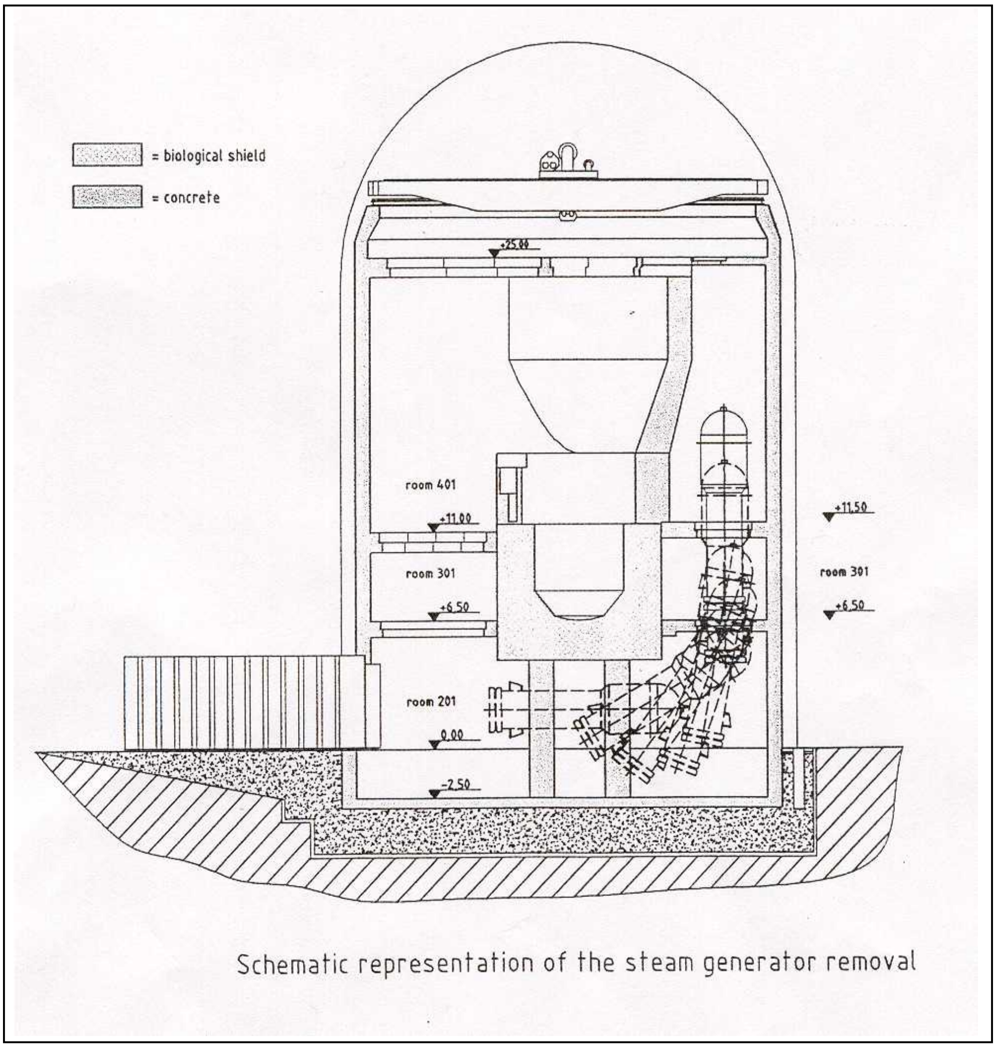


Fig. 3: Schematic Representation of the Steam Generator Removal

4.0 Processing of Large Components at HDB as Illustrated by the Example of the Steam Generator

By making use of the experience gained from the prior processing of other large MZFR components and in particular of steam generator I, the personnel dose accumulated during the treatment of steam generator II could be kept comparatively small.

4.1 Facilities at HDB

All large components of the MZFR have been subjected to further processing at the HDB "equipment decontamination facility" or at the "LAW scrapping plant". The equipments available in these plants, i.e. the saw for large components, the dismantling caisson, the sandblasting caisson, the decontamination caisson, or the press (cf. Fig. 4), allow complete conditioning under the same roof in nearly all cases.
The conditioning stations are arranged such that the internal transportation paths are very short and contact of the personnel with the waste is minimized.

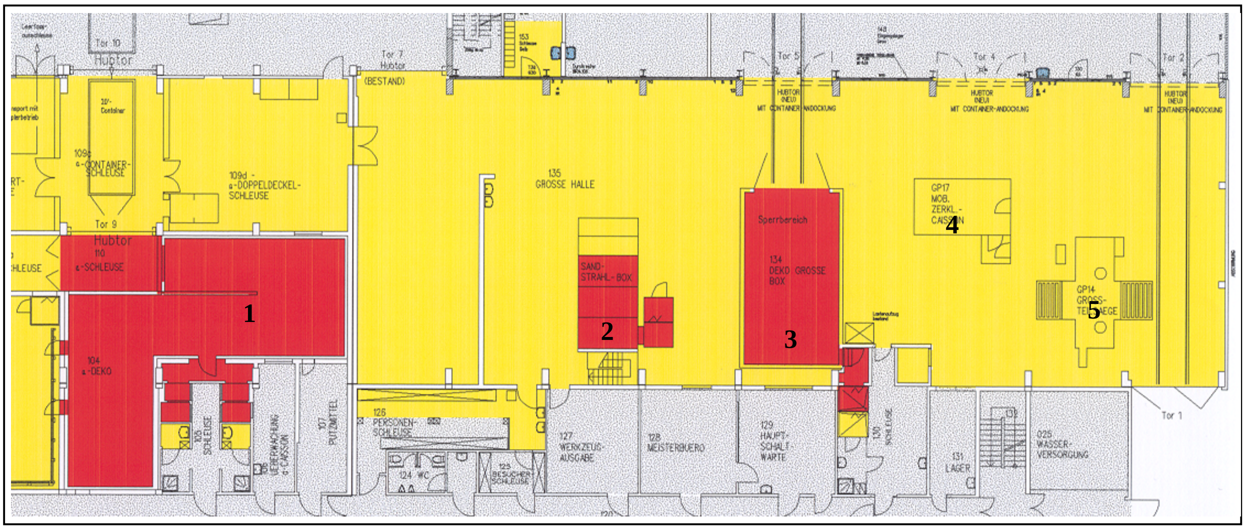


Fig. 4: Section of the Equipment Decontamination Plant, HDB:

1 / 3: Processing caissons for highly contaminated wastes
2: Sandblasting caisson
4: Cutting caisson
5: Saw for large components

4.2 Processing of Steam Generator II

The steam generator II was transferred to HDB. Its surface dose rate profile is represented in Fig. 5.

4.2.1 Protection Measures for Dose Minimization

- Shielding: For the protection of the surroundings and the personnel, the entire component was surrounded by a shielding structure of 60 mm sheet steel. The shielding structure consisted of 6 segments with the window required for conditioning being opened exclusively.
- Decontamination: Prior to conditioning, the tube bundle of the primary system was decontaminated in an acid circuit. As the steam generator was conditioned separately, the acid solution applied by HDB was much stronger than that of MZFR (see Sec. 2.2). A mean decontamination factor of 3 was reached.
- Remote-controlled conditioning: Dismantling of the steam generator tube bundle was largely done in a remote-controlled manner. Both the cutting of the pipes as well as the movements of the entire steam generator primary system in the conditioning caisson were performed automatically.

4.2.2 Conditioning

- **Primary system:** During conditioning and, hence, while opening the steam generator primary system, high contaminations were encountered in addition to the high dose rate (dose rate profile, cf. Fig. 5). For this reason, this work was performed under full protection with external air supply in a conditioning caisson. The tube bundle was cut in a largely automated manner along the tube guiding units. As a consequence, personnel had to be present only for setting the cutting tool and removing the cut-off tubes. The tool was carried by a shielding structure which covered the tube bundle and the flange base.
- **Secondary system:** The secondary system was subjected to thermal dismantling in a tent especially constructed for this purpose in the equipment decontamination area. To prevent incorporation, protective suits and breathing masks with external air supply had to be worn. During conditioning, the entire component was packaged, as described above. Upon the dismantling of the roof section, the remaining part was separated in two half shells, but left on the tube bundle for shielding purposes at first. The half shells were lifted off directly before the transport of the steam generator primary system to the conditioning caisson.

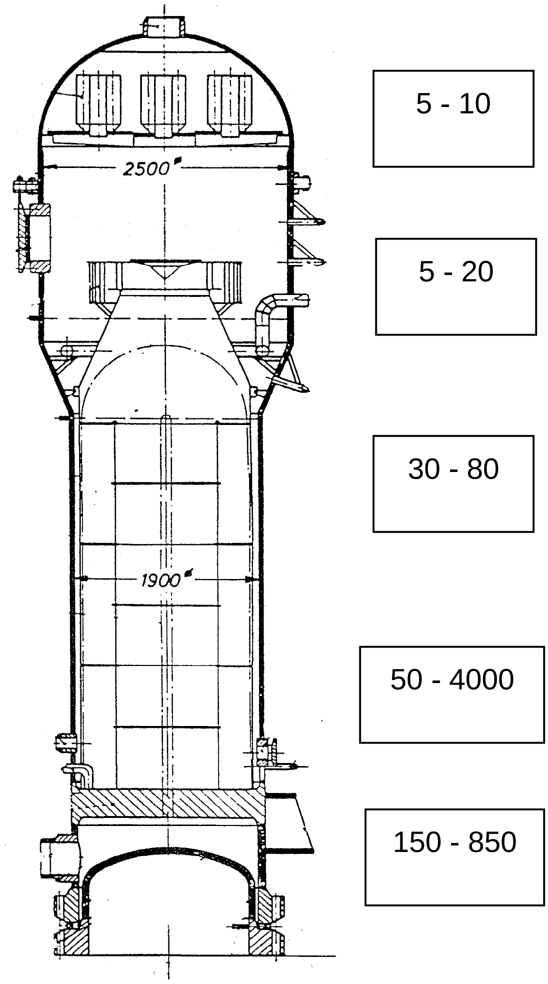


Fig. 5: Dose Rate Profile of the Steam Generator Primary and Secondary Systems All Data is given in µSv/h

The collective dose resulting from the individual processing steps is as follows:

Working step	Collective dose
Decontamination circuit	2.0 mSv
Dismantling of the secondary system of the steam generator	1.6 mSv
Transportation within the building	2.0 mSv
Dismantling of the primary system of the steam generator	68.2 mSv
Total	**73.8 mSv**

Chart 3: Collective Doses resulting from the Individual Processing Steps at HDB

The doses resulting from incorporation can be neglected.

5.0 Radiation Exposure of the Personnel

5.1 Radiation Exposure of the Personnel During MZFR Dismantling

The information given below refers to the decommissioning activities performed in the reactor building under the 6th sectional license for decommissioning. Here, the major proportion of the dose was accumulated.

All decommissioning activities in the MZFR are performed within the framework of activity plans. These activity plans are checked in advance by an expert and, subsequently, approved by the licensing authority. Decommissioning activities have to comply with the personnel collective dose limits given in the ICRP-60 recommendation. As an additional requirement for all decommissioning activities in the MZFR, a personnel dose of 10 mSv/a and person was not to be exceeded, except for well-founded individual cases, where the dose may be exceeded by a factor of 2.

Radiologically relevant dismantling work under the 6th sectional license for decommissioning was performed within the framework of the activity plans 706, 707, and 709. These activity plans comprise the following activities:

AP 706: Dismantling or partial dismantling and removal of components of various systems, e.g. element monitoring, cooling and cleaning system of the loading machine, main cooling and moderator circuits, storage and volume control systems.

AP 707: Dismantling work in the reactor and pool building, in particular dismantling of fuel element handling systems, e.g. fuel element loading machine, transfer machine, fuel element lock, and pertinent pipings.

AP 709: Dismantling of various systems, such as the primary cooling circuits, moderator circuits, and accumulator system, including pertinent large components, such as the steam generator, moderator cooler, and accumulator.

The collective doses actually reached when performing the work were far below the planned dose values (cf. chart 4):

Activity plan	Number of persons	Planned dose [mSv]	Dose reached [mSv]
AP 706	39	200	25
AP 707	35	146	36
AP 709	82	585	124
Σ		**931**	**185**

Chart 4: Comparison of the Planned and Actually Reached Collective Doses, MZFR

Hence, the actually reached collective dose corresponds to about 20% of the value planned. For all activities performed within the framework of the 6th sectional license for decommissioning from April 1997 to December 1998, the personnel was exposed to a collective dose of about 209 mSv.

5.2 Dose Exposure During Conditioning at HDB

So far, conditioning of the large components listed in chart 5 resulted in a collective dose of about 180 mSv. Here, the non-official doses measured (measured by electronic dosemeters) were used as a basis.

Most of the collective dose resulted from the conditioning of the steam generators (167 mSv). The maximum personnel dose of the staff in charge of conditioning amounted to 12 mSv/a.

Components	**Collective dose [mSv]**
Steam generator I	93.5
Steam generator II	73.8
Moderator coolers	4.7
Accumulator	0.4
Loading machine	3.7
Tilting device	0.3
Main coolant pumps	1.7
Transfer system	2.1

Chart 5: Collective doses resulting from the conditioning of the large components at HDB

6.0 Conclusions/Outlook

It is obvious from the above description of the dismantling of the MZFR primary system that the following aspects have to be taken into account when evaluating the radiation exposure to be expected for the personnel during dismantling in a shut-down nuclear power plant:

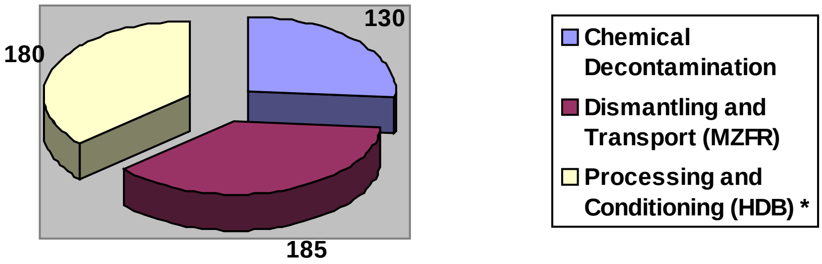
Irrespective of the dismantling method chosen, which strongly depends on the space available, the schedule specified, and the financial boundary conditions, an evaluation of the radiation exposure of the personnel must not only be based on the preparatory working steps and the dismantling work as such. The statements made above show that further processing or conditioning of the dismantled components considerably contributes to the total radiation exposure of the personnel.

The requirement of the personnel exposure of 10 mSv per year and person made for the MZFR was observed reliably. For two persons, a maximum personnel dose of 12 mSv/a was measured.

The limit values of currently 50 mSv/a and person given in the Radiation Protection Ordinance and valid for the HDB were complied with. Also here, the maximum personnel dose was found to be about 12 mSv/a for two persons.

Incorporation over the entire period of dismantling and conditioning work resulted in a small effective dose of the personnel working at the MZFR and the HDB.

Less than 2% and 0.0% of the emission limits approved for the MZFR were reached for tritium and aerosols, respectively. The emissions measured at the HDB were also far below the approved limits.



* Here, it is referred to personnel dose-relevant processing, the remaining processing is done remotely.

Fig. 6: Collective dose resulting from the preparation for dismantling, removal and processing of the primary circuit components (in mSv)

REFERENCES

1. Dr. Wolski, Hirning, *Chemische Dekontamination von Primär- und Nebensystemen im MZFR Karlsruhe*, Final Report KWU NR-D/1995/031

2. W. Demant, E. Prechtl, Internal Progress Reports on the Multi-Purpose Research Reactor (MZFR) within the Meetings of the Technical Advisory Group, OECD/NEA Co-Operative Program on Decommissioning