CENTRAL DEPARTMENT RESEARCH REACTOR

# Short description

## Decommissioning of the research reactor FRG-1 and dismantling of the research reactor plant and of the hot laboratory and the disassembling of reactor pressure vessel of nuclear ship Otto Hahn

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

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**Purpose of the short description**

With the application documents for the decommissioning of the research reactor FRG-1 and the dismantling of the research reactor system (consisting of the FRG-1 and the remaining parts of the FRG-2) along with the hot laboratory of the Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH and the reactor pressure vessel with shield tank of the nuclear ship Otto Hahn, "a brief, readily understandable description of the installation and its likely effects on the public and the neighbourhood” is to be presented, in accordance with § 3 para. 4 of the Ordinance on the Procedure for Licensing of Installations under § 7 of the Atomic Energy Act (Nuclear Licensing Procedure Ordinance - AtVfV).

All essential aspects of the overall planned measures for the dismantling of the research reactor plant and of the hot laboratory and the reactor pressure vessel with shield tank of the nuclear ship Otto Hahn are summarized in an intelligible form in this brief description. For this purpose, the short description contains:

- Information on the site, the facility and the dismantling project
- A description of the resulting radioactive residual materials as well as information about intended measures for their reduction and safe utilization
- Information on the regular disposal of radioactive residual materials as radioactive waste and its intended treatment and anticipated storage until their final disposal
- The likely effects on the general public and the neighbourhood, as well as information about other environmental impacts of the project
- An overview of the examined alternatives

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**List of Abbreviations**

| | |
|---|---|
| approx. | approximately |
| AtG | Atomic Energy Act |
| AtVfV | Ordinance on the Procedure for Licensing of Installations under § 7 of the Atomic Energy Act (Nuclear Licensing Procedure Ordinance) |
| C-14 | Radionuclide Carbon-14 |
| CAMC | contact arc metal cutting |
| cf. | confer |
| Co-60 | Radionuclide Cobalt-60 |
| Cs-137 | Radionuclide Cesium-137 |
| DIN | German industrial standard |
| e.g. | for example |
| EN | European industrial standard |
| etc. | Et cetera |
| FRG | Research reactor plant Geesthacht |
| FRG-1 | Research reactor Geesthacht – 1 |
| FRG-2 | Research reactor Geesthacht – 2 |
| GKSS | Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH (Company for nuclear energy utilization in shipbuilding and shipping mbH) Today HZG |
| GmbH | Company with limited liability |
| H-3 | Radionuclide Hydrogen-3 (Tritium) |
| HAKONA | Hall for Component Follow-up Examination |
| HL | Hot laboratory |

| | |
|---|---|
| HZG | Helmholtz-Zentrum Geesthacht - Zentrum für Material- und Küstenforschung GmbH<br>(Helmholtz Centre Geesthacht - Centre for Materials and Coastal research) |
| KBR | Brokdorf nuclear power plant |
| KKB | Brunsbüttel nuclear power plant |
| KKK | Krümmel nuclear power plant |
| KKS | Stade nuclear power plant |
| KrWG | Closed Substance Cycle and Waste Management Act |
| Mg | Megagrams – A measurement of 1,000,000 g, formerly metric tons |
| mSv | milliSievert (physical unit of body dose) |
| MW | Megawatt (physical power) |
| para. | Paragraph |
| RDB | Reactor pressure vessel |
| RDB-OH | Reactor pressure vessel with shield tank of the nuclear ship Otto Hahn |
| Sr-90 | Radionuclide Strontium-90 |
| StrlSchV | Radiation Protection Ordinance |
| SZK | Site interim storage Krümmel |
| TBH | Transport supply hall |
| UVP | Environmental impact assessment |
| UVU | Environmental impact study |

**Definitions**

| | |
|---|---|
| Activation | Operation in which a material becomes radioactive by bombardment with neutrons, protons or other particles. |
| Activity | Number of nuclei decaying per second in a radioactive substance. The Becquerel (Bq) is the unit of measurement. |
| Activity retention | Containment of the radioactive inventory. |
| Be-metal block reflector | Beryllium metal block reflector of the FRG-1 served for the reflection and bundling of neutrons to the execution of experiments on material samples. |
| Clearance measurement | Activity measurement, the result of which allows for a decision on the release of the material by comparison with the given exemption levels. |
| Collective dose | Product of the number of persons of the exposed population and the mean dose per person. |
| Controlled area | Area in which persons can receive during a calendar year an effective dose of more than 6 mSv or higher organ doses than 45 mSv for the eye lens or 150 mSv for the skin, hands, forearms, feet and ankles. |
| Decommissioning | The term "decommissioning" refers in the Atomic Energy Act to the measures in the time period between the final termination of operation on the one hand and the beginning of safe enclosure or dismantling of the system or of system parts, on the other hand. |
| Decontamination | Elimination or reduction of contamination. |
| Demolition | In the case of conventional construction, this means the complete or partial destruction and disposal of buildings of all kinds. |

| | |
|---|---|
| Discharge | Surrender of liquid, aerosol-bonded or gasiform radioactive substances from installations and facilities on ways provided for this purpose. |
| Dismantling | Dismantling a nuclear plant includes the removal of structures (buildings, systems, components), which were the subject of the approval for the construction and the operation of the plant pursuant to § 7 para 1 AtG or are to be evaluated accordingly[1]. |
| Dosimeter | Measuring instrument for the determination of the dose and/or dose rate. |
| Exclusion area | Part of the controlled area where the local dose rate may be higher than 3 mSv/h. |
| Exemption levels | Values of activity and specific activity of radioactive substances as specified in Appendix III StrlSchV, under which a release is permissible in accordance with § 29 StrlSchV. |
| Exhaust air | Exhaust air emitted to the environment. |
| Final disposal | Plant for the final storage of radioactive waste, in which radioactive waste is disposed maintenance-free, for a temporally unlimited period and secure. |
| Incident | Sequence of events the occurrence of which pre-vents the continued operation of the installation or the work activities for safety-related reasons and for which the installation has to be designed or for which precautions have to be taken to protect the work activities concerned. |
| Interim storage | Long-term storage of radioactive waste until transportation to the federal final storage. |

[1] Guide to the decommissioning, the safe containment and the removal of systems or system parts according to § 7 Atomic Energy Act, 23. Juni 2016 (BAnz AT 19.072016 B7).

| | |
|---|---|
| Local dose | Dose, which is measured at a given location. |
| Operational waste, radioactive | Radioactive waste, which resulted from the operation of the FRG or the HL or result from the remaining operation. |
| Phasing out | Phasing out is the operation of all supply, safety and auxiliary systems necessary for the decommissioning as well as the operation of the facilities necessary for the dismantling of components, systems and buildings after issue of the decommissioning approval. |
| Primary water | Cooling water which comes in direct contact with the fuel elements. |
| Processing | Dismantling, assortment, collection, temporary storage during the processing and decontamination of radioactive residual substances as well as activity measurements of radioactive residual substances. |
| Radiation protection | The protection of people and the environment against the harmful effects of ionising radiation. |
| Radioactivity | Property of certain substances being able to transform without external influence and thereby emit a characteristic radiation. |
| Research reactor plant | The research reactor plant (FRG) consists of the FRG-1 and the still existing plant components of the FRG-2. |
| Residual material, non-radioactive | Substances, movable objects, systems and system parts resulting during decommissioning and dismantling which are neither contaminated nor activated. |

| | |
|---|---|
| Residual material, radioactive | Substances, movable objects, systems and system parts resulting from the decommissioning and dismantling which are contaminated and/or activated and will be harmlessly recycled or disposed of properly as radioactive waste. |
| Supervised area | Operational area which not belong to the controlled area in which persons can receive during a calendar year an effective dose of more than 1 mSv or higher organ doses than 15 mSv for the eye lens or 50 mSv for the skin, hands, forearms, feet and ankles. |
| System | Summary of components of a technical device that performs independent functions as part of the plant. |
| Treatment | Processing of radioactive wastes to waste products (e.g. by solidifying, embedding, casting or dehydration). |
| Waste, conventional | Non-radioactive substances which will be taken for recovery or disposal under the rules of the law on recycling management. |
| Waste, radioactive | Radioactive substances pursuant to § 2, para. (1) of the Atomic Energy Act, which, according to § 9a of the Atomic Energy Act, are to be disposed of in a regulated manner, except discharges pursuant to § 47 StrlSchV. |
| Wipe test | Examination of surfaces for wipable contamination. |
| Withdrawal | Procedure for the residual dismantling and clearance of buildings with the aim of no longer having to routinely enter cleared areas of the building, in order to avoid renewed contamination of these building areas. |

## 1 Introduction

The research reactor FRG-1 of the Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH (HZG) has been definitively shut down since 28 June 2010, and is in its post-operational phase. The last irradiated fuel elements were transported to the Department of Energy in America on 24 July 2012. The research reactor plant (FRG) and the hot laboratory (HL) have been free of fuel elements since then.

At the HZG site, in direct proximity to the premises of the Geesthacht research complex, there is also a fuel-free reactor pressure vessel with a shield tank of the nuclear ship Otto Hahn (RDB-OH). It was dismantled in June 1981 at the port of Hamburg and was transported to the Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH (GKSS), today HZG, and since then has been stored in a shaft construction (concrete shaft) especially designed for this purpose. This concrete shaft constitutes another operational site along with the Disassembling Hall still to be constructed to disassembling the RDB-OH.

The dismantling of the FRG, the HL and disassembly of the RDB-OH should be performed in the framework of a single, comprehensive decommissioning and dismantling authorisation according to § 7 paragraph 3 Atomic Energy Act (AtG).

The dismantling work of the FRG and the HL is thereby divided into the following three steps:

- Dismantling reactor plant FRG,
- Dismantling HL and
- Residual dismantling overall plant.

Areas of the plant require conversion measures to maintain the necessary functionality for the phasing out. If their conclusion is not prevented or made more difficult by the dismantling of plant components, the dismantling work will start in the respective areas of the plant.
First, setting up the site and the establishment of transport logistics take place, for example, through the installation of transport paths and the construction of auxiliary equipment (e.g. barrel lift).

The disassembling of the RDB-OH is sub-divided into the following steps:

- Erection of the Disassembling Hall,
- Disassembling of RDB-OH and
- Residual disassembly and decontamination of the Disassembling Hall and concrete shaft.

To disassembly the RDB-OH, a building, known as the Disassembling Hall, is built over the concrete shaft and is directly adjacent to the existing Hall for Component Follow-up Examination (HAKONA). The actual disassembly area is connected to the existing concrete shaft. The required infrastructure to disassembly the RDB-OH, e.g. ventilation, the control area access, material lock etc. is arranged around the disassembly area. The concrete cells of the FRG and the HL will be used for optimized geometric and radiological packaging of the RDB-OH waste.

It is intended to remove all plant parts of the FRG, the HL and the disassembly hall of the RDB-OH and if possible to decontaminate and release below exemption levels in accordance with the Radiation Protection Regulation (StrlSchV). Radioactive plant parts, where decontamination is not possible nor appropriate, are assigned to the radioactive waste. Full clearance is intended for the remaining building structures and the plant site, so that they will subsequently be ready for alternative use or conventional demolition.

## 2 Alternatives

In accordance with the Atomic Energy Act, the so-called safe enclosure is valid as an alternative to immediate dismantling. For the research reactor plant and the hot laboratory, this variant was examined by HZG. The safe enclosure was rejected, as very elaborate measures are necessary to reach such a condition in the plant. The FRG itself has no containment, which would be suitable for the creation of a safe enclosure.

Also, the dose rates of the plant components for dismantling are already within a range that allows a manual or remote dismantling, partly with local use of shielding. A remote controlled dismantling is not necessary. Thus, the secure containment would also have no significant advantages over the immediate dismantling with regard to the activity and dose rate reduction due to the radioactive decay.

In addition, the scenario “safe partial enclosure of the empty reactor basin” was reviewed. This scenario was rejected because a structural-physical durability analysis or a stability survey of the reactor pool is not possible for the period of the "safe partial enclosure". This is because the construction of the research reactor plant is partially placed inside the Geest slope.

The RDB-OH, on the other hand, is in a state which virtually corresponded to the safe enclosure after approximately 35 years. As a result of the radioactive decay, the activity and dose rate level decreased in this period. Another comparably major reduction cannot be expected within the next years. The next process step is therefore the disassembling.

As a procedural alternative to store the low and intermediate radioactive waste in the transport preparation hall (TBH), the storage of the low and intermediate radioactive waste inside the FRG and HL was also analysed. However, this scenario was rejected both for logistical and radiological reasons.

# 3 Location

## 3.1 Geographical Situation

The research reactor plant, the hot laboratory and the reactor pressure vessel with shield tank of the nuclear ship Otto Hahn are located on the site of the Helmholtz Zentrum Geesthacht Zentrum für Material- und Küstenforschung GmbH (see Figure 3-1).

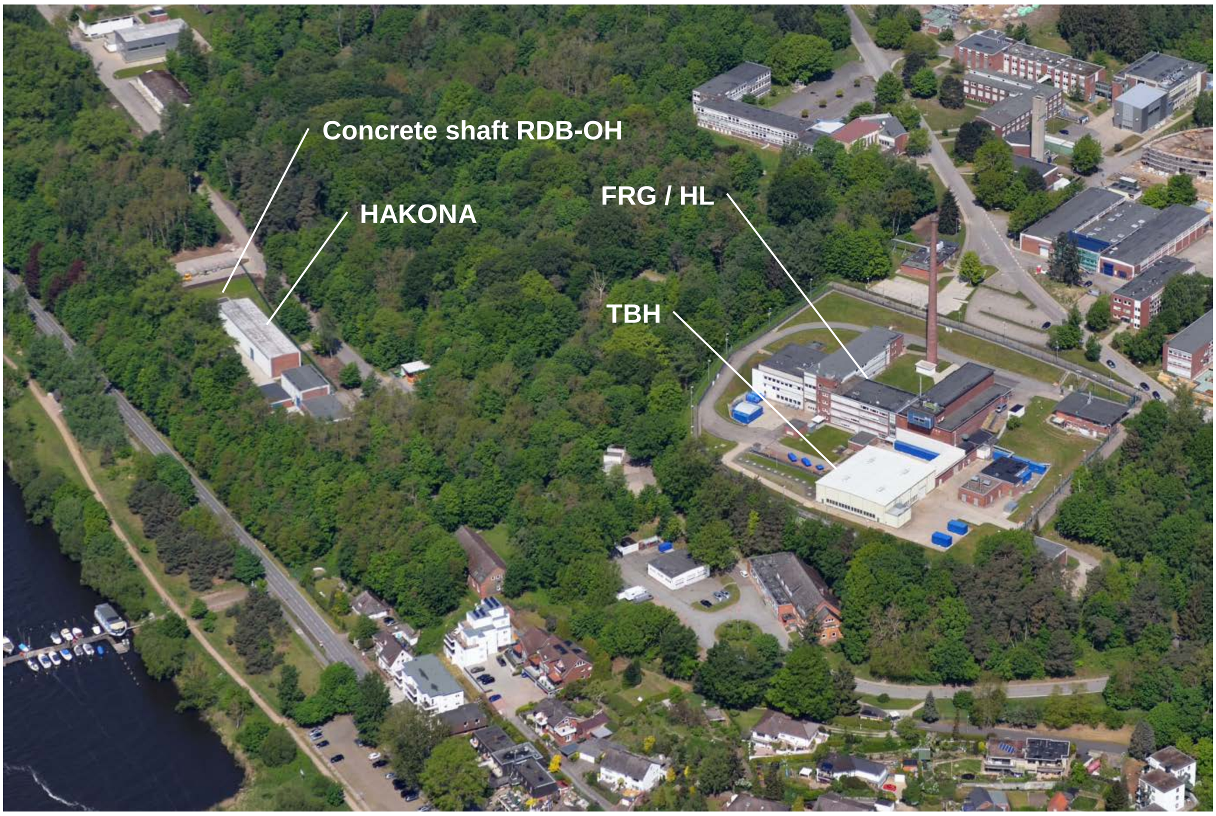


Figure 3-1: Aerial view of the FRG, the HL, the TBH and the concrete shaft of the RDB-OH next to the Hall for Component Follow-up Examination (HAKONA) (from 2016)

The HZG site (see Figure 3-2) is located about 35 km south-easterly of the city centre of Hamburg in the District of Lauenburg (Schleswig-Holstein). The city of Geesthacht designated the area (approx. 200 hectare) as special use area or forest. It is bordered to the South towards the Elbe, by the Elbuferstrasse located direction parallel to the river in southeast-northwest orientation. To the northwest lies the site of the Krümmel nuclear power plant (KKK) and the upper basin of the pumped-storage unit Geesthacht. The Geesthacht district of Grünhof and Tesperhude are located to the East of the site.


Figure 3-2: The HZG site and its surroundings within a radius of 10 km

## 3.2 Settlement

About 63,000 people live in the towns and municipalities within a radius of 10 km around the HZG site. The average population density is approximately 200 inhabitants/km² in the entire 10 km radius, which is below the average of the Federal Republic of about 230 inhabitants/km².

The settlement closest to the site is the Geesthacht district of Grünhof and Tesperhude. The community of Krümmel lies about 1 km away in northwest direction. The town centre of Geesthacht is approx. 5 km away.

### 3.3 Land Use

In the Duchy of Lauenburg and Stormarn districts, the countryside of the Geest is almost exclusively used for agricultural and forestry use. In the districts of Harburg and Lüneburg as well as in the easternmost included part of the marshes and Vierlande belonging to Hamburg, there are, however, almost entirely marsh areas with very high proportion of agricultural land. Commensurate with the soil conditions, large scale grassland use is also to be found here.

Characteristic surface water in the vicinity of the HZG site is the Elbe. It runs approximately in the south-east direction between Lauenburg in the south and Geesthacht in the north. There are also smaller natural and artificial watercourses (e.g. Elbe-Lübeck Canal), which flow into the Elbe. These rivers and other open waters in the vicinity of the HZG are also used for leisure, for inland navigation, for sports boat traffic or for sport fishing.

There are six nature reserves located within a radius of 10 km. Moreover, within this radius, there are natural reserves and areas, which, according to Natura 2000, are listed as a flora and fauna habitat area or as a bird sanctuary and offer special protection of the habitat.

The forests surrounding the site area are important for recreation associated with the landscape. The cycle route along the bank of the Elbe should also be emphasised.

### 3.4 Commercial and Industrial Areas, Military Facilities

Several industrial areas are located within a radius of 10 km. To the northwest of the HZG site, for example, are the "Grüner Jäger" industrial areas with a quartz producer, a machine factory, a manufacturer of machine parts and a wholesaler as well as "Düneberg" with a larger number of industrial plants, such as electrical plants or machine factories.

In addition, there is, the nuclear power plant Krümmel (KKK) in the north-west of the site.

There are no military installations within a radius of 10 km.

### 3.5 Traffic Routes

The Federal Highway 5 (B-5) connects the plant site to the city of Geesthacht and the town of Lauenburg. On the northern bank of the Elbe runs the Elbuferstrasse, from which several connecting roads to the B-5 branch out. The highway L 217 between Marschacht and Artlenburg runs at a distance of around 800 m along the southern bank of the Elbe.

The track system, which runs along the HZG, has been shut down and dismantled in the area of the radioactive waste storage facilities and the Disassembling Hall to be erected.

The Elbe shipping route passes the site directly in the Southwest. Due to the proximity to Hamburg, the easy access to trans-regional waterways and the North Sea the Elbe has a high traffic activity in terms of inland waterway.

Hamburg international airport (37 km Northwest), the airfield at Uetersen-Heist (54 km Northwest), as well as the landing sites of Lüneburg (17 km South-Southeast), Hamburg-Finkenwerder (41 km West-Northwest) and Lübeck Blankensee (48 km North-Northwest) are located within a radius of 50 km around the site.

Within a radius of 2 km of the location of the HZG and nuclear power plant Krümmel (KKK), and up to an altitude of about 670 m above sea level, there is an area with aircraft flight restrictions. An overflight ban exists for visual flight traffic in this area.

### 3.6 Meteorological Conditions

The climate is strongly influenced by the proximity of the North and Baltic Sea. Accordingly, maritime weather is dominating but during easterly winds also continental air masses become relevant. Typical there are relatively mild winters and often only moderately warm summers, usually with unsettled weather.

In recent years, there was a dominant prevailing wind direction from the south-west. Seasonally, the highest wind speeds are in winter (on average about 5.4 m/s) and autumn (4.9 m/s). The average annual precipitation amounts to 721 mm. Thermal inversion conditions occur mainly in the months of November to February.

### 3.7 Geological and Hydrological Conditions

The HZG site is located directly on the Geest Slope, which has plentiful forests, consisting of sandy and pebbly deposits of the Saalian sub-glacial moaraines and end moraines. The northern Geest slope, which extends from Hamburg-Bergedorf to Geesthacht, formed the former shore of the Elbe glacial valley. Incipient erosion created both ravine-like incisions into the Geest Slope both as low-relief and low-waterbody areas.

In this regard, the geology of the region has remained unchanged over the last millennia and extends from Hamburg-Bergedorf via Escheburg to Geesthacht.

The groundwater level is located at the site at the level of the Elbe water level. The Elbe is not influenced by the tide in the area of HZG anymore. However, the area influenced by the tide extends from its mouth into the North Sea near Cuxhaven to the weir in Geesthacht. The plant site is far above the groundwater level, due to its altitude.

At a distance of approx. 1.5 km from the site is the Krümmel water works with four delivery wells with a delivery depth between 70 m and 120 m. The drinking water recovery area extends from Kümmel in north-northeasterly direction to Schwarzenbek. The HZG-site is located approximately 500 meters southeast of drinking water recovery area. About 5.3 km to the northwest, other deep wells are to be found for public water supply to Geesthacht.

### 3.8 Seismic Conditions

The HZG location is located in the North German lowlands. The regional unit is not located in a seismic zone according to the DIN EN 1998-1/NA:2011-01.

### 3.9 Radiological Initial Loading

The radiological situation at the HZG site is primarily influenced by:

- the Krümmel nuclear power plant (KKK) and
- the Krümmel interim storage site (SZK).

The KKK and the SZK are located northwest at a distance of about one kilometre from the plant site. The discharge limits authorized for the operation of the KKK result in a radiation exposure below the limits defined in the StrlSchV. The Krümmel interim storage site has no influence on the radiological initial loading. The possible direct radiation has no influence on the HZG site because of the distance.

The effective dose for the radiological initial loading induced by the KKK as a result of gaseous discharges is below the value of 0.1 mSv in a calendar year, taking into account the authorized maximum discharge values of the KKK.

On the HZG site are located several facilities (supply hall, HAKONA) and institutions (federal state collecting facility) with a license for handling radioactive substances in accordance with § 7 StrlSchV (or § 3 in earlier versions). For these facilities no radioactive gaseous discharges are intended during normal operation. They have no ventilation systems which allow any systematic discharge from the respective buildings. Therefore, there is no significant activity emission from these facilities or installations. This also applies, even if activity concentration in the respective interior have exhausted the activity threshold values of Annex VII part D table 4 in conjunction with § 47 para. 4 StrlSchV.

The effective dose for the radiological initial loading by the KKK through the liquid discharges (HZG local area) is below 0.1 mSv in a calendar year, taking into account the authorized maximum discharge values of the KKK. In addition, possible other initial loadings from other plants and facilities are taken into account, such as research facilities and hospitals (e.g. through radionuclide emissions from patients in nuclear medicine).

For the distant area (Elbe downwards), in addition the radiological initial loading of the power plants Stade (KKS), Brokdorf (KBR) and Brunsbüttel (KKB) are taken into account including their authorized maximum discharge values. The result is an effective dose value of less than 0.2 mSv per calendar year.

# 4 Research Reactor Plant, Hot Laboratory and the Reactor Pressure Vessel with Shield Tank of the Nuclear Ship Otto Hahn

## 4.1 Plant History

<u>Research reactor plant:</u>

| | |
|---|---|
| 20.10.1958 | Issue of the authorization for the construction and operation of the research reactor FRG-1 |
| 23.10.1958 | Commissioning FRG-1 |
| 10.08.1959 | Issuance of operating licence up to a capacity of 200 kW |
| 10.12.1959 | Issuance of operating licence up to a capacity of 5 MW |
| March 1963 | Commissioning FRG-2 |
| 1967 | Large-scale expansion of facilities (such as separate cooling circuits) |
| 23.11.1973 | Issuance of operating licence up to a capacity of 21 MW |
| 06.06.1974 | Issuance of operating licence up to a capacity of 15 MW |
| 1987 | Inspection of the interior concrete of the basins and renovation of determined damage; subsequently various retrofitting measures for the adjustment of the plant to the state of the art of science and technology |
| 1991 | Final decommissioning FRG-2 |
| 17.01.1995 | Decommissioning authorization FRG-2; subsequent dismantling and disposal of significant parts (such as the primary circuit) |
| 28.06.2010 | Final decommissioning FRG-1; |
| | In the subsequent operation, among other things the fuel elements were disposed of, experimental facilities were passed to external facilities, pitches were prepared for the dismantling and structural changes carried out in the area of the old and new experimental hall. |

<u>Hot laboratory:</u>

| | |
|---|---|
| 1971 | Commissioning |
| until 1992 | Investigation of predominantly irradiated pressure vessel materials and pilot fuel rods in the context of reactor safety research |

| | |
|---|---|
| since 1992 | Investigation, dismantling and packing of HZG radioactive residual substances and wastes |

Nuclear ship Otto Hahn

| | |
|---|---|
| 13.06.1964 | The only German nuclear ship Otto Hahn drive launched |
| up to 1968 | Installation of the nuclear drive |
| 11.10.1968 | First test drive |
| 1972 / 1973 | Converted from 1st to 2nd core and change the fuel assembly and control geometry |
| up to 1979 | Operating as a nuclear research vessel and passing as ore carrier |
| 1979 | Decommissioning of nuclear drive |
| June 1981 | Dismantling of the reactor pressure vessel with shield tank in Hamburg port and transport to the Gesellschaft für Kernenergieverwertung in Schiffbau und Schifffahrt mbH (GKSS), today HZG |
| 1982 | Decontamination, release and conversion of "Otto Hahn" to a container vessel with conventional diesel drive |

## 4.2 Functional Principle

The FRG-1 produced neutrons for scientific experiments. The neutrons were made available through radiant tubes to different experimental facilities in the experimental hall. In addition, sample irradiations were carried out in the core for the neutron activation analysis of internal and external users.

The FRG-2 was used mainly as a material test reactor. A series of instrumented capsules were developed and deployed for the irradiation of material samples, where conditions of nuclear power plants were simulated (pressure, temperature, medium).

Both research reactors were running as swimming pool reactors in an open top water basin, which is divided into the following 4 areas (see Figure 4-1):

- Operating pool with thermal column (Pool I) (FRG-1).
- Operating pool with irradiation window (Pool II),
- Storage pool (Pool III) and
- Experimental pool (Pool IV) (FRG-2).

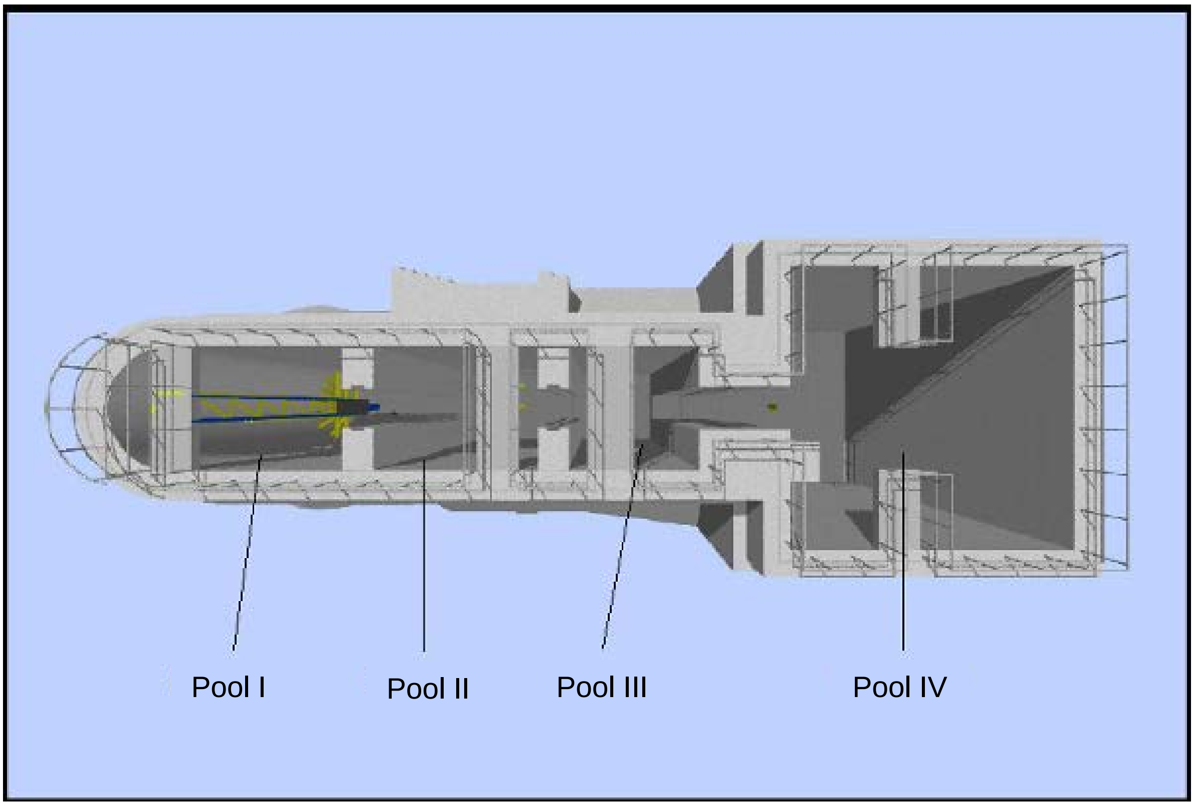


Figure 4-1: Top view of the reactor pool

The essential components of the research reactors are respectively the reactor core with the fuel and control fuel elements and the two cooling circuits (primary and secondary circuit) for heat dissipation. The performance of the research reactor was controlled by raising or lowering the control rods by means of a control rod drive. With the help of the primary coolant pump, the water was passed from top to bottom through the fuel elements and transferred out of the pool to the heat exchanger. There, the heat of the primary water was transferred to the water of the secondary circuit. Then, the primary water flowed back into the reactor pool. In the secondary circuit, the heated water was pumped to the cooling tower, where it was "spayed" and thus gave its heat to the environment (see Figure 4-2).

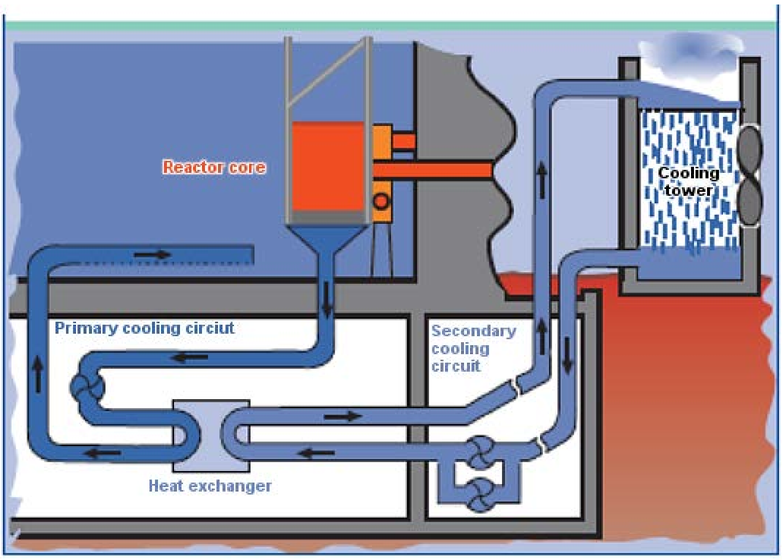


Figure 4-2: Cooling circuit of the FRG-1 (primary and secondary circuit)

**Reactor Pressure Vessel with Shield Tank of the Nuclear Ship Otto Hahn**

The nuclear ship Otto Hahn was operated with a pressurized water reactor with a thermal power of 38 MW and operated with water in the primary circuit as a coolant and moderator. The drive steam is generated for the conventional steam turbine in the secondary circuit.

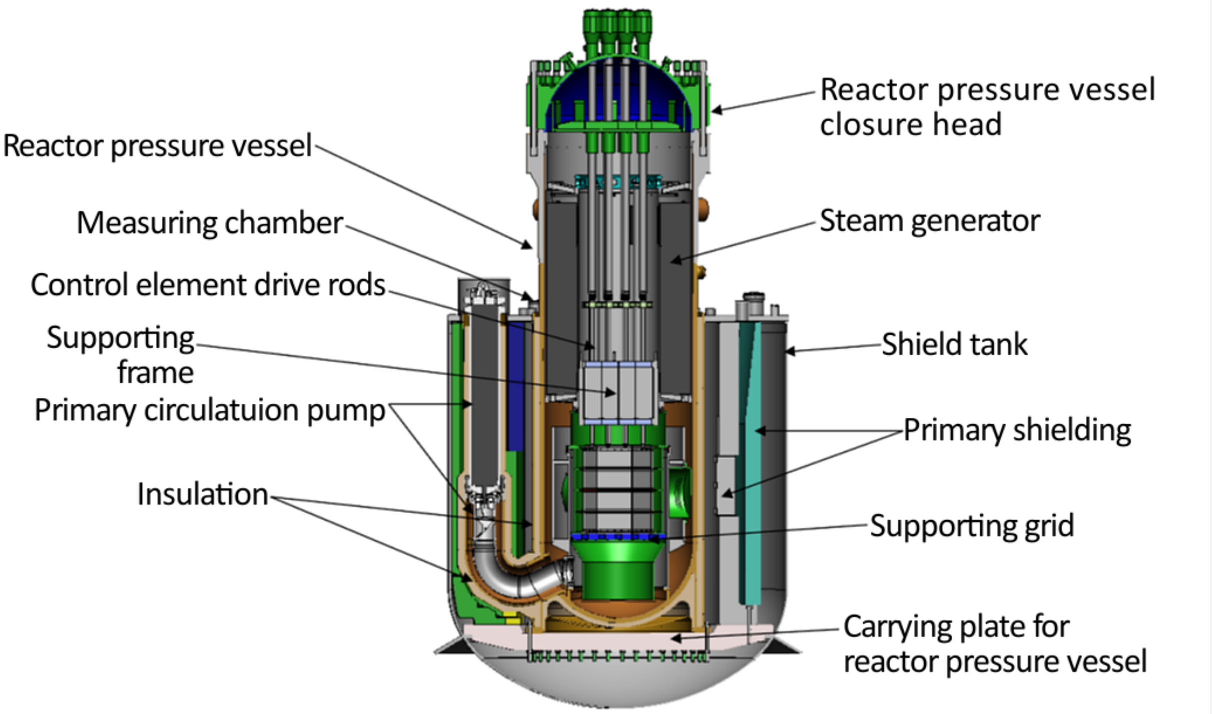


Figure 4-3: Construction of the reactor pressure vessel with shield tank

The progressive aspect for this reactor type compared to the conventional pressurized water reactors, was the relocation of components previously located outside the reactor pressure vessel (e.g. steam generator and pressure holder) into the reactor pressure vessel. Support constructions for the components and the connecting pipelines become superfluous as a result. Due to this compact design, also the reactor insulation outside of the reactor pressure vessel could also be simplified.

The circulation of the primary water was performed with three freestanding primary circulation pumps (cf. also Figure 4-4). They are connected to the RDB via the three double-walled pump nozzles. The primary coolant is suctioned from the backflow section of the RDB via the external sheath of the pump nozzle and is pumped via the pump through the internal pump nozzle from below into the water guide channel. From there, the primary coolant flowed through the reactor core from bottom upward and was heated up. The heated primary coolant left the core upward and was then cooled by the steam generator from top to bottom again and is suctioned in again by the primary circulation pump after flowing through the steam generator.

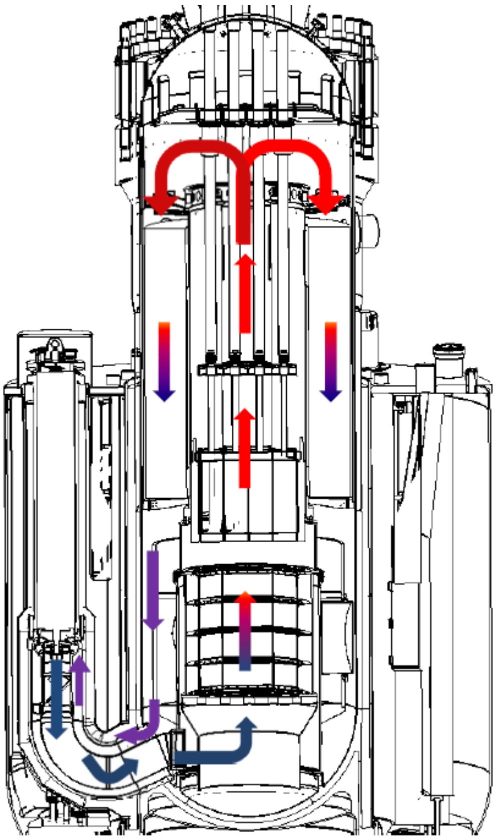

Figure 4-4: Function of the primary circiut pumps and the coolant flow inside the RDB during operation

## 4.3 Technical Condition

**Research Reactor Plant and Hot Laboratory**

The reactor building with the FRG, the HL as well as other auxiliary buildings represents the central building complex of the plant. It consists of the reactor part which is located on the eastern side (oriented in a south-north direction) and realized as a hall construction placed over the reactor pools with the research reactor FRG-1 and remainders of the research reactor FRG-2. In addition, there are the laboratory buildings, consisting of experimental hall, east-west laboratory wing, irradiation channel and the western part of the building with the hot cells.

In the location map (Figure 4-5) the arrangement of the significant buildings on the plant area is represented.

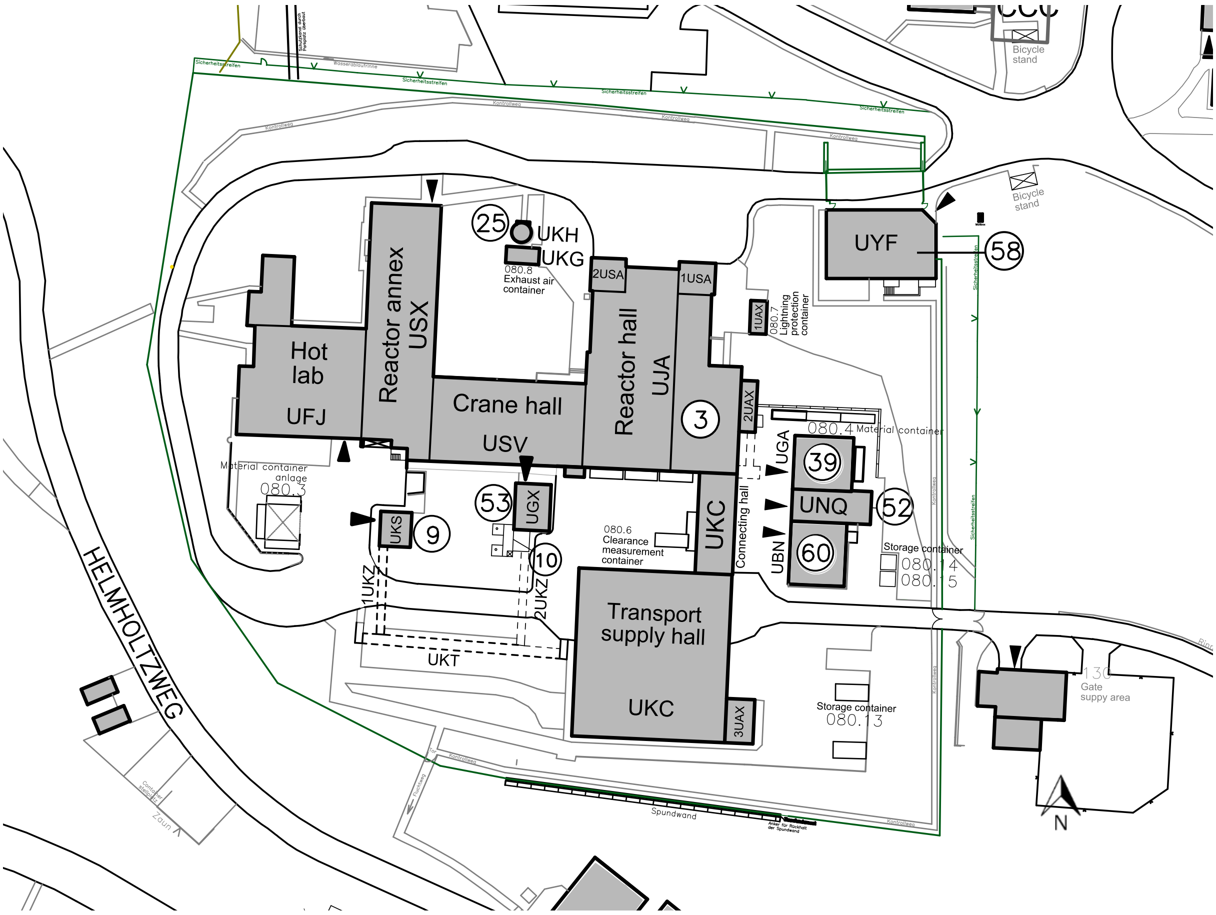


Figure 4-5: Location map of the FRG and the HL

Legend:

| Building | ID | Designation |
|---|---|---|
| 3 | UJA | Reactor hall |
| 3 | USV | Crane hall |
| 3 | USX | Reactor annex |
| 3 | UFJ | Hot lab with dosimetric annex |
| 3 | UKC | Connecting hall |
| 3 | UKC | Transport supply hall |
| 3 | UKT | Service passage for radioactive waste water tanks |
| 3 | 1/2UKZ | 2 connective shafts to the radioactive wastewater tanks |
| 9 | UKS | Deco station |
| - | UKG | Exhaust air container |
| 25 | UKH | Vent stack |
| 39 | UGA | Well house |
| 52 | UNQ | Compressor building |
| 53 | UGX | Acid warehouse I |
| 58 | UYF | Guard building |
| 60 | UBN | Emergency power building |

All systems and equipment which are required for the necessary remaining work and the dismantling are in operation or ready for operation (such as wastewater collection and treatment system, energy supply, ventilation system).

**Reactor Pressure Vessel with Shield Tank of the Nuclear Ship Otto Hahn**

The reactor pressure vessel with the shield tank of the decommissioned nuclear ship Otto Hahn was put into storage for a planned follow-up examination programme in June 1981. It is placed inside a shaft structure which is especially created for this purpose (concrete shaft, cf. Figure 4-6) at the HZG site. The shaft is located in direct proximity to the site of the Geesthacht research reactor plant (approx. 220 m).

Before the transportation of the RDB-OH, the RDB and the shield tank were drained as much as possible. The residual water quantity in the RDB is estimated to be < 1.0 m³ and that in the shield container < 0.1 m³. The RDB closure head is tightly sealed, is primarily closed with original screws and was not opened for transport preparation. Shielding made of lead is attached to the outside around the 3 primary pumped and in the closure head area.

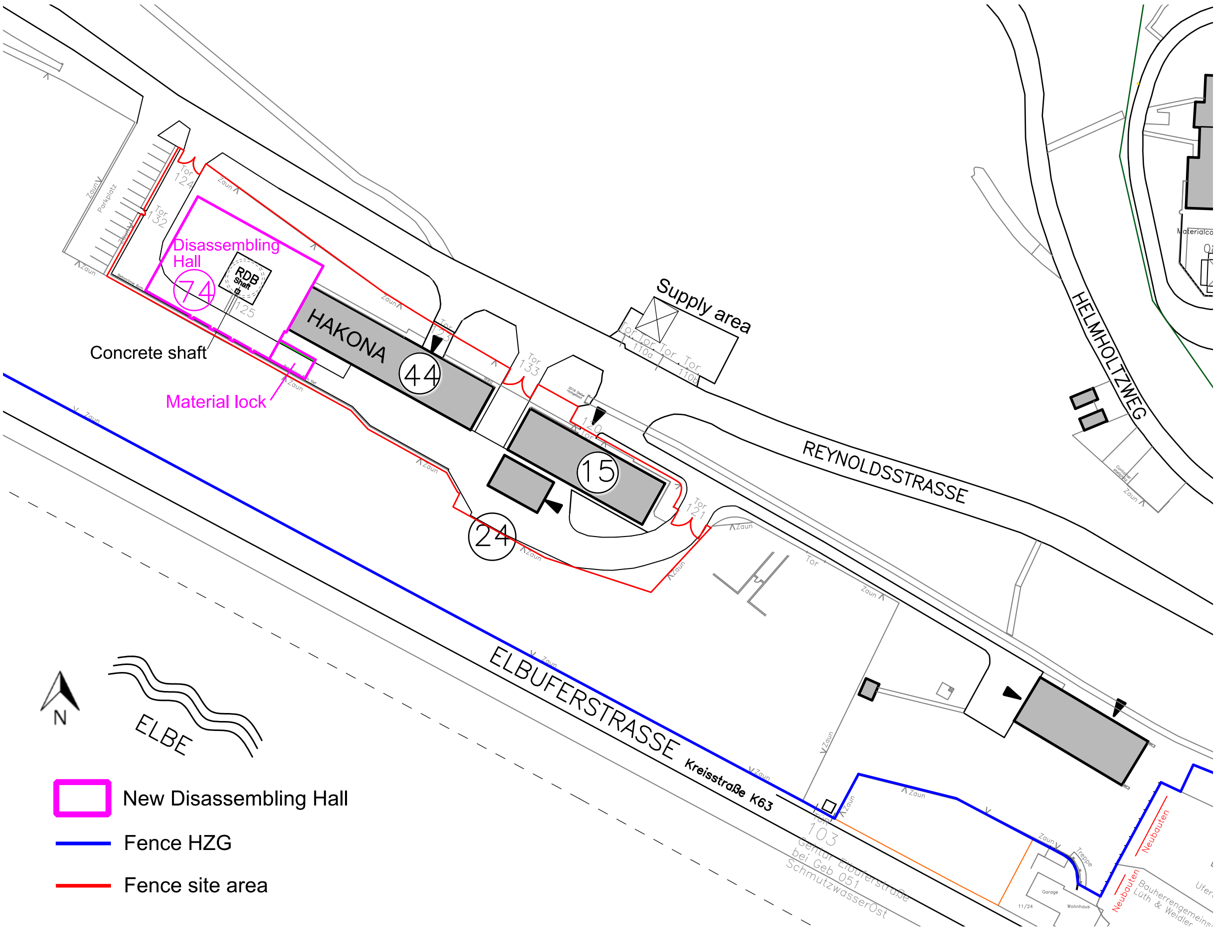


Figure 4-6: Location of the concrete shaft with the RDB-OH and the to be built Disassembling Hall

Legend:

| Building | Designation |
|---|---|
| 15 | Federal state collection facility |
| 24 | Washing building |
| 44 | HAKONA (Hall for Component Follow-up Examination) |
| 74 | Disassembling Hall to be constructed over the shaft structure |

## 4.4 Radiological Condition

**Research reactor Plant and the Hot Laboratory**

The conservatively estimated total activity inventory (activation and contamination) of the FRG and the HL is approximately 5.0 E15 Bq at the beginning of the dismantling.

The metal blocks and reflectors made of beryllium include about 80 % and the irradiation facilities approximately 16 % of the total activity inventory. The proportion of activity from stainless steel reactor pool installations, $\gamma$-absorber shields and radioactive waste, which is stored in the concrete cells 2 to 4 in the hot laboratory (aluminium, flammable and metallic mixed waste), amounts to approximately 4 %. The activity of the other activated materials such as activated concrete is 3 – 4 orders of magnitude lower. Activation of the soil below the reactor building can be ruled out.

The proportion of contamination in the total activity accounts for less than 1 ‰ for all operational waste and less than 1 % for the building surfaces. The main contaminated areas are in the reactor tank, the piping of the primary circuit and the radioactive cleaning circuits, as well as the inner surfaces of the waste water and ventilation systems.

**Reactor Pressure Vessel with Shield Tank of the Nuclear Ship Otto Hahn**

The estimated overall activity inventory (activation and contamination) of RDB-OH is approximately 5.6 E14 Bq.

Particularly the core internal fittings are defining factor for the overall activity (lower support grid, core shroud, water guide channel and support cylinders). The percentage of these highly activated internal fittings near the core relating to the overall activity of Co-60 is approximately 99.7 % at the start of disassembling.

In terms of decontamination, the steam generator provides the relevant components due to the very large surface of the heat generator heating pipe.

# 5 Dismantling

## 5.1 Dismantling of the FRG and the HL

The dismantling of the research reactor plant and of the hot laboratory should be connected directly to the post-operational phase of the FRG-1. This should be performed together with the disassembling of the RDB-OH under a common and carried out within the framework of a single and comprehensive decommissioning and dismantling authorization.

The dismantling project is thereby divided into the following three steps:

- Dismantling research reactor plant,
- Dismantling hot laboratory and
- Residual dismantling overall plant.

The dismantling begins once the required conversion measures which are necessary for the maintenance of the phasing out have progressed so far that their conclusion is not prevented or made more difficult by the dismantling of plant components.

Figure 5-1: Aerial view of the FRG and the HL (from 2016)

It is planned that activated core structures of the RDB-OH are transported to the existing concrete cells of the FRG and the HL and will be optimized under geometrical and radiological aspects in accordance with the acceptance conditions for the federal final dispose.

### 5.1.1 Structural Measures

No structural measures are intended on a larger scale for the dismantling of the FRG and the HL. A ceiling opening will be created for the establishment of a transportation path for radioactive residual substances from the reactor hall into the old experimental hall. In order to create further necessary transportation paths for the dismantling, walls, interfering edges etc. will be removed as required.

### 5.1.2 Dismantling Equipment and Processes

Proven, commercial dismantling equipment and dismantling tools are intended for the dismantling. Manual dismantling is performed with hand-held dismantling equipment and tools, whose use is already proven in many dismantling projects (e.g. separating, drilling and cutting equipment).

A hydraulic excavator, which can hold different tools for processing as attachments (such as hydraulic concrete cutter or scissors), a wire saw with electro hydraulic drive, as well as other auxiliary equipment are provided for the concrete removal in addition to the above-mentioned hand-held devices, especially for the reactor pool.

### 5.1.3 Decontamination Procedures and Facilities

In order to eliminate radioactive contamination, different decontamination procedures are applied. The decontamination works take place in areas with an existing exhaust system. If necessary, a mobile filter unit can be added. If the decontamination aim is not achieved at a part of the plant, this part of the plant will be subjected once again to a decontamination procedure, where this is appropriate from a radiological and economic point of view.

Mechanical decontamination procedures for the treatment of surface contamination are intended for the dismantling of the FRG and the HL (such as wiping, brushing, milling). In addition, HZG also has stationary decontamination facilities, such as a dry blasting box.

### 5.1.4 Dismantling Research Reactor Plant

This dismantling step includes the dismantling of the reactor pool, the dismantling in the reactor hall with adjoining rooms, the dismantling in the basement of the reactor and the dismantling in the old experimental hall.

**Dismantling Reactor Pool**

In the context of the dismantling of the reactor pool, initially all systems and equipment no longer needed (pool equipment, permanently installed pool structures etc.) are dismantled and then subsequently the activated portions of the pool structures and the liner are dismantled.

At the beginning of the dismantling, components from the FRG-1 are still available in Pool I and in Pool IV from the FRG-2. The pool fittings with relatively high dose rates are initially dismantled under water with the existing operational tools in accordance with the established work procedures. If necessary they are disassembled and transferred to shielded transport or waste containers.

After the shielded transport or waste containers have been lifted from the reactor pool, their surfaces are decontaminated. If necessary, the removed components in the hot cells of the HL are subsequently disassembled and packed into waste containers.

After the disassembly of the higher activated components, the pool water is continuously drained and the other, non- or low-activated pool installations are disassembled. During the discharge, a decontamination of the tiles in the reactor pool takes place. If the emptying of the pools is sequential from Pool I to IV, the dismantling of the pool installations of Pool I can already be continued, while the draining and decontamination of the tiles in the other pools is still in process.

Subsequently, all feedthroughs in the pool walls are drilled out, the pool walls disassembled and the facilities above the reactor pool dismantled, disassembled to transport size (e.g.

mesh box size or 200-ℓ-drum). If necessary, they will be decontaminated and for the most part taken on the clearance path.

The partial demolition of weakly activated areas of Pool I on the outside takes place with industry proven dismantling tools (hydraulic excavators, concrete cutter) in an enclosure with air extraction (directed air flow into the demolition area). The demolition tools will be implemented accordingly for the dismantling of the activated concrete within Pool I. The dismantling takes place in principle from top to bottom in several layers. First the tiles are removed with the immediately underlying concrete. This fraction is expected to dispose of as radioactive waste. Then the underlying layers, which will be expected to be clearable, are milled off. The structures of Pools II to IV are in principle handled in the same way, whereby activation in Pools II and III is not to be expected.

In case of a necessary static procedure with the load-bearing structures, heavy load bearing constructions will be deployed for the partial bracing in accordance with the guidelines of a structural engineer.

After the dismantling of the concrete structures, the liner areas with activation exceeding the clearance value will be determined and dismantled mechanically e.g. with grinders. After the decontamination of the remaining liners, liner segments will be cut out in exposed areas (such as intersections) as well as other controlled surfaces. The underlying concrete will be checked for contamination due to liner leaks. In a subsequent step, if necessary any still contaminated structure will be dismantled.

**Dismantling Reactor Hall with Adjoining Rooms, Reactor Cellar and in the old Experimental Hall**

All remaining, no longer necessary facilities and plant components will be dismantled. The dismantled plant components will be disassembled on site as far as they have transportation size (e.g. mesh box or 200-ℓ-drum). If necessary, they will be decontaminated and disposed of.

Air ducts and other still needed facilities of the infrastructure will be dismantled within the context of the remaining dismantling of the entire plant.

### 5.1.5 Dismantling Hot Laboratory

This dismantling step includes the dismantling of the concrete cells, the dismantling of the dosimetry cells and the dismantling within the remaining space ranges of the HL.

**Dismantling Concrete Cells**

The dismantling of the concrete cells and the lead cell can begin when they have been cleared of operational waste and are no longer needed. This is after the completion of the disassembly activities in the phasing out of the FRG and after the disassembling, decontamination and packaging of parts from the RDB-OH.

Before the disassembly of the manipulators and the leaded windows, the cells, the manipulators and the leaded windows are decontaminated. The disassembly can be performed procedurally only towards the operating room. Immediately after the disassembly of a manipulator or a window, the resulting holes will be sealed again for reasons of ventilation. During removal, the ventilation system ensures a directed air flow from the operating room (supervised area) into the cell room.

Subsequently there is an access to the transport tunnel, which can be used for internal decontamination of the tunnel and dismantling of its installations, if necessary. If required, the work will be carried out in an enclosure with mobile ventilation system.

The dismantled plant components will be disassembled on site as far as they have transportation size (e.g. mesh box or 200-ℓ-drum), if necessary decontaminated and disposed of. The lead blocks can presumably be released or used in other nuclear facilities.

**Dismantling Dosimetry Cells and in the Remaining Areas of the HL**

All remaining, no longer necessary facilities and plant components will be dismantled. The dismantled plant components will be disassembled on site to transportation size (e.g. mesh box or 200-ℓ-drum). If necessary, they will be decontaminated and disposed of.

Air ducts and other still needed installations of the infrastructure will be dismantled within the context of the remaining dismantling of the entire plant.

#### 5.1.6 Residual Dismantling Overall Plant

After the basic facilities and equipment in the FRG and the HL have been broadly dismantled and decontaminated, the entire infrastructure of the buildings will be dismantled. All contaminated systems and facilities, and all non-contaminated systems and facilities, which complicate or restrict the clearance of the remaining buildings, will be dismantled. In addition, the buildings and underground systems (such as waste water system) will be radiologically assessed and decontaminated or dismantled, if necessary.

**Waste Water System**

If only small amounts of waste water accrue in the controlled area, the waste water system for the radioactive contaminated waste water can be shut down and dismantled. The conventional waste water pipes remain until the demolition of the buildings.

**Ventilation System**

After the removal of the plant parts and equipment in a room or building area, the fixed ventilation systems in these areas will be shut down and dismantled. The controlled areas thereby remain separate in terms of ventilation from the supervised areas, until the release of the controlled area conditions or clearance.

The withdrawals from the residual operating room takes place gradually in the direction of the exhaust air filter/operating rooms of the exhaust air. During the dismantling of the air ducts (as before with running ventilation) the room ventilation is ensured without air ducts.

**Remainder Dismantling and Decontamination**

In the context of the remainder dismantling, still existing systems, which were used for the dismantling or the treatment of residual substances, will be dismantled (e.g. decontamination facilities).

In this phase, any facilities still necessary will be readily movable, e.g. mobile building site lighting, temporary battery-buffered escape route lighting, construction site power distribution point.

All rooms and building areas will be decontaminated and submitted to a preliminary investigation for clearance. This concerns in particular the areas with possible airborne contamination from dismantling using dust producing dismantling procedures.

Completely dismantled, decontaminated and cleared rooms and building areas, which are not required as traffic routes or transportation paths, will be locked and sealed as regards ventilation. In these areas, there will then be no more fittings or plant components, unless these are likewise cleared. The basis for a clearance of plant components and building parts is the StrlSchV in conjunction with the exemption levels specified therein.

## 5.2 Disassembling of the RDB-OH

The disassembling of the RDB-OH should then occur in advance of or simultaneously with the dismantling of the FRG and the HL. The disassembling of the RDB-OH should be performed with the dismantling of the FRG and the HL as part of a joint and comprehensive decommissioning and dismantling license.

First a building, the so-called Disassembling Hall, will be constructed over the concrete shaft to disassembly the RDB-OH. The existing concrete shaft is structurally connected to the new Disassembling Hall and it is equipped with the required infrastructure and a control area for handling other open radioactive materials.

Disassembling is sub-divided into the three following steps:

- Erection of Disassembling Hall,
- Disassembling of RDB-OH and
- Residual disassembling and decontamination of the Disassembling Hall and concrete shaft.

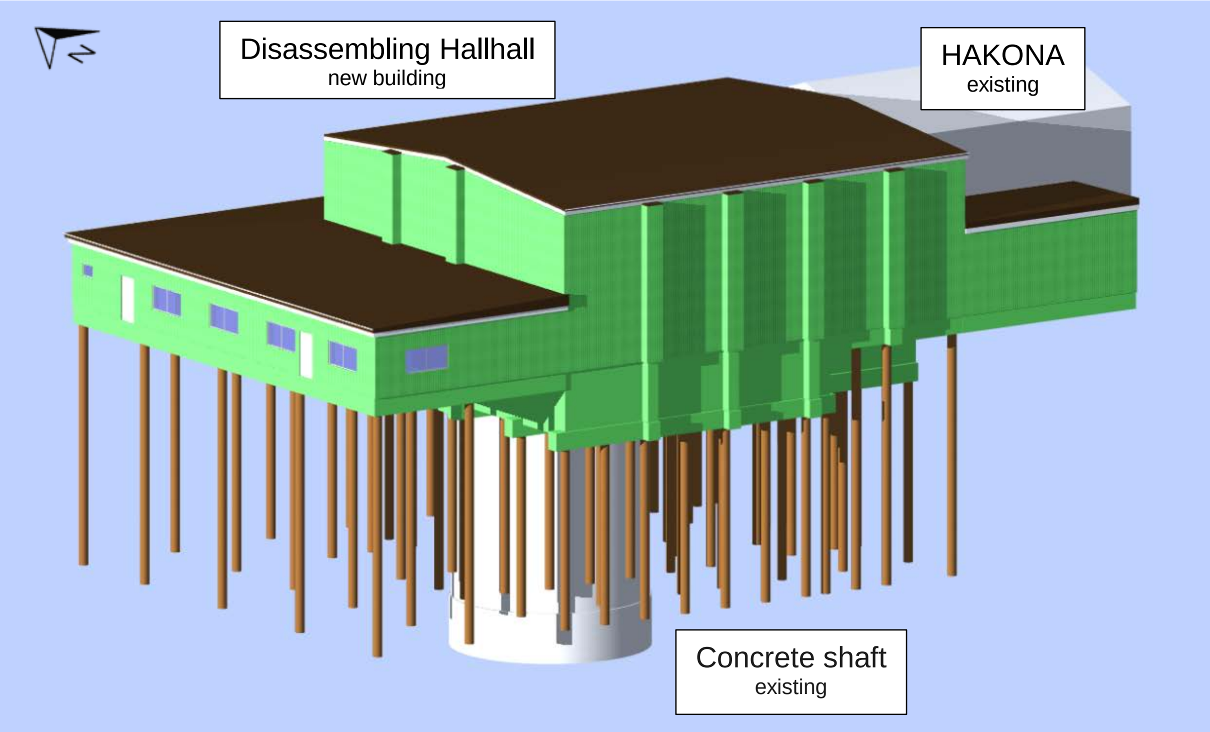


Figure 5-2: Isometric of Disassembling Hall (light green) and the concrete shaft

The activated core constructions are transported to the existing concrete cells of the FRG and HL by means of shielded transport or waste containers. There they are packaged will be optimized under geometric and radiological aspects and according to the acceptance conditions for the Federal Final Disposal.

### 5.2.1 Construction Requirements / Erection Disassembling Hall

A Disassembling Hall which is primarily above ground will be erected for the disassembling of the RDB-OH over the existing concrete shaft. It is directly adjacent to the existing Hall for Component Follow-up Examination (HAKONA). The existing concrete shaft is structurally connected to the new Disassembling Hall and is equipped with the required infrastructure and a control area for handling other open radioactive substances.

### 5.2.2 Dismantling Equipment and Processes

For the disassembling of the RDB-OH, the same manual hand-held degradation device or dismantling tools are used, as also provided for the dismantling of the FRG and the HL.

In addition, tested and proven remotely handled tools and thermal disassembling processes are planned for the disassembling of the activated parts, such as a plasma cutting module, CAMC module or autogenous flame cutting module (adaptable on the packing manipulator of the auxiliary bridge).

### 5.2.3 Decontamination Procedures and Facilities

Only simple decontamination methods are planned in the Disassembling Hall to remedy radioactive impurities on the components. They are limited to the removal of contamination which can be wiped off, by methods which only create a little waste water and secondary waste. These are manually-performed processes with cleaners such as cleaning cloths with citric acid, oxalic acid or other proven decontamination cleaners. The cleaning cloths with the wiped off contamination and the residue from the detergent are collected in suitable drums and taken in for disposal. Furthermore, stripping varnishes can be used to connect and remove non-adhesive contamination. There is the possibility to pack components which can be contaminated properly on site and then transport them to the HL for further treatment.

An ultrasound bath is provided on site for the decontamination of tools and smaller equipment which are used during the disassembling of the RDB-OH.

### 5.2.4 Disassembling of the RDB-OH

As part of the disassembling of the RDB-OH, first the three main coolant pumps are dismantled to avoid that they and the top areas of the main coolant pump nozzle becoming contaminated during later disassembling steps. This process is performed in the same manner as the manner to replace or repair main coolant pumps during reactor operation.

Then the control element drive rods are manually disassembled like the process for the operational fuel element change according to the existing specialised instructions.

Now the RDB closure head can be opened and disassembled. It is placed on an appropriate stand base, roughly decontaminated and then disassembled. The individual parts are decontaminated after disassembling and are expected to be extensively releasable.

The support frame is also disassembled like during an operational fuel element exchange. Then the decontamination and post-disassembling follows. Post-disassembling occurs mechanically by means of saws. The parts of the support frame, which are not activated or are below the exemption values, can be expected to be released after successful decontamination. After disassembling of the support frame, the water level in the RDB is raised to the lower edge of the steam generator.

The steam generator was built in the RDB as one single unit and can only be removed at once. The steam generator is lifted with the bridge crane. Here it is packed into a contamination protection (e.g. plastic film) in order to avoid any contamination carry-over into the Disassembling Hall. It is expected that the decontamination of the steam generator requires an elaborate infrastructure and generates a large quantity of waste water. Because of this it is preferred to pack the steam generator as a whole and to transport it to a suitable external facility for decontamination and post-disassembling.

The activated core internal fittings are disassembled inside the RDB and under water with remote-controlled or remote-handled devices and packed into screen baskets. The screen baskets are lifted out with a shielding bell. They are taken to the existing concrete cells of the FRG and the HL using a shielded transport or waste container. There they are optimally packed according to the terms of acceptance for the Federal Final Disposal taking into account geometrical and radiological aspects.

After the disassembling of the core internals, the largest percentage of activity is removed from the RDB-OH. The water level in the RDB is lowered. Here, if necessary, the RDB wall is cleaned simultaneously using high-pressure water jetting to remove loosely adhering contamination.

Then the shield tank is opened with thermal processes and the shield tank cover is cut out in segments. The segments are decontaminated and are then subsequently available for a clearance.

Then the shielding plates are disassembled and decontaminated in reverse order in relation to the previous installation.

Before the RDB is disassembled, the insulation (rock wool) is removed between the shield tank internal wall and the RDB as well as in the area of the pump nozzles. The RDB is then separated with a thermal separating process from top to bottom, shot by shot. The cut line on the upright RDB occurs using a force manipulator from outside. The disassembling area is covered under a tent during the work. The separated shots are then lifted as a whole with the bridge crane, decontaminated. Then they are subsequently disassembled in a partially automated manner using a mobile compass saw in the post-disassembling area of the Disassembling Hall.

After the RDB and the interior shield tank cylinders are disassembled, the floor plate in the shield tank and the remaining external shield tank sheath are disassembled.

### 5.2.5 Residual Disassembling and Decontamination of the Disassembling Hall and the Concrete Shaft

After the RDB-OH is disassembled, the entire infrastructure will be disassembled in terms of a withdrawal from the Disassembling Hall and the concrete shaft. Here all contaminated systems and equipment are disassembled. As well all non-contaminated systems and equipment which complicate or hinder the release of the Disassembling Hall and the concrete shaft are disassembled. Then the structural components of the Disassembling Hall and the concrete shaft are themselves radiologically assessed, decontaminated if necessary and determined free of contamination through measurement.

## 6 Phasing Out

The phasing out of the FRG, the HL and the operation of the disassembly hall comprises all systems and installations that are still necessary. It includes as well all supporting activities, which are necessary to comply with the remaining protection objectives. The phasing out also encloses the dismantling of the FRG / HL and the disassembly of the RDB-OH. The phasing out systems of the FRG and the HL are already present from the subsequent operation and can continue to be operated unchanged or modified, if necessary. Phasing out systems or replacement systems (e.g. ventilation, sewage system, and alarm systems) will be re-established, if this is necessary and practical from technical and/or economic criteria. All operating systems and devices of the disassembly hall will be installed during the erection of the disassembly hall and put into operation.

The following essential systems and installations are required in the context of the phasing out of the FRG and the HL as well as the operation of the disassembly hall:

- Ventilation systems,
- Waste water collecting and treatment systems FRG and HL,
- Power supply,
- Control systems / communication equipment,
- Fire protection systems,
- Parts of the reactor protection instrumentation,
- Radiation protection instrumentation,
- Media supply (e.g. compressed air, demineralized water supply, industrial water supply)
- Physical protection system,
- Lifting devices / transport equipment.

The phasing out systems of the FRG and the HL as well as the operating systems of the disassembly hall will be adapted gradually and continue to be operated according to the dismantling progress. This continues until they are no longer needed and will be dismantled at the end of the dismantling project.

# 7 Radiation Protection

The radiation protection ensures the protection from ionizing radiation of the population, the environment and the personnel, who carry out the dismantling activities. The radiation protection principles for "limitation of doses" as well as "avoidance of unnecessary radiation exposure and dose reduction for man and the environment" will be maintained.

The significant tasks of radiation protection are:

- Definition and monitoring of the radiation protection areas,
- Radiation protection monitoring including the completion of the clearance procedure,
- Radiation protection planning including dose assessment and residual material management.
- Radiation and activity monitoring.

## 7.1 Radiation Protection Areas

The radiation protection areas of the FRG, the HL and the disassembly hall are separated according to StrlSchV into supervised, controlled and exclusion areas and temporarily changing controlled areas.

The entire site of the FRG and the HL is surrounded by a security fence. The disassembly hall of the RDB-OH is surrounded by a fence. Both fences represent the limit of the supervised area. Structural and administrative radiation protection measures, such as shielding, filtering of the exhaust air or measures to prevent inadvertent dispersion of radioactive substances ensures the compliance with the radiation limits.

Controlled areas are areas surrounded by the supervised area, where persons can receive in accordance with the provisions of StrlSchV an effective dose of more than 6 mSv in a calendar year or an organ dose of more than that the values defined there. In case of need, temporary controlled areas will be established by the radiation protection officer. All controlled areas are delimited and marked with a radiation warning sign "CONTROLLED AREA", so an accidental entry cannot happen.

Exclusion areas in accordance with the provisions of StrlSchV are areas of the controlled areas in which the local dose rate may be higher than 3 mSv/h. Exclusion areas are marked and delimited by the radiation protection with the radiation warning sign and the addition of "EXCLUSION AREA - KEEP OUT-". In addition, the exclusion areas are secured so that people cannot gain uncontrolled or accidentally access.

### 7.2 Radiation Protection Monitoring

The radiation monitoring devices used during operation are also used for the period of the phase out and dismantling of the FRG and the HL. A local dose rate monitoring system will be installed and operated in the Disassembling Hall for the continuous monitoring of the radiation level during the disassembling of the RDB-OH. In addition, aerosol monitors are used for the continuous measurement of suspended radioactive particles in the air.

Within both operational sites the FRG / HL and the disassembly hall of the RDB-OH, mobile radiation monitoring devices are available, which can be used for everyday use. There are sufficient $\alpha$-, $\beta$-, and $\gamma$-measuring stations available for the evaluation of aerosol and water samples, wipe tests, other radioactive preparations or for the analysis of samples with unknown isotope mixtures.

According to a fixed schedule, all the rooms, corridors and staircases of the buildings will be monitored regularly through measurements.

Contamination monitors will be used in order to recognise personal contamination. These are located in the external area of the controlled areas in which open radioactive substances are handled. Alternatively, a control of persons is possible, by means of mobile radiation monitoring devices.

There are two independent dosimeter for monitoring occupationally exposed persons:

- Electronic dosimeter with a display for daily monitoring,
- Dosimeter of an official measurement body which will be evaluated regularly.

### 7.3 Radiation Protection Planning

Before beginning with the dismantling work, a radiation protection planning takes place with the objective of minimising the collective and individual doses, as well as the radioactive waste, taking into account technical and economic considerations.

For the collective dose determination, the number of active persons in the respective dismantling area as well as the respective average dose rate within this area was measured for each work procedure.

For the dismantling of the FRG and the HL, a total collective dose of approx. 181 man-mSv was estimated. By far the largest amount of the estimated total dose with approx. 102 man-mSv originates from the dismantling of the activated structures of the reactor pool. The remaining dose splits between the dismantling of the HL and the remaining dismantling in the entire plant. This is in particular due to the dismantling of the contaminated waste water system as well as the removal of the operating waste from concrete cells 2–4.

A total collective dose of approximately 190 man-mSv is estimated for the disassembling of the RDB-OH and the measures to the subsequent clearance of the controlled area.

The estimated total dose for the measures of the decommissioning of the FRG-1, the dismantling of the FRG and the HL and the disassembling of the RDB-OH is therefore approx. 371 man mSv.

### 7.4 Radiation and Activity Monitoring

Activity retention measures will be taken for the dismantling of the FRG, the HL and the RDB-OH (such as reducing the pollutant release). For this, dust barriers, such as tent enclosures or foil covers will be set up in dismantling areas, in which separating, lifting or demolition work is carried out that generates dust or aerosols. An extraction with mobile filtering equipment is used at the point of origin in cases of high dust generation.

**Gaseous Discharges at the Operational Site of FRG / HL**

Within the controlled area of the FRG and the HL, airborne, radioactive materials (aerosols, gases) can occur during phasing out and the dismantling of the FRG and the HL. The nuclide composition of the aerosol discharges is dominated by the nuclides Co-60, Cs-137 and Sr-90.

The following licensing values were requested for the radioactive gaseous discharges with the exhaust air in the calendar year:

- Aerosol radionuclides 3.7 E07 Bq,
- Gaseous radionuclides
  - H-3 (Tritium) 1.5 E11 Bq,
  - C-14 1.2 E09 Bq.

With maximum exhaustion of the licensing values, results an effective dose for individual persons in the population at the most unfavourable receiving point in the environment of < 1 µSv in a calendar year.

Licensing values for radioactive iodine and noble gases can be omitted for the decommissioning of the FRG-1 and the dismantling of the FRG and HL. They are no longer relevant due to the setting of the reactor operation and the removal of all fuel elements.

**Gaseous Discharges at the Operational Site of the Disassembly Hall RDB-OH**

During the disassembling of the RDB-OH, airborne, radioactive substances (aerosols, gases) can occur within the controlled area of the Disassembling Hall. It is planned that all work which can generate a mobilisation of loosely bound activity into the room air of the Disassembling Hall, are performed with suitable extraction or within closed working tents including mobile extraction and filtering. It is assumed that these measures are effective. The internal threshold value for the aerosol activity of 10 Bq/m³ ensures that the activity concentration of the exhaust air stays below the exemption levels defined in Annex VII, part D, table 4, column 2 of the StrlSchV. A filter efficiency of > 99.97 % is taken into account.

Due to the license pursuant to § 7 AtG, the following licensing values were requested for the radioactive gaseous discharges with the exhaust air in the calendar year:

- Aerosol radionuclides 1.0 E07 Bq
- Gaseous radionuclides
  - H-3 (Tritium) 1.0 E08 Bq,
  - C-14 1.0 E09 Bq.

**Liquid Discharges at the Operational Site of FRG / HL**

For the phasing out and the dismantling of FRG and HL, the following licensing values were requested for the radioactive liquid discharges with the wastewater in the calendar year:

- Total activity (without tritium) 2.0 E09 Bq,
- Tritium 4.0 E10 Bq.

The nuclide composition of discharges with the wastewater is also dominated by the nuclides Co-60, Cs-137 and Sr-90.

**Liquid Discharges at the Operational Site of Disassembly Hall RDB-OH**

Within the controlled area of the Disassembling Hall to be erected, waste water results from the daily cleaning and decontamination work. In addition, once waste water results from the filling water when draining the concrete shaft and from the reactor and shield tank residual water.

The waste water is collected in the controlled area of the Disassembling Hall and is transferred to an approved tank truck or tank container, conditioned and disposed external. No discharge of waste water from the area of the operational site Disassembling Hall with RDB-OH is planned.

Therefore, no application is required for licensing values for the discharge of radioactive substances with waste water.

**Radiation Exposure**

For the calculation of the potential radiation exposure due to discharge with the exhaust air, the resulting value for the effective dose in the calendar year is approx. 3.2 E-02 mSv. This value applies to the most exposed age group of infants (> 1 – ≤ 2 years) with the assumption of a complete exhaustion of the licensing values for the discharge of radioactive substances with the exhaust air. This value results almost exclusively from the radiological initial loading (cf. chapter 3.9). The most unfavourable receiving point is located at a distance of 1,100 m in sector 11 at the fence of KKK (for exposure path, external exposure and inhalation) or sector 12 northeast of the outdoor switchyard of KKK (Ingestion), see Figure 3-2.

The amount of the exposure which is caused by discharges from FRG / HL and the disassembly hall RDB-OH, is < 1 E-03 mSv/a.

For the calculation of the potential radiation exposure through discharge with the wastewater, the resulting value for the effective dose in the calendar year is approx. 1.0 E-01 mSv in the local area of the HZG and approx. 1.4 E-01 mSv in the distant area. This value applies to the age group for baby (≤ 1 year) with the assumption of a complete exhaustion of the licensing values for the discharge of radioactive substances with the wastewater. The potential radiation exposure results for the local or distant area almost exclusively from the radiological initial loading (cf. chapter 3.9). The amount of the exposure which is caused by discharges from FRG and HL, is at < 3 E-03 mSv/a.

The potential radiation exposure from the discharge of radioactive substances with the exhaust air and the wastewater are respectively below the limit value of 0.3 mSv for the effective dose in the calendar year according to § 47 StrlSchV. Also the dose values for the organs and tissues are compliant to § 47 StrlSchV.

The radioactive substances actually discharged with the exhaust air and waste water will be determined. This is performed by measurements within the framework of the emissions monitoring, balancing and documentation according to the current state of the art.

The potential radiation exposure in the surroundings of the FRG / HL and the disassembly hall of the RDB-OH consists of the potential radiation exposure from the emission of radioactive substances with the exhaust air and the waste water and the potential radiation exposure from the direct radiation from the operational site.

Operational measures ensure that the sum of the external exposure from the direct radiation and the exposure from discharges from both operational sites is safely below the limit for the effective dose according to § 46 StrlSchV of 1 mSv in the calendar year for individuals of the population at the border of the surveillance areas.

## 8 Residual Material and Wastes

The total mass of the FRG, HL and the disassembly hall of the RDB-OH amounts to approx. 39,000 Mg. In Figure 8-1 the mass flows are represented with the expected disposal paths. It is expected that less than 1 % of the entire mass must be disposed of as radioactive waste. The largest part (more than 99 %) can be conventionally disposed of.

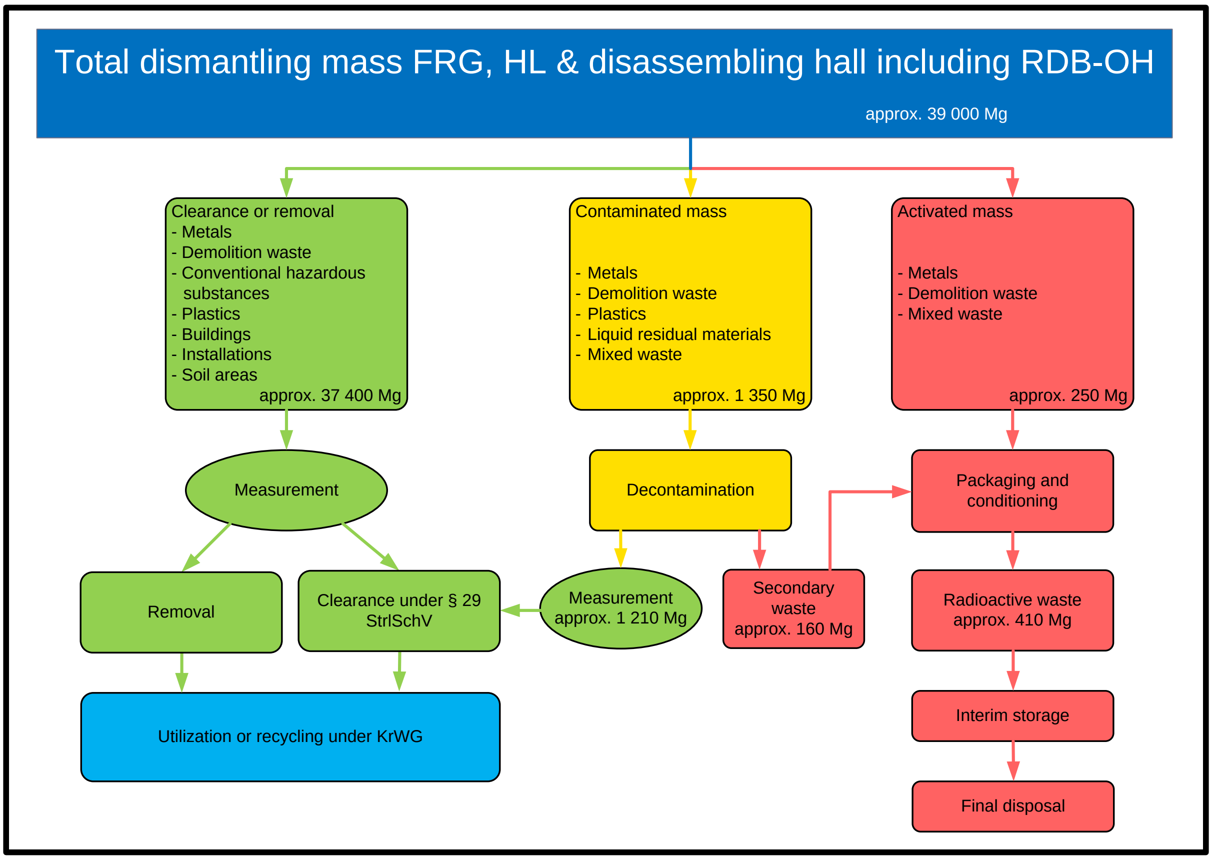


Figure 8-1: Representation of the total mass balance

During the dismantling of the FRG, HL and the disassembly of the RDB-OH, the following measures are applied for the avoidance of additional radioactive residual substances:

- Avoidance of contamination carry-over.
- Use of best practices, equipment and installations.
- The intended disposal route for the accumulating waste is determined on the basis of a radiological characterisation before the start of the respective dismantling work.
- Objects and materials that are not required in the controlled area must not be taken in.

All masses to be dismantled as part of the dismantling of the decontaminated or possibly activated structures of the FRG, the HL and the disassembling of the RDB-OH are either disposed of as radioactive waste or they are released in accordance with § 29 StrlSchV, if the corresponding exemption levels are not exceeded,. Residual materials will be released directly on site, if they can be decontaminated and evaluated directly without processing or with minimal effort by means available at HZG. Radioactive waste for which an external handling step is not reasonable (e.g. builder's rubble) is directly packed into suitable containers according to the terms of acceptance for the Federal Final Disposal. The radioactive waste of the FRG and the HL then will exclusively be stored in the TBH. The radioactive waste of the RDB-OH is placed into storage in the HAKONA. All other contaminated and activated residual materials and waste which occur during disassembling is processed and treated in external conditioning and treatment plants. The treated or conditioned radioactive waste is then returned and also put into storage in the TBH, HAKONA or in another external storage site until the transportation to the Federal Final Disposal. The corresponding acceptance conditions for the intermediate storage are complied with.

A clearance according to § 29 StrlSchV may also be performed at third parties, e.g. at external conditioning and treatment of residual materials.

The complete residual material and waste flow will be documented.

In Figure 8-2 the principal routes are represented for the disposal of the radioactive residual material and waste incurred in the dismantling process.

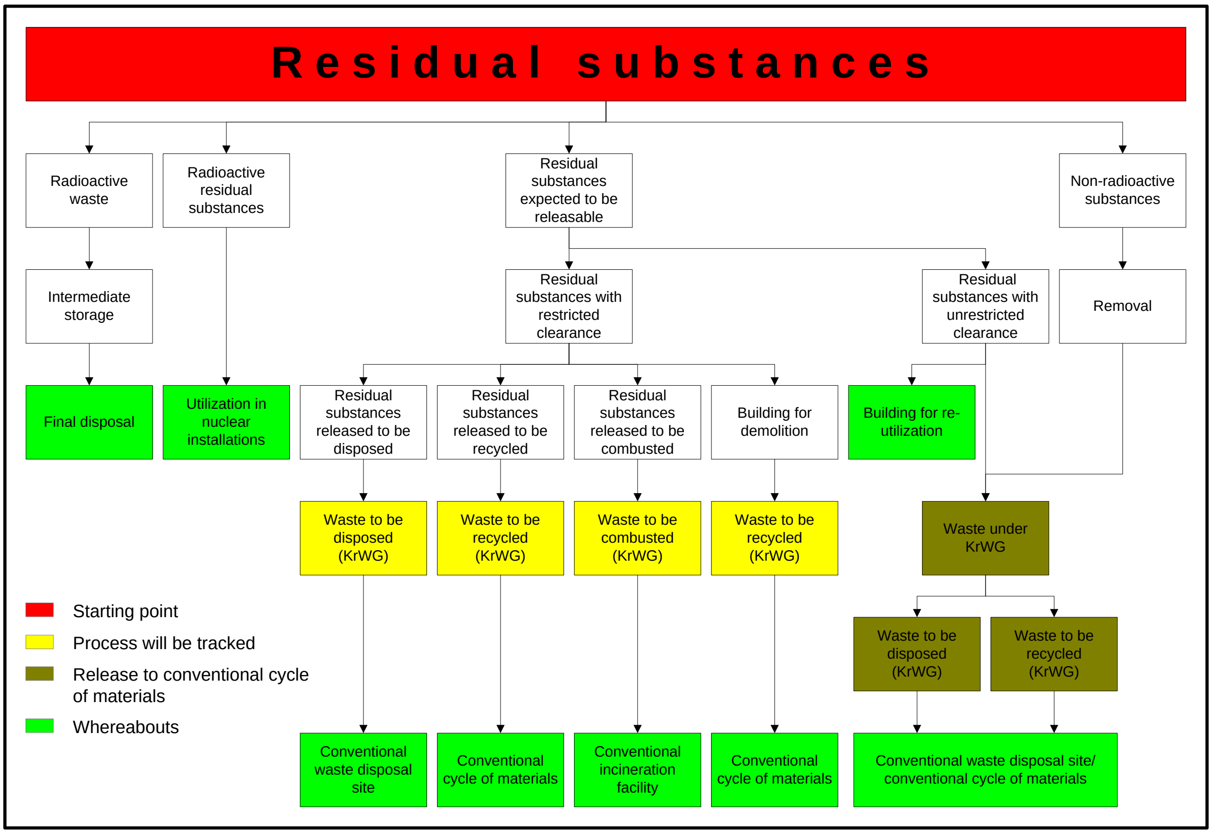


Figure 8-2: Residual material disposal routes

## 9 Accident Analysis

For planning decommissioning in accordance with StrlSchV, structural or technical protective measures shall be undertaken, under consideration of the potential damage extent, in order to limit radiation exposure in the event of design basis accidents through the release of radioactive substances into the environment. The effective dose caused by the release of radioactive substances into the environment thereby must not exceed the so-called incident planning value of 50 mSv.

The estimate of the total activity inventory of the FRG and the HL including operating waste resulted in a value of approx. 5.0 E15 Bq. The activity inventory is thereby almost completely trapped in the activated plant structures of the reactor pool installations, the reactor pool and operating waste and thus not directly releasable. Significantly less than 1 % of the total activity inventory is present as contamination.

The estimation of the total activity inventory of the RDB-OH resulted in a value of approx. 5.6 E14 Bq. The activity inventory is thereby almost completely trapped in the activated plant structures of the RDB-OH and thus not directly releasable. Significantly less than 1 % of the total activity inventory is present as contamination.

The protection measures to be taken for the dismantling of the FRG, HL and the disassembly of the RDB-OH are determined by the hazard potential still present in the plant and the probability of the occurrence of an accident. The potential danger results primarily from the still existing, unfixed activity inventory (essentially as a part of the contamination present in the plant), which can be released partially into the environment during accidents. This may happen for example during dismantling or transporting plant equipment within the plant, as well as when handling with radioactive residual materials and waste.

For the following event sequences to be considered within the accident analysis for the FRG, HL and the RDB-OH the release of radioactive substances into the environment cannot be ruled out. These events are divided into two groups:

- Internal events:
    - Fire,
    - Load drop,
    - Leakages,
    - Failure of radiation protection or supply equipment.

- External events:
    - High water / flooding, storm, heavy rain, ice and snow,
    - Penetration of gases,
    - Explosion due to chemical reactions,
    - External fire,
    - Earthquake,
    - Aircraft crash (beyond design-basis).

The considered safety-relevant event sequences and their corresponding potential radiation exposures in the environment, result in values for the most unfavourable reference person in all cases, which is clearly below the incident planning value.

For the operational site FRG / HL, the case of the load drop is the covering event. It was shown that the possible radiation exposure is maximum 0.1% of the permissible exposure (50 mSv) according to StrlSchV as a result of accidents.

The earthquake represents the worst event for the operational site Disassembling Hall RDB-OH as well as for the HZG site with a potential radiation exposure of 3.4 E-2 mSv. This corresponds to an exhaustion of the incident planning value of maximum 7 %. Thus, it was shown that sufficient precaution has been taken against possible events.

Furthermore, an aircraft crash into the FRG / HL or the disassembly hall of the RDB-OH is assumed as a very rare, beyond-design-basis event. The consequences of an aircraft crash are treated and evaluated as a beyond-design-basis event according to the provisions of the "Basic Recommendations for disaster control in the vicinity of nuclear installations". It was show that no drastic measures for the disaster control are necessary.

## 10 Impact on the Environment

The environmental impact assessment (UVP) determines, describes and assesses the effects of the decommissioning of the research reactor FRG-1 as well as the dismantling of the FRG / HL and the disassembly of the RDB-OH on the affected objects of protection:

- Humans, including human health,
- Animals, plants and biological diversity,
- Soil,
- Water,
- Air,
- Climate,
- Landscape,
- Cultural heritage and other material goods.

The basis of the UVP is an environmental impact assessment (UVU) performed on behalf of the HZG.

Possible significant or considerable negative effects on the objects of protection by the effect factors of conventional air pollutants, noise, vibrations, light and heat emissions, utilization of land and sealing, construction of structures, water extraction, drainage of conventional waste water and accumulation of radioactive and conventional wastes can be excluded. This is because the predominant part of the dismantling activities takes place within buildings, and emissions due to their insignificance are not able to cause any relevant additional effects.

The potential radiation exposure through radioactive discharges with air and waste water is significantly below the legal limit value. Immission monitoring ensures with through appropriate measures that the limit of the effective dose of 1 mSv/a for members of the public is always securely complied with.

There is still no sufficient precise planning for the conventional demolition of the FRG, HL and disassembly hall of the RDB-OH. A process which is customary and proven by industry will be applied for dismantling. Possible effects on the environment can be minimized or avoided if necessary through additional measures. Potential significant or considerable negative effects on the objects of protection are not expected according to the current state of planning. The conventional demolition will be requested and reviewed in a timely manner with the required construction application process according to the regional building regulations of Schleswig-Holstein.

Overall, the UVU results show that no significant or considerable negative effects are to be expected from the decommissioning of the research reactor FRG-1 as well as the dismantling of the FRG / HL and the disassembly of the RDB-OH on the objects of protection, especially for the people and the environment.