

DISASSEMBLY OF THE RESEARCH REACTOR FRJ-1 (MERLIN)

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ABSTRACT

This report describes the past steps of dismantling the research reactor FRJ-1 (MERLIN) and, moreover, provides an outlook on future dismantling with the ultimate aim of a "green field site". MERLIN is an abbreviation for **MEDIUM ENERGY RESEARCH LIGHT WATER MODERATED INDUSTRIAL NUCLEAR REACTOR**.

In 1985 the FRJ-1 (MERLIN) was shut down as the first of the two reactors at Research Centre Jülich. An important step was performed in the year of shutdown by removing the fuel elements from the plant. In the following years, no explicit dismantling activities took place. Only in 1995 were the first steps towards dismantling undertaken – at first, however, exclusively in the conventional area, by disassembling the air coolers. Disassembly of the first nuclear facilities started three years later. This essentially involved the cooling loops (secondary and primary cooling system) and the experimental devices that had been used in the course of various experiments at the reactor. After disassembly of these systems, the former reactor core was addressed. The reactor tank internals present in the core served, among other things, to accommodate the fuel elements during the phases of reactor operation. In addition, components were present in the core region, which served to control the cooling water flow in the reactor tank and optimise the neutron flux for an effective experimental utilization. Due to their positioning, these components were generally highly activated. Particular problems were posed by the material combination of the tank internals. Although most of them were made of aluminium, fastening elements (bolts and nuts) of stainless steel had been used for assembly. On account of the activation levels of aluminium and steel differing by several magnitudes, therefore, all bolted connections had to be removed from the aluminium components for minimizing the high-level waste. The reactor tank internals were removed by remote handling, under water and down to a depth of approx. 6 m. After completion of the above disassembly work, the tank water was drained from the reactor tank and the reactor block prepared for dismantling. The reactor block essentially consists of the reactor tank (aluminium), the thermal shield (lead) and the biological shield (normal and heavy concrete), which is surrounded by a steel liner on both sides. In autumn 2001, the first dismantling activities started at the reactor block. Dismantling was performed on the radiological basis of core samples drilled in advance from the biological shield and the inner (near-core) steel liner. The result of the samplings reflects the radiological condition of the reactor block.

INTRODUCTION

The research reactor FRJ-1 (MERLIN) was a light-water-moderated and -cooled swimming pool reactor of British design. It was constructed from 1958 to 1962 on the premises of the Research Centre. Since 1964 it was operated for the implementation of experiments, initially with 5 MW and since 1971/72 with 10 MW thermal power. After increasing the thermal power, 4 horizontal beam tubes, 2 thermal columns and various vertical in-core irradiation rigs were available for experiments at an average thermal neutron flux of 3.2×10^{13} n/cm²s and a maximum thermal neutron flux of 1.1×10^{14} n/cm²s.

After approx. 21 years of operation the FRJ-1 (MERLIN) was finally shut down in 1985 and transferred to shutdown operation. In the same year, the fuel elements were removed from the plant and, after interim storage in the spent-fuel pool of the neighbouring FRJ-2 (DIDO), transferred until 1988 to the USA and then to Great Britain (Dounreay) for reprocessing. Under the still valid operating licence, the following years were used for the implementation of measures in preparation for decommissioning and dismantling.

However, the continuous planning and execution of decisive dismantling work was only started in 1996. Until then, the planning capacities of the Research Centre had been tied up by the preliminary planning for the Spallation Neutron Source (SNQ), the subsequent planning and construction of the COSY particle accelerator and the seismic upgrading of the FRJ-2 (DIDO). The project team set up in 1996 is still responsible even today for dismantling the reactor. It has the same functional structure, but partly a different staff configuration caused by age-conditioned fluctuation. It comprises staff members from several institutes and thus makes use of the synergies from project and special departments including the special experience and internal know-how of the operator's last so-called "know-how carrier" still left. The operator's staff belong almost exclusively to the operating crew of the FRJ-2 (DIDO), the second research reactor on the Research Centre's premises, which is still operated as a neutron source primarily for solid state research. For planning, engineering, administration and waste management within the framework of dismantling measures, up to the present, in-house capacities have been used as far as possible, but due to the increasingly complex tasks and lack of capacity external specialists are increasingly called upon. Manual dismantling work has been and will also be performed in future exclusively by external specialists.

LICENSING STATUS AND PROCEDURE

Before the FRJ-1 (MERLIN) was finally shut down, an application under the German Atomic Energy Act was filed in September 1984, which comprised decommissioning of the facility and initially only safe enclosure. In 1996/97 this application was replaced by a modified application abandoning safe enclosure, which had become possible due to the meanwhile reduced activity inventory. The application specifically concerned the decommissioning of the reactor and the dismantling of plant components no longer needed. These comprised essentially the cooling loops, except for the still required ancillary systems of the primary coolant circuit (make-up feed system, cleaning system, drain system) and the experimental devices. The application was complied with in July 1997 by granting the 1st partial licence.

In September 1999 a further application was filed for the dismantling of plant components. This essentially comprised the removal of the reactor tank internals and the internals still left in the experimental channels of the beam tubes and thermal columns. Moreover, draining of the reactor tank water with subsequent dismantling of the remaining primary cooling system was applied for. The reactor tank internals comprised the components in the core region of the

reactor tank serving, on the one hand, to accommodate the fuel elements and, on the other hand, to optimize the coolant and neutron flux (s. Fig. 1).

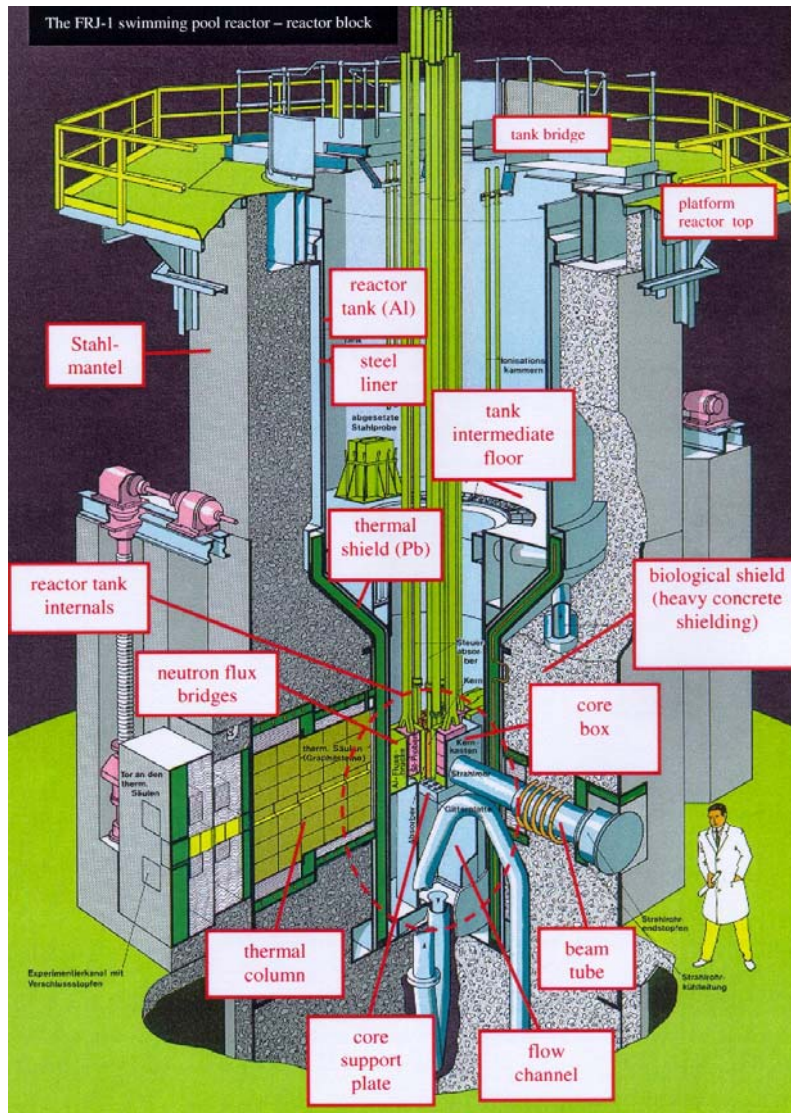


Fig. 1 Reactor block of the FRJ-1 research reactor (MERLIN)

The internals of the experimental channels were essentially shielding components, which had been integrated into the beam tubes after disassembly of the experiments, and graphite used for neutron moderation in the thermal columns. The application was complied with in April 2000 by granting the 2nd partial licence.

In November 2000, the dismantling of the reactor and storage block of the FRJ-1 was applied for. The reactor block with its central component, the reactor tank, served to safely accommodate the fuel elements including the radiological shieldings required. Moreover, the experimental devices for the implementation of irradiation experiments were integrated in the reactor block. Essential components are here the biological shield of concrete, including a surrounding inner and outer steel liner, the thermal shield of lead, the reactor tank of aluminium, and beam tubes and thermal columns as the experimental devices (s. Fig. 1). As a basis for application, test bores were already drilled in spring 1999 in the biological shield and the inner steel liner of the reactor block, which revealed the radiological condition of the

reactor block. The storage block served to store irradiated experiments from the experimental devices. This includes a cubic block of normal concrete with the dimensions 2.6 m x 2.1 m x 2.8 m. Eight receiving tubes as well as a set-down chamber served for the storage and decay of activated experimental and reactor specimens. For reasons of shielding, various blocks of steel and lead were integrated into the storage block. The application of November 2000 was complied with in late July 2001 by granting the 3rd partial licence.

DISMANTLING HISTORY

Dismantling begins

When the 1st partial licence was granted, the first dismantling work concerning contaminated and/or activated plant components of the reactor facility became possible. By the end of 1998 the complete secondary cooling system and the major part of the primary cooling system were dismantled. Furthermore, the experimental devices, including a rabbit system conceived as an in-core irradiation device, were disassembled and disposed of. In total, approx. 65 t of contaminated and/or activated material as well as approx. 70 t of clearance-measured material were disposed of within the framework of these activities. In general, and this also applies to the dismantling steps described below, the contaminated and/or activated parts removed were transferred to the Service Department for Decontamination of Research Centre Jülich, where they were disintegrated in existing facilities (e.g. in the REBEKA disintegration cabins), decontaminated, conditioned (e.g. supercompacted), burned (solid and liquid materials), vaporized (water) or interim-stored in the radioactive waste store, depending on their radiological condition. Clearance-measured plant parts were ultimately disposed of conventionally (e.g. scrap trade, landfill disposal).

Radiological condition

In order to assess the radiological condition, core samples were drilled in early 1999 from the biological shield of the FRJ-1. With drilling diameters of 76 mm in the outer region and 56 mm in the inner region of the biological shield at a maximum total depth of approx. 1.80 m four drillings were performed at different heights and core samples were subsequently taken from the radiologically significant inner steel liner. Due to the composition of the heavy concrete based on magnetite with nailtip scrap addition 14 drill bits were needed for drilling. This also indicated that diamond cutting tools are rather unsuitable for dismantling the biological shield. The gamma-spectrometric and radiochemical investigations of the drilling samples took place in the "Large Hot Cells" and at the Institute for Safety Research and Reactor Technology of Research Centre Jülich. The results of these investigations showed the activity distribution in the reactor block.

For a comprehensive description of the radiological condition, moreover, in the second half of 1999 a contamination atlas was prepared for the reactor building. Gamma-spectrometric and radiochemical investigations were performed on representative wipe and scratch tests and allocated to the sampling locations. Representativeness was ensured by incorporating reactor radiation protection staff who were informed about the past of the reactor plant. At the same time, plans for handling the individual areas were drawn up in preparation for later clearance measurements.

Preparation for dismantling the reactor block

With the granting of the 2nd partial licence in April 2000 the way was paved for removing the core internals from the reactor tank. These internals were essentially the core support plate, the core box, the flow channel and the neutron flux bridges (s. Fig. 1). The core support plate served to accommodate the fuel elements enclosed in the core box. The flow channel served to connect the core support plate by form-fitting to the cooling water return opening in the tank bottom and thus ensured optimum flow through the support plate. The neutron flux bridges acted as a link between the core box and the thermal columns. The aim was to improve the neutron flux for utilization in various experiments in thermal columns I and II. All components consisted of aluminium, the connecting elements such as bolts and nuts, however, of stainless steel.

Particular problems were encountered in removing the reactor tank internals due to the cramped conditions in the core region along with the unfavourable fastening methods. The majority of the components had been mounted in the assembly phase using slotted screws perpendicular to the viewing direction. Moreover, single components had been secured by hexagon bolts and nuts not readily accessible after installation. Due to the high activation of the core internals, disassembly had to be remotely controlled under water. All removal work was carried out from a tank intermediate floor (s. Fig. 1). A precondition for removal was minimizing the high-level waste. For this reason, the separation of aluminium and steel, whose activation level differed by several magnitudes, was a primary goal. This meant, however, that all bolted connections had to be unscrewed from the aluminium components. To fulfil this requirement, it was necessary to design and manufacture various special tools with which both the slotted screws and the other bolted connections (hexagon screws with nuts) could be remote-handled and unscrewed under water up to a distance of 6 m or in the case of nonreleasable screw connections by means of a special milling technique. In order to visualize the screw connections arranged as a rule perpendicular to the viewing direction, an 8 mm video endoscope was used, which was directly attached to the tool. This system is also excellently suited for positioning the tools for the unscrewing and milling procedure (s. Fig. 2).



Fig. 2 Unscrewing bolted connections in the region of the reactor core viewed through the video endoscope

Individual reactor components had to be cut under water inside the reactor tank. On the one hand, this step served to disassemble components welded onto the reactor tank and to adapt removed reactor components to the waste containers used, on the other hand, this served to create manipulation openings required for the further removal of the reactor tank internals. Mechanical cutting was selected for the corresponding demolition work and all processes had to be remote-controlled down to a depth of 6 m. For the existing aluminium thicknesses amounting up to 100 mm for the core support plate, a pneumatic compass saw was upgraded for under-water application (s. Fig. 3).



Fig. 3 Cut through the core support plate in the reactor tank using a special underwater saw

Due to the cramped conditions in the reactor tank, moreover, a special grab for loading the reactor components had to be designed and manufactured. This special grab is characterized, in particular by its compact design and suitability for underwater application. Furthermore, it had to fulfil the requirements for remote-controlled unscrewing and closing over a distance of up to 6 m.

The construction of a mock-up had proved particularly efficient, which reproduced the reactor tank internals taking account of the special removal conditions on a 1:1 scale. Apart from its function as training equipment for remote-controlled disassembly as well as a test device for the trial and modification of the special tools, it served especially the official expert for the testing and acceptance of tools and work flows. This procedure has proved particularly effective and time-saving.

The waste parts arising were packaged in waste containers, generally 200 l drums, and transferred to the Service Department for Decontamination of the Research Centre. This included approx. 2.5 t of waste parts with a total activity of approx. 8×10^{11} Bq. Due to the activation level of the reactor components it was necessary, as a rule, to place the waste containers into shielded transport casks (MOSAİK II-15 casks from GNS).

After completion of the disassembly work, the reactor tank was freed as far as possible from fixed contamination with the aid of different cleaning systems and the water was drained from the reactor tank. In preparation for the impending dismantling of the reactor block, shieldings of steel were then introduced into the reactor tank.

Apart from the removal of the reactor tank internals, which accounted for the major part, further measures had to be carried out in preparation for the dismantling of the reactor block.

This concerned, on the one hand, the remaining ancillary systems of the primary cooling loop (make-up feed system, cleaning system, drain system), which were also disassembled and disposed of after draining the reactor tank water. On the other hand, components were still present in the experimental devices of the reactor block, beam tubes and thermal columns, which had to be removed and disposed of before starting to disassemble the reactor block. Among other things, approx. 10 t of graphite blocks were thus removed from the thermal columns and disposed of via the Decontamination Department. Due to the high area dose rates in the region of the thermal columns, removal also had to be remote-controlled using special tools and, in part, under shielding.

DISMANTLING THE REACTOR AND STORAGE BLOCK

In early October 2001 dismantling of the reactor block of the FRJ-1 was started. The relevant contract for planning and implementation was awarded in late 2000 to the GNS (Gesellschaft für Nuklear-Service mbH)/SNT (Siempelkamp Nukleartechnik) dismantling consortium.

The FRJ-1 (MERLIN) reactor block

The reactor block of the FRJ-1 is a sandwich structure (s. Fig. 1), whose main component is represented by the biological shield. In the core region, the biological shield consists of heavy concrete with a thickness of approx. 1.80 m and a density of approx. 4.200 kg/m^3 . Above the conical region of the reactor block (s. Fig. 1) the biological shield consists of normal concrete with a density of approx. 2.350 kg/m^3 . In this region, the biological shield is iron-reinforced and exhibits a thickness of about 1 m. The biological shield is externally and internally surrounded by a steel liner of different thickness (12 to 25 mm). The radiologically interesting inner steel liner has a thickness of approx. 13 mm. On the inside, in the core region, a thermal shield of aluminium-clad lead with a thickness of approx. 100 mm is additionally provided. The central component of the reactor block is the reactor tank of up to 13 mm thick aluminium, which formally housed the reactor tank internals. Various experimental devices in the form of beam tubes and thermal columns are integrated into the reactor block. They consist of dissimilar materials such as aluminium, lead, steel, wood and, moreover, are surrounded by a network of cooling pipes.

Dismantling concept

The reactor block is being dismantled in several phases from top to bottom and from inside to outside. Mechanical techniques are preferred but, if required, thermal cutting techniques are also used. A rock chisel is used for dismantling the biological shield. In thermal cutting, a possible spread of radioactive aerosols is avoided by the use of a special separate filter unit connected to the reactor exhaust air. The mechanical and thermal cutting tools as well as the rock chisel are in part positioned and guided by remote-controlled electrohydraulic working robots (s. Fig. 4).

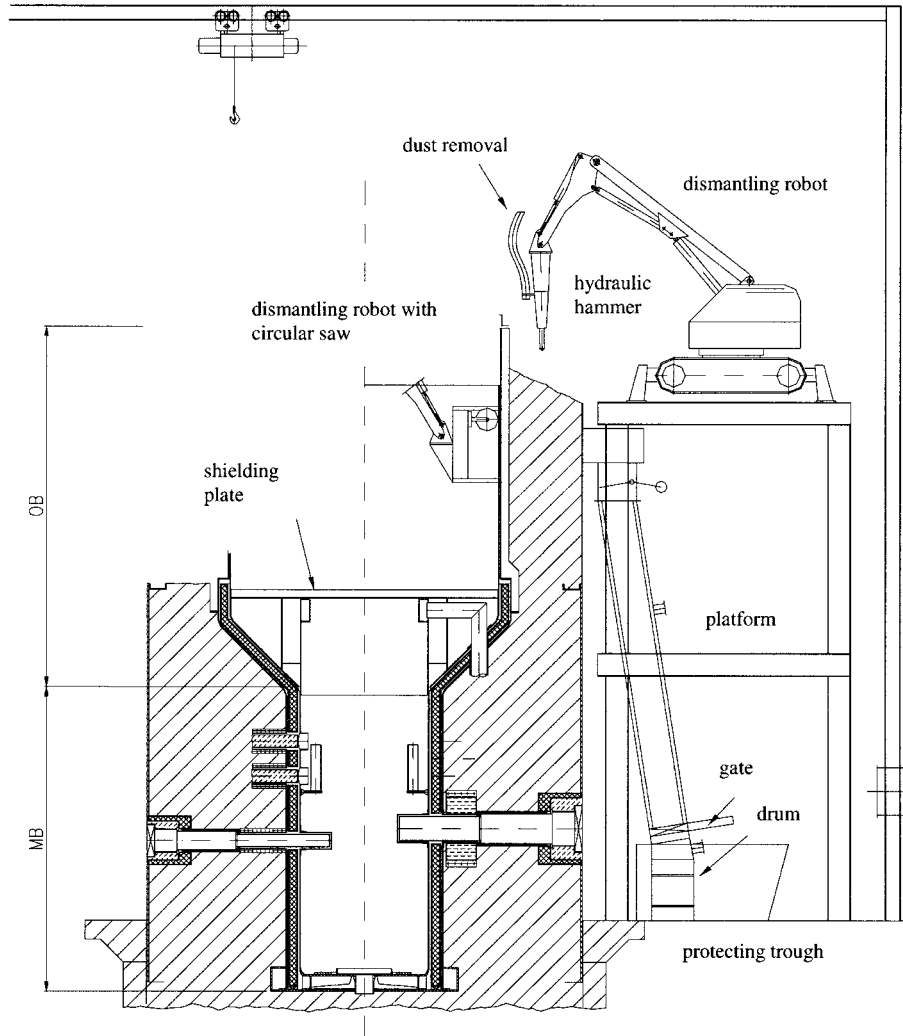


Fig. 4 Concept for dismantling the concrete structures of the biological shield with the aid of a remote-controlled electrohydraulic working robot

In order to avoid a spread of contamination, the reactor block is provided with a self-supporting casing equipped with special lock areas for the transport of materials and persons. The air is permanently extracted from this casing by a special ventilation system with safety afterfilter. For the manipulation of tools and waste packages, an auxiliary crane with a carrying capacity of 1 t will be integrated into the casing structure. Access to the respective regions of work is obtained via a heavy-load scaffold with working platform on which the working robots also move.

Radiation protection

The essential task of radiation protection is radiation protection monitoring of the staff and plant. In addition, it exercises the function of construction management, clearance measurement and logistics of waste management. The most up-to-date measurement technology and a high-performance database system is used in support.

Waste volumes

In dismantling the reactor and storage block approx. 170 Mg of activated radioactive waste with a total activity of approx. 3.5×10^{11} Bq is expected to arise. This waste will be delivered to the Decontamination Department of the Research Centre. The largest part of the reactor block with a mass of approx. 750 Mg can probably be clearance-measured and can be disposed as uncontaminated waste.

Representative samples are taken from the structures and evaluated in a nuclide-specific manner. The resulting nuclide vector is taken as a basis in total γ -clearance measurements for calculating the activity. The decision measurements are performed for the waste in drums with the aid of a clearance measurement device equipped with plastic detectors. Direct measurements and representative samplings are made on larger unit structures such as steel girders.

The waste arising during dismantling is further disintegrated as far as necessary and feasible, separated according to material type and, as a rule, directly packaged in 200 l drums. For the concrete of the biological shield, for example, this means that it must be crushed by a special device to fulfil the required homogeneity criterion of the clearance-measurement device. Without this step, the percentage of material that cannot be clearance-measured would considerably increase due to infringement of the homogeneity criterion. As far as required, the shielded MOSAIK II-15 transport casks can be used for the waste drums. Other packagings available are e.g. steel plate containers and troughed containers.

OUTLOOK

The completion of work for dismantling the reactor and storage block is scheduled for the end of 2002.

In preparation for the decontamination and clearance measurement of the building regions with subsequent release from the German Atomic Energy Act initial concepts are to be developed in parallel with the dismantling activities at the reactor and storage block. A relevant application with the licensing authority will probably be filed in 2002. Simultaneously, the corresponding activities can be put out for tender and contracts awarded. Provided that the corresponding activities will begin in mid-2003, at the latest, the envisaged project completion by the end of 2004 with the aim of a "green field site" is realistic from the present perspective.