CHALLENGES FOR THE RADIATION PROTECTION DEPARTMENT IN THE SCIENTIFIC ENVIRONMENT OF A RESEARCH REACTOR LIKE FRM II

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Abstract

The research reactor FRM II provides neutrons in an energy range from cold up to hot neutrons for scientific, medical and industrial applications and plans to expand the spectrum with an ultra-cold neutron source in the future. With an increasing number of scientific projects, the instruments providing neutrons for the experiments, are constantly being improved and further developed, requiring approval by radiation protection experts. Additionally, external staff and users have to be instructed and radiologically surveilled. Besides the scientific projects, new reactor installations, like the Mo-99 irradiation facility, are under construction, while general maintenance work on reactor operations side is performed. The unique design and scientific application of FRM II present a challenge for the radiation protection team, who has to handle general radiological controls, sophisticated waste management and reactor specific tasks in the frame of German laws and requirements.

1. Introduction

The research reactor FRM II is a tank in pool reactor with 20 MW thermal power designed to provide neutrons for scientific use as well as for medical and industrial applications.
The compact fuel element has a cylindrical geometry. It contains 113 evolvent fuel plates with 8.1 kg high enriched U_3Si_2 dispersed in an Al matrix. Heavy water (D_2O) serves as moderator, surrounding the fuel element, while the fuel plates themselves are cooled with light water in the center of the fuel element. Close to the reactor core are located a hot and cold source to provide a wide neutron energy range for the different applications. Details can be found on the website [1]
The unique design of the fuel element provides an undisturbed thermal neutron flux of 8 x 10^{14} n/cm²/s² at a comparably low thermal power of 60 MWth. A regular schedule provides up to four reactor cycles of 60 days per year. The reactor is operated as a central scientific institution by the Technische Universität München. see Figure 1.

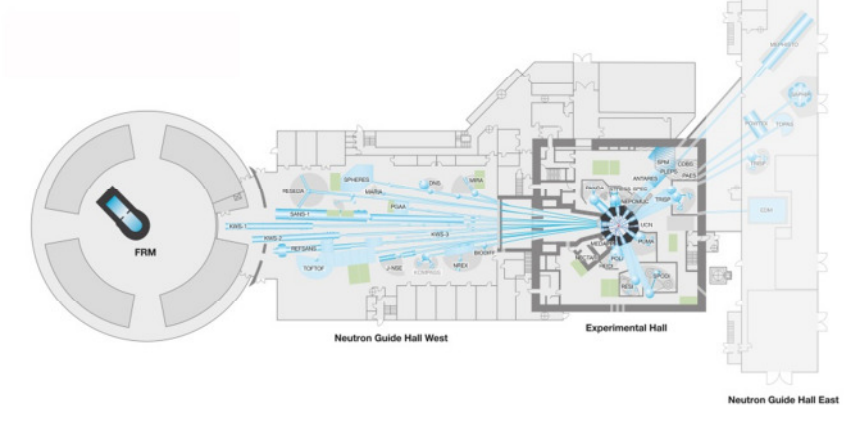

Figure 1: Overview of the scientific installations.

The FRM (also known as ”atomic egg”), Germany’s first reactor, is currently under the process of decommissioning.
The reactor core of the FRM II is located in the center of the Experimental Hall, in which mainly experiments are set up that require thermal neutrons. The beamtubes that lead the neutrons to the Neutron Guide Hall West and East provide the experiments in these locations with cold and in the near future ultra-cold neutrons (Neutron Guide Hall East is currently under construction and commissioning), see Figure 1.
Reactor operation is organized in five departments under the direction of the technical director. Radiation protection which is a part of the reactor monitoring department, is responsible to assure that all radiological processes in and around the installation are compliant with the regulations from the Atomic Energy Law und the Radiation Protection Ordinance. Furthermore the radiation protection is under supervision of the Bavarian Environment Agency (LfU).
In addition to the standard tasks like dose monitoring, contamination control, emission and immission monitoring, non-standard tasks in the frame of the scientific and medical applications have to be performed. These additional tasks are for example radiological surveillance of around 600 experiments per year, which includes radiation and contamination monitoring and accountancy of radioactive samples for scientific use. For this case, FRM II developed an online tool, called Sample Tracker, in which users have to register all samples with exact material composition that shall be used in the scope of an experiment. The tool calculates the expected activation and provides information to decide if the sample has to be registered by the radiation protection department. The reasons for this can be different: Maybe the sample will be activated during the experiment above a limit, it had already been activated or the material is fissionable.
Further, in contrast to power reactors, the majority of the external staff at FRM II is working in controlled areas during reactor operation and not during the maintenance break.
In the following, the special challenges for the radiation department in regard of the special reactor design and use of the reactor are presented on the example of the replacement of the beamline plug JMA 16 (see Figure 2 & 3).

2. Replacement of the beamline plug JMA 16

The replacement of the beamline plug JMA 16 is an example for a project that was accompanied by the radiation protection department in 2017. The beamline SR 6 is located in the Experimental Hall. The former filler plug was replaced by a new one as required for the future operation of the ultra-cold neutron source (UCN).

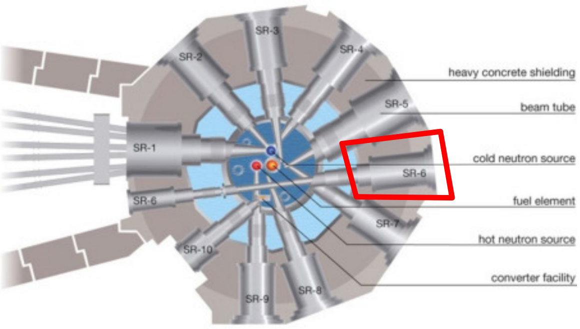

Figure 2: Section of the reactor pool with the beam tubes, the position of the beamline plug JMA16 is marked.

Figure 3: The available space in the Experimental Hall.

2.1. Planning phase

The first step was to plan the disposal of the used beamline plug as well as the procedure of the replacement itself from a radiological point of view.
In order to be compliant with the conditions of acceptance of KONRAD (the German waste disposal facility for radioactive waste with negligible heat generation) the plug was characterized regarding radiological issues and material composition [2].
Therfore, a Monte Carlo simulation was performed to calculate the activation of the plug which consists of two parts (nose and rear part), see Figure 4. The calculation resulted in an estimated dose rate of 1 Sv/h at the plug "nose". The rear part of the plug was based on the results of the Monte-Carlo analysis estimated to be free releasable as non-radioactive material.

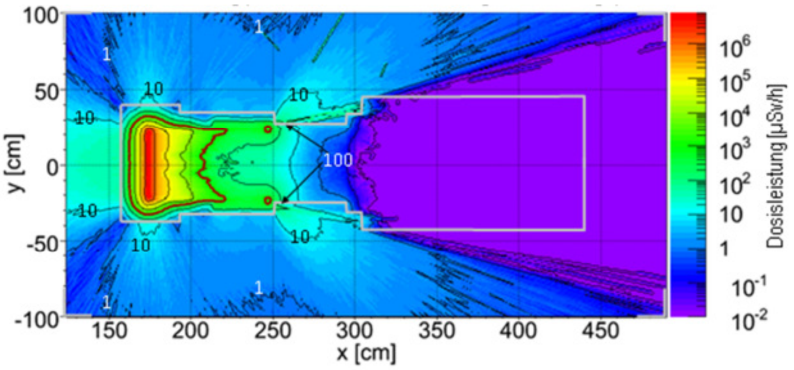

Figure 4: Results of the Monte Carlo simulation.

For disposal, the plug will be separated in two parts by the Gesellschaft für Nuklear-Service mbH (GNS). After conditioning the activated plug nose will be transferred to KONRAD, the rear part is planned to release as non-radioactive material. In September 2016, GNS prepared a disposal concept and submitted it to the Federal Office for Radiation Protection as first step of the entire disposal process.
A special challenge of the plug replacement was the little room around the plug position in the Experimental Hall (see Figure 3) as well as the high dose rate of the plug nose. For this reason, the work procedures had to be planned carefully. Special tools for exchange of the plug and a shielding for the plug nose were constructed.
In preparation of the work under tightened radiological conditions, the handling of the old and new plug was exercised on a mock-up outside the controlled area (see Figure 5).
The complete technical realization of the plug replacement had to be reported to the Bavarian State Ministry of the Environment and Consumer Protection, the nuclear supervisory authority of the FRM II, and finally approved by theirs technical experts (TÜV). In October 2017, the nuclear supervisory authority gave approval for the project start.
The radiation protection of FRM II accompanied the entire planning phase in an advisory function. This way, in collaboration with the science and reactor operation department, the work process was optimized for the given radiological conditions. A dose evaluation [3] was performed with the result that a collective dose for the entire exchange process of about 630 µSv had to be expected.

Figure 5: Mock-up for the exchange of the beamline plug JMA16 with the plug replacement machine in the neutron guide hall east.

2.2. Pulling out the filler plug

The plug replacement machine, the shielding gate and other tools were dismounted after practical training and rebuilt in the controlled area in front of the filler plug in the Experimental Hall. Additionally, some parts of the installed scientific experiment setups that were located in close neighborhood to the beamline plug were dismounted to provide more room for the radiological work.
For radiation protection monitoring, dose rate meters and an aerosol monitor were installed at defined positions around the working area which was covered with tarp to reduce the risk of contamination.
An area for remote control of the plug replacement machine was set up behind a shielding wall. To be able to monitor the changing procedure cameras were installed at different points.
During the radiological work, the experimental hall was closed for scientists and personal, except the ones needed for the work procedure. The replacement took place in the presence of the technical experts of the nuclear supervisory authority and the Bavarian Environment Agency.

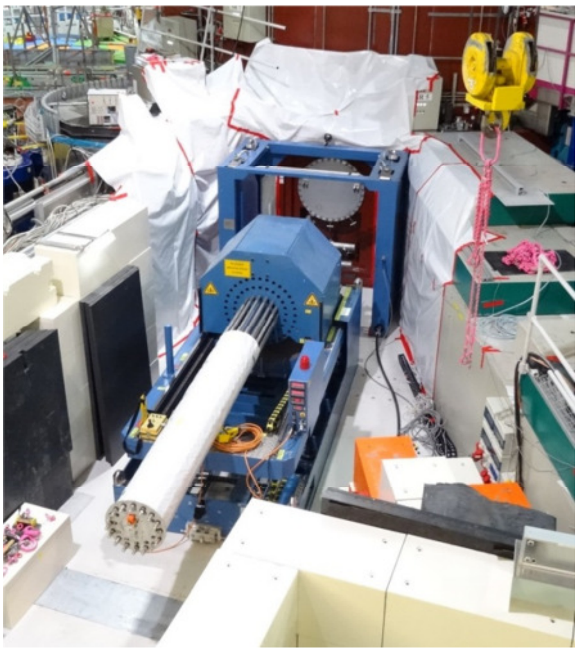

Figure 6: plug replacement machine in front of the beamline six in the experimental hall before the replacement started. The plug is still behind a closure plate.

The dose rate was constantly monitored during the pull out of the plug. A detailed protocol with the measured values was generated after every working step. This is a general practice to track and document all information about specific incidents and to safe this information for similar procedures in the future.

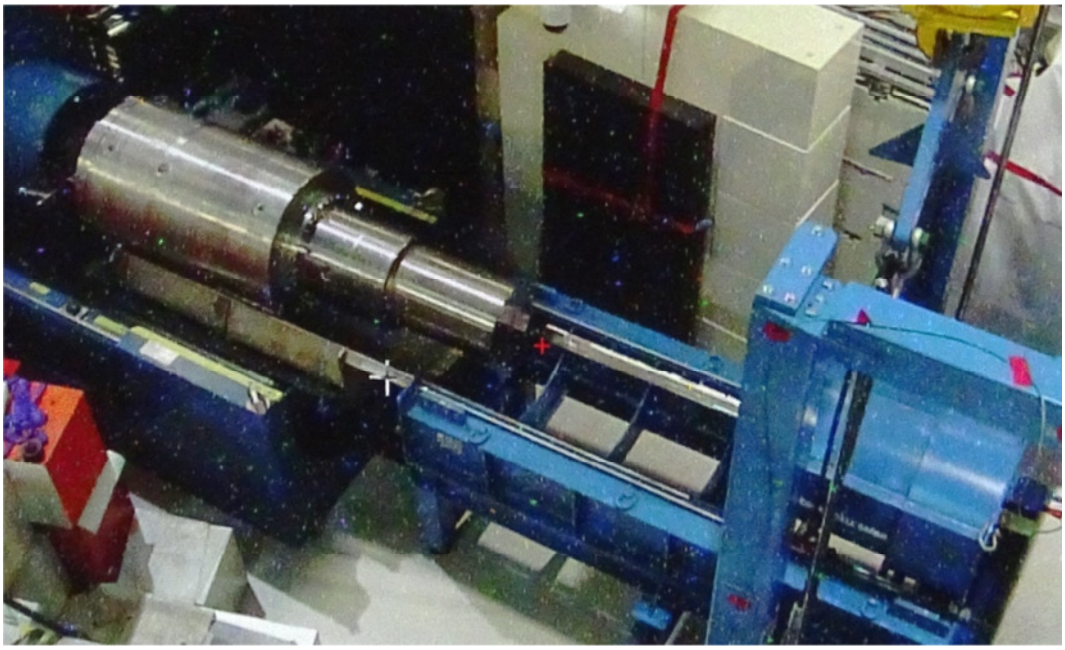

Figure 7: The former plug already pulled out, positioned in front of the plug nose shielding

After the plug was pulled out, the shielding gate, which is part of the plug replacement machine was closed in front of the beamline opening exit. Afterwards, the plug nose shielding was put in front of the plug and the plug was pulled into its shielding.

From this moment on, the dose rate in the area around the plug was low enough for staff to work close to the shielded plug nose.

To verify the calculated activity and the material composition, representative material samples were taken from the plug (see Figure 8). Additionally several dose rate measurements as well as gamma ray spectrometry measurements were carried out.

For transport to conditioning the plug with the plug nose shielding was craned into a 20'-container.

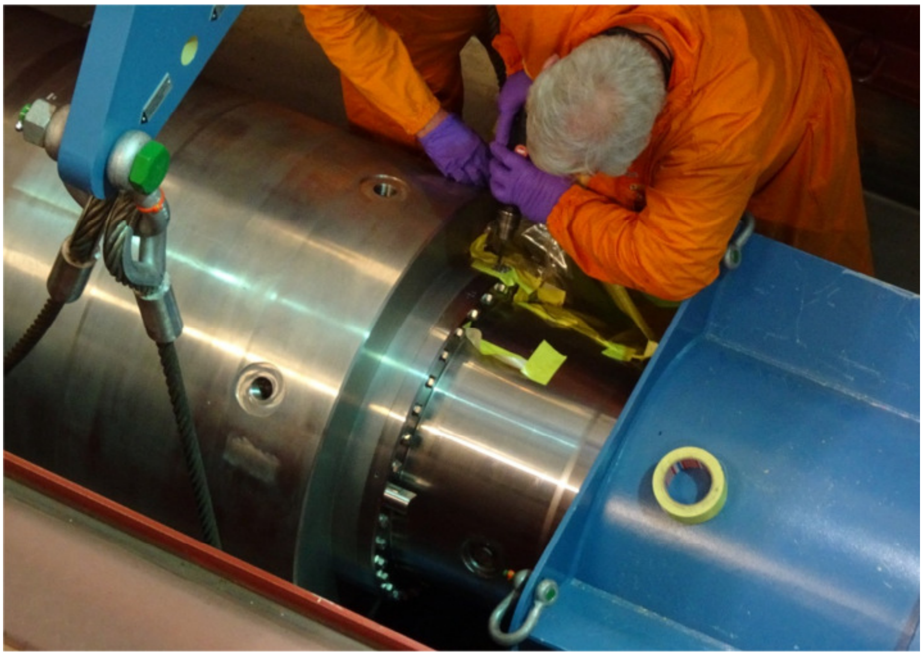

Figure 8: Drilling the samples out of the plug

2.3. Setting the new plug

Prior to the installation of the new plug, quality assurance department performed a visual inspection with a camera of the beamline SR 6.
Afterwards, the new plug was placed on the replacement machine and pushed into the open beamline SR 6 (see Figure 9). The dose rate constantly decreased during the insertion of the plug. The plug in its final position can be seen in Figure 10.

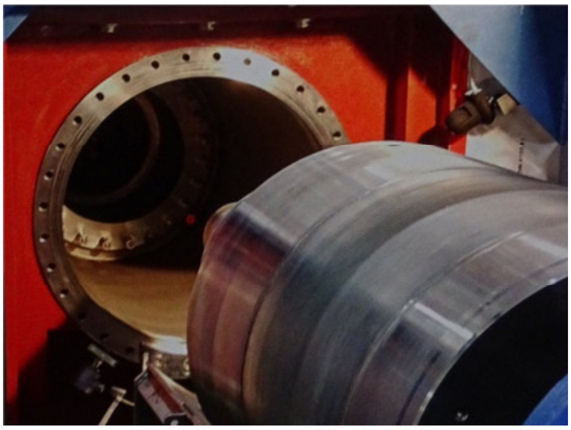

Figure 9: New plug gets pushed into the beamline.

Figure 10: The new plug in its final position

2.4. Summary

As a result of the detailed preparation and the excellent cooperation between the different departments and working groups of FRM II, the exchange of beamline plug was very successful and went completely smooth.
The actual collective dose of the personnel of 160 µSv was significantly lower than the estimated 630 µSv. Furthermore, only minor contamination and no radioactive aerosols were detected.

3. References:

[1] FRM II description, http://www.frm2.tum.de/en/the-neutron-source/

[2] Anforderungen an endzulagernde radioaktive Abfälle (Endlagerungsbedingungen, Stand: Dezember 2014) - Endlager Konrad – (Rev. 2)

[3] Richtlinie für den Strahlenschutz des Personals bei Tätigkeiten der Instandhaltung, Änderung, Entsorgung und des Abbaus in kerntechnischen Anlagen und Einrichtungen: Teil 2: Die Strahlenschutzmaßnahmen während des Betriebs und der Stilllegung einer Anlage oder Einrichtung - IWRS II vom 17. Januar 2005, Nr. 13, S. 258