FRM II Converter Facility

Volker Zill
Heiko Gerstenberg
Axel Pichmaier
Technical University of Munich
Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II)
Lichtenbergstrasse 1, 85748 Garching - Federal Republic of Germany

Abstract

One of the secondary sources at FRM II, the so called converter facility, is feeding fast neutrons into beamline 10 for medical and scientific applications. The neutrons are produced by fission in a pair of fuel plates containing highly enriched U. These fuel plates are installed at the edge of the moderator tank in a mobile carrier that is moved into the moderator tank only when required in order to slow-down the burn-up and extend the lifetime of the plates.

In our presentation, we will report on the dismantling of the device, replacement of its fuel plates, assembly and commissioning of the converter facility after the completion of the work. We will also describe the repair of the position sensor and the maintenance of the cooling pumps being done in the framework of the exchange of the fuel plates.

1. Introduction

The FRM II is a heavy water moderated reactor with 20 MW of thermal power. It is mainly used for neutron scattering experiments but also operates a tomography facility and a positron source. Furthermore, isotope production, silicon doping, and neutron activation analysis are important activities at the FRM II.

One of the secondary sources at FRM II, the so called converter facility, is feeding fast neutrons into beamline 10 for medical and scientific applications. The neutrons are produced by fission in a pair of fuel plates containing highly enriched U. These fuel plates are installed at the edge of the moderator tank in a mobile carrier that is moved into the moderator tank only when required in order to slow-down the burn-up and extend the lifetime of the plates.

2. The converter facility

2.1 Function

The converter facility (SKA) is supplying fast neutrons($\approx 1.5 \times 10^9$ n/cm²s) for multiple medical and scientific applications and experiments. The beam covers an area of 20 cm x 30 cm.

2.2 General description

The main components of the converter facility (SKA) are:

- the installations inside the reactor pool,
- the rooms for medical and scientific irradiation and
- the operating and monitoring station.

2.3 Installations inside reactor pool

The outer cylinder jacket of the moderator tank is equipped with a rectangular nozzle, where the inner and outer converter duct is mounted. The inner duct enters the moderator tank and forms the barrier between heavy and light water. The outer duct is flanged to the inner duct outside the moderator tank and is surrounded by light water (pool water).

The converter facility contains 2 fuel plates (250 x 176 x 3,3 mm³ each) being produced in the so called sandwich technology. The uranium is highly enriched (93 % U-235) and mixed with silicide, afterwards rolled between aluminium plates. The fission in the plates generates a thermal heat of about 70 kW. A pair of fuel plates is installed within the mobile carrier.

The parking position of the mobile carrier is outside the moderator tank and not exposed to neutron irradiation.
By an electrical driving unit and a spindle the mobile carrier is moved from the parking position into the working position inside the moderator tank where it is irradiated by thermal neutrons. Consequently fission processes are initiated in the converter plates and fast neutrons are liberated.

Two redundant pumps suck pool water and guide it through pipes, compensators and the inner duct to the converter plates for cooling. Finally the heated cooling water exits into the reactor pool. The pool itself is equipped with a dedicated cooling system.
Sensors measure the inlet and outlet temperature of the cooling water and the mass flow as well.

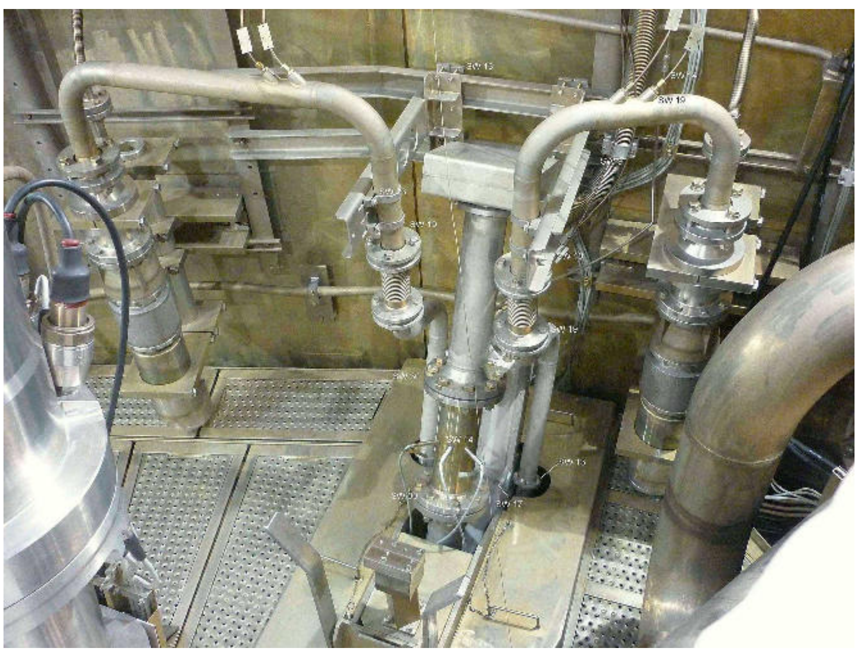

Fig 1. The installations of the converter facility inside the reactor pool

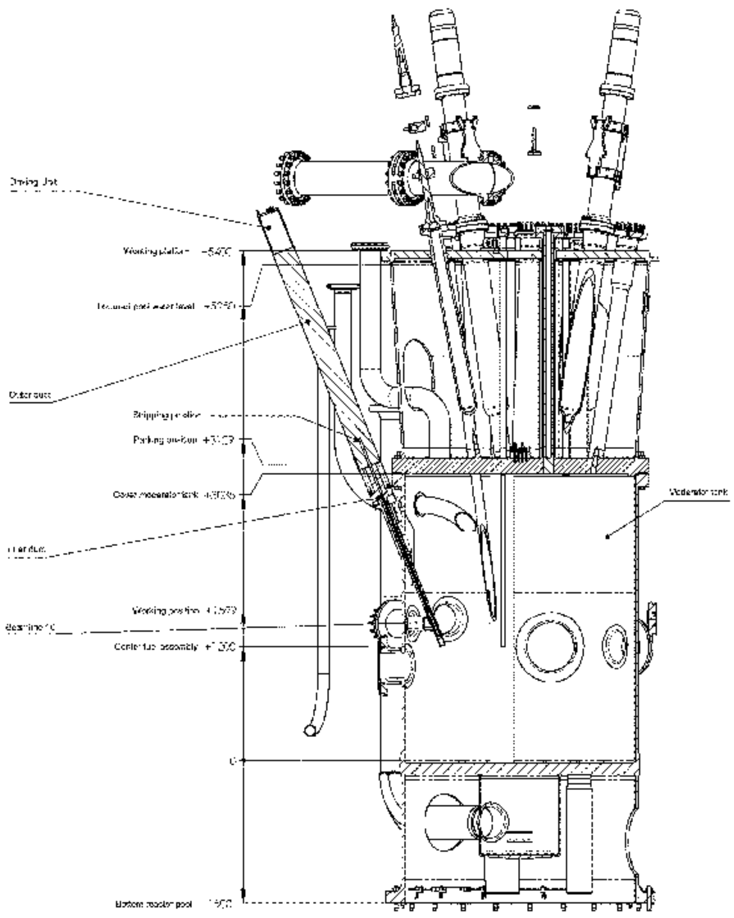

Fig 2. Cross-section moderator tank with converter facility at FRM II

2.4 Rooms for medical and scientific irradiation

The irradiation rooms of the converter facility are located in the experimental hall. They are efficiently shielded by about 1 m of concrete.
The beamline 10 fed by the neutrons from the converter facility is situated in the reactor pool wall. It is filled with helium to allow excellent neutron transmission. A shutter inside the line is foreseen to interrupt the neutron beam if necessary for example in order to position the patients or handle probes at the scientific equipment without being exposed to an unacceptable high dose rate.

2.5 Operating and monitoring station

The operating and monitoring station of the converter facility is located in front of the irradiation rooms in the experimental hall. An operator or medical doctor runs and monitors the facility.

3. Operation

The mobile carrier offers two positions related to the operation and stand-by mode of the converter facility. The parking position of the mobile carrier is located outside the moderator tank. Consequently the fuel plates are not exposed to reactor neutrons and no fission neutrons are produced in the converter facility.

By an electrical driving unit and a spindle the mobile carrier can be moved from the parking position to the working position inside the moderator tank.
The thermal neutrons at this position initiate nuclear fission in the uranium converter plates. These fast neutrons provide a fission spectrum and feed beamline 10 for medical and scientific applications in the irradiation rooms at FRM II.

4. Fuel exchange

4.1 Necessity of exchange of the converter plates

The FRM II including the converter facility has been commissioned in 2004. The maximum fuel burnup for converter plates had been limited to 72 MWd. Detailed calculations providing a local resolution of burnup showed that the maximum values are achieved at different hot spots after about 10 years of operation.

In addition the linkage operating the sensor indicating “converter plates in working position” was hard-running or even tight and foreseen to be repaired provided the gamma dose of the workers involved could be limited to acceptable values

In addition at this time the cooling pumps operated for already 55000 hours and maintenance was necessary.

4.2 Assembly of mobile carrier

Fresh fuel plates were delivered by AREVA/CERCA and a new carrier by NTG. The used carrier containing the spent fuel plates is stored within the FRM II reactor pool for further decay of the induced radioactivity.
In preparation of the maintenance break the new carrier was assembled and stored.

Fig 3. The new mobile carrier containing fresh fuel plates

4.3 Removal of the outer converter duct

The reactor pool water was lowered by approximately 5.4 m allowing carrying out the work on a permanently installed platform inside the reactor pool.
First all thermocouples, positioning and flow sensors were disconnected and plugs covered by tight blind caps. All pipes including the compensators and supports were disassembled

and removed from the reactor pool. Subsequently the driving unit was dismounted. To secure the spindle a magnetic brake was installed.

Due to high gamma radiation a specially designed remote tool was used to unscrew the eight capsule nuts. They were stored in a box and taken to the hot cell for cleaning and inspection. By turning the spindle manually the carrier was moved into the shipping position; as a result the carrier was contained completely in the outer duct.

For moving the outer duct by crane to the spent fuel pool it was coupled to a special load attachment device, pulled carefully out of the inner duct, tilted to vertical, turned by 180° and hitched up at the moderator tank. During the entire handling the dose rate at the working platform was measured to be below 50 µSv/h. Finally the pool water level was increased to normal (12 m) and the pool gate was removed by crane.
The outer duct was moved to the spent fuel pool by crane into a replacement device. It was visually inspected by camera under supervision of the external expert organization of our relevant authorities without any concerning findings.

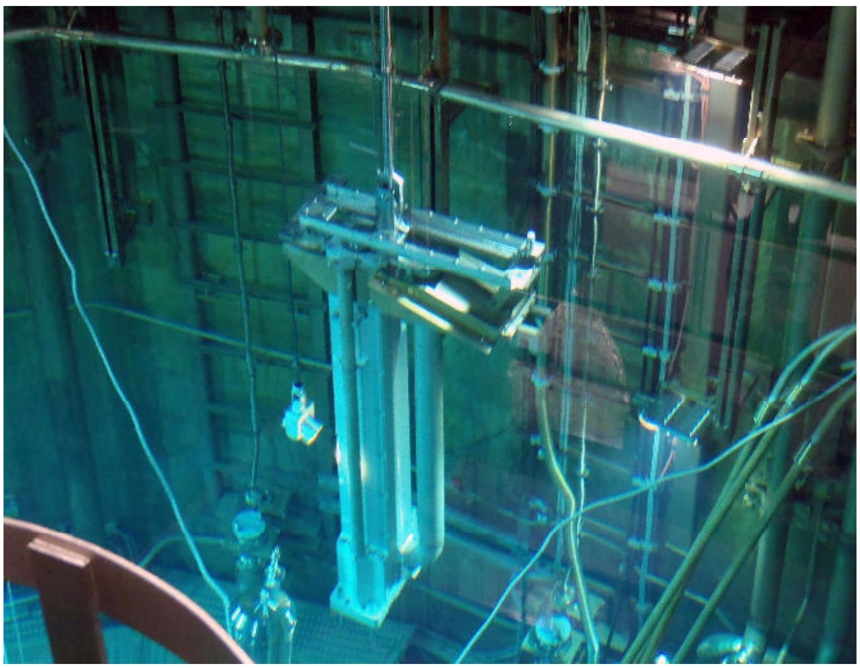

Fig 4. Removal outer duct to the spent fuel pool by crane

4.4 Removal of the used carrier containing the spent fuel plates

In the replacement device the carrier was pulled out of the outer duct by turning the spindle, decoupling by turning, swung out and caught by a special gripper.
All handling steps were supervised by camera. A visual testing of the carrier did not show any concerning findings. The carrier containing the spent fuel plates was mounted into a storage rack inside the spent fuel pool about 10 m below the surface. The dose rate nearby was measured to be as high as 200 Sv/h. The spent fuel is supposed to be kept in this position until its final disposal. Its cooling is ensured by natural convection of pool water.

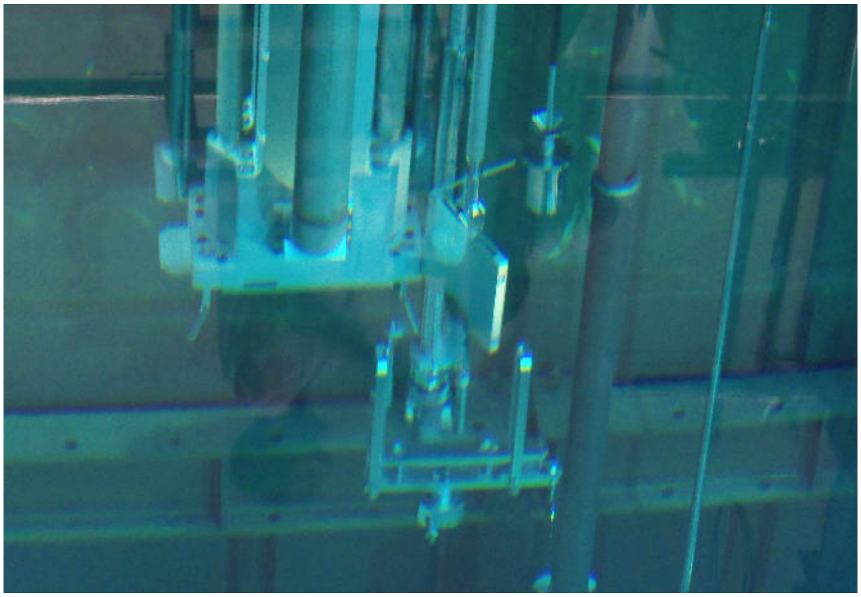

Fig 5. Removal of carrier containing spent fuel plates

4.5 Dose rates at the outer duct

As mentioned above a hard-running linkage operating a sensor had to be repaired in connection with the exchange of the fuel plates. For this purpose the outer converter duct had to be removed from the pool to the reactor hall. Due to the expected high gamma dose rate this work could only be done under careful inspection by radioprotection staff. The duct was slowly pulled out of the water by crane and in parallel the dose rate was continuously measured.

The major contribution to the dose rate (140 mSv/h in contact) arose from the steel screws of the clutch. The structural parts of the duct made of aluminium provided only drastically lower dose rate values. This geometry allowed the removal, transportation and repair of the linkage using various radioprotection provisions.

Fig 6. Checking the dose rate during pulling out of water of the outer duct

4.6 Repair of the linkage

The repair of the linkage had to be done in vertical geometry. For this purpose a rack in the reactor hall was modified for the maintenance of the outer duct. 10 cm lead shielding were put in a floor channel and a further 5 cm lead wall for the protection of the staff.
The reactor hall was closed and only few persons of the reactor staff operated the crane and manipulated the duct to the rack. It was fastened by screws and the additional shielding was erected. In consequence the dose rate at the workplace was lower than 50 µSv/h.
The rod of the linkage for the switching sensor "working position" was corroded and stuck within the sleeves. Hence the used stainless steel linkage was replaced by a new one made from aluminium and the fits were enlarged(> 0,2 mm).
The spindle was lubricated and all surfaces were cleaned.
The transport of the outer duct to the replacement device was performed in reverse order.

Fig 7. Outer duct in the rack in the reactor hall with shieldings

4.7 Reassembly of the new carrier and the outer duct

Due to the inactivity of the fresh fuel plates inside the carrier they were mounted manually to the gripper in the reactor hall. The carrier was slided in the replacement device, swung in and coupled to the spindle of the outer duct. All handling steps were inspected by camera again.
Because of the low dose rate it had been decided, to move the duct in air over the closed pool gate through the reactor hall into the reactor pool to the parking position at the moderator tank.
Two technicians in the reactor pool turned it, tilted it by 22° into the installation position and put it on the moderator tank flange. A function control of the installation by turning the spindle was performed successfully.
Under supervision of the external expert organization the nuts were fastened with turning moment by a special remote tool.

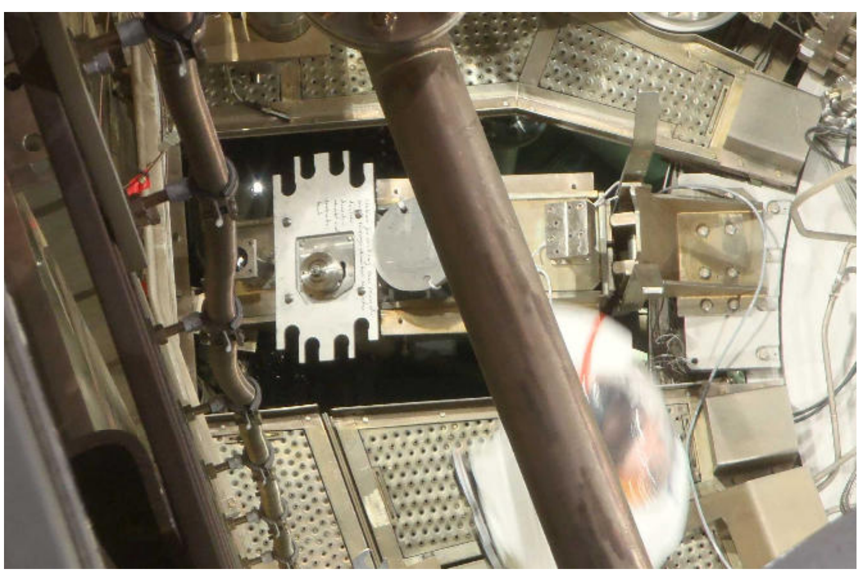

Fig 8. Outer duct in installation position on the moderator tank flange

5. Inspection and maintenance of the pumps

The cooling system was almost completely disassembled, providing a good situation for a maintenance of the pumps. The pumps are canned motor pumps with hydrodynamic fluid bearings.

The power and sensor cables were disconnected and pulled back to the corresponding pump.

With licensed load attachment devices the pumps were removed from the reactor pool. In our “hot workshop” a specialized company performed the maintenance. The bearings had a little bit of wear after 55000 hours of operation and were replaced preventively.

After reassembly the pumps were moved to reactor pool, fastened and connected electrically.

Fig 9. Canned motor pump of the converter facility

6. Commissioning of the converter facility

Cold commissioning

In May 2016 after assembly of the cooling system the first check was performed in the presence of members of the external experts organization. All sensors, the pumps, the displays and lockings were checked.

Nuclear commissioning

In July 2016 the nuclear commissioning was performed at power levels of 5, 17 and 20 MW.

The pumps were switched on, the inlet and outlet temperatures were measured as well as the mass flow and the power of the fuel plates was calculated on that basis. Afterwards the results were compared to the ones from the first commissioning in 2004. All tests were finished with positive results, and the reactor operation was continued normally.

7. Interpretation and conclusion

Dose (In advance estimations):

Collective dose:	569 µSv (2000 µSv)	including 208 µSv for repair of the linkage
max. individual dose:	212 µSv (580 µSv)	
max. daily dose:	38 µSv	

Amount of time:
For the entire project described above 2 technicians had to work a total of 30 h (15 × 2 h) within the reactor pool area. Additional staff supported the work from the periphery.

Conclusion:
Due to careful preparation the exchange of the fuel plates in FRM II's converter facility was done according to schedule without any unexpected incidents.
The special tools, already purchased during first commissioning, functioned superb even in connection with highly activated components.