SAFETY ASSESSMENT BY THE RSK FOR THE GERMAN RESEARCH REACTORS AFTER THE ACCIDENT IN THE FUKUSHIMA-I REACTOR WITH SPECIAL EMPHASIS ON MEASURES APPLICABLE FOR THE FRM II

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ABSTRACT

The Reaktorsicherheitskommission (RSK) is an expert group of operators, technical support organizations (TSO) and scientists that consults the German Federal Ministry of the Environment (BMUB) in questions concerning reactor safety. Following the events at the Fukushima-I nuclear power plant (NPP) in 2011 the RSK has carried out an overall assessment of the German nuclear fleet with respect to extreme (beyond design base) events. This paper deals only with research reactors (RR) and especially the FRM II for which the RSK has proposed several measures to even further improve its overall hardness with respect to beyond design base events or mitigate their consequences. The findings of the RSK, its recommendations and their status of implementation will be presented.

1. Introduction

The FRM II is a tank in pool reactor with 20 MW thermal power. A single fuel element, containing 113 fuel plates with highly enriched Uranium, is cooled by light water and placed in a moderator tank filled with heavy water. This setup yields an unperturbed thermal equivalent flux of 8×10^{14} n/cm²/s over a cycle of 60 days. Generally, the reactor is run for up to four cycles per year. The FRM II has reached criticality for the first time on Mach 2nd, 2004. It is, therefore, the most modern research reactor in Germany.

The main purpose of the FRM II is scientific research in beam tube experiments. However, it is also used for radioisotope production; it operates a Silicon doping facility and an installation for medical treatment. Details can be found e. g. in [1]. A sketch of the overall FRM II design is given in Fig. 1.

During the events in Fukushima NPP the FRM II happened to be on a scheduled maintenance break. Upon request of the German federal government the FRM II, like every other nuclear facility, underwent a so-called stress test by the RSK. Special emphasis was put on seismic events, flooding and other natural events, superposition of such events and manmade hazards like aircraft crashes. Additionally, independent event sequences relevant for research reactors have been postulated and analysed, even under aggravated conditions. Following these analyses the RSK has deduced recommendations for the FRM II with respect to its robustness under such circumstances. The RSK findings summarized in this paper are based on [2] and [3].

The following main aspects have been evaluated in detail for the three still operational German research reactors FRM II, FRMZ and BER II: vital safety functions of the RR and their behaviour in seismic events, flooding, other natural events, postulated events (like long lasting station blackout (SBO) with emergency power supply requirements, complete loss of

ancillary cooling systems – of which only the SBO was found to be relevant for the FRM II), robustness of emergency preparations for safety measures even under aggravated conditions due to external events; consequences of the release of burnable or toxic gas.

This article focuses on the FRM II.

2. Procedure of evaluation of the RR

The goal of these RR evaluations was to find out whether the fundamental safety requirements

- to control reactivity
- to cool the fuel assemblies and
- to limit the release of radioactive material

could be met under more difficult conditions, e. g. due to large scale external destruction, than those taken into account during the licensing process. Additional event sequences have been postulated, most prominently the non-availability of the electric grid to supply safety-relevant installations.

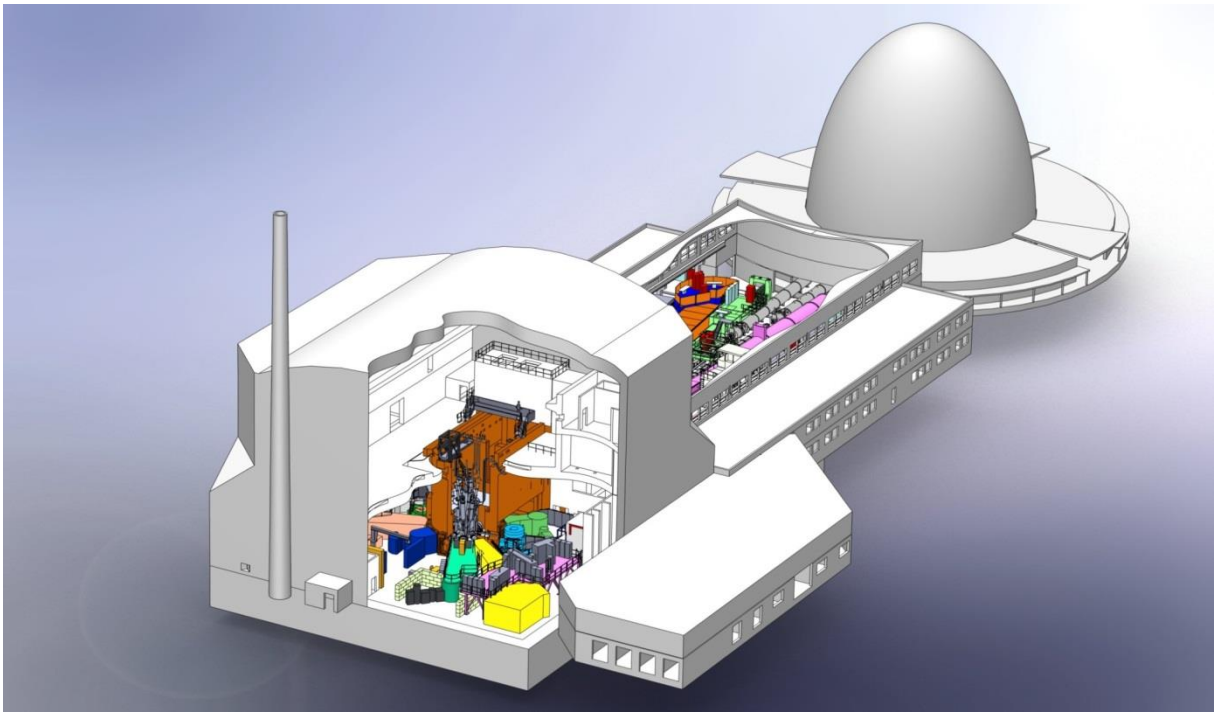

Fig. 1 : Overall view of the FRM II (foreground), the neutron guide hall (middle) and the FRM I ("atomic egg", now under decommissioning).

The established site specific emergency measures, even under extreme conditions like core melt-down, have been evaluated especially in view of large scale destruction of the relevant infrastructure also in the surroundings of the affected RR.

Although these evaluations are based on requirements for NPP, a graded approach has been taken bearing in mind that the risk associated with a RR is much lower than that of a NPP. This is due to the fact that radioactive inventory of a RR is typically several orders of magnitude smaller than that of a NPP.

The conditions investigated were:

- Seismic events
- Flooding

- Other naturally occurring adverse conditions
- Postulated events like long lasting (> 2 h) station blackout
- Robustness of preventive measures
- Airplane crash
- Release of gas (explosion, other effects of burnable gas, toxic gas)
- Terrorist attacks

3. Results of the evaluation

Following the analysis in [3] several recommendations have been made by the RSK.

3.1. Generic recommendation to RR

The RSK has recommended generic measures for the German RR:

- Every RR should work out a site specific emergency concept for internal preventive and mitigating emergency measures based on the risk associated with the respective RR. This concept should be based upon recommendations given for NPP in [4].
- Adverse environmental conditions should be taken into account when planning such measures.
- Methods to cope with beyond design base LOCA-type accidents should be considered in the emergency planning.
- For beyond design base scenarios when standard instrumentation to monitor reactor and radiation parameters might fail sufficient backup is to be made available.
- In the event of a core melt-down a concept to minimize the release of radioactivity should be available.

3.2. Specific evaluation of the FRM II

Immediately following the events at the Fukushima NPP the evaluation of the FRM II by the RSK, based on information provided by the licensee and other available information, gave the following results [3]:

3.2.1. Seismic events

Cornerstone of the FRM II safety concept is the integrity of the reactor pool and related structures. The design requirement for the FRM II is robustness against an earthquake of magnitude VI ½ (MSK). Although strong hints towards the robustness of the FRM II in general and in particular the reactor pool even against a magnitude VIII quake existed, no conclusive prove could be provided by the licensee in 2012. The RSK therefore concluded that further investigations should be carried out and be evaluated by the TSO.

3.2.2. Flooding

The FRM II is designed to withstand a flood that is to occur statistically every 10 000 years. Even more severe flooding, however, would not do any damage that might endanger the vital safety functions of the FRM II. Therefore the RSK gave the FRM II the best grade (“level 3”) regarding flooding and did not request any further measures.

3.2.3. Other naturally occurring adverse conditions

No such conditions could be identified that would require further action.

3.2.4. Postulated events

The only relevant event is the station black out (SBO). Because of the diesel/battery buffering the safety functions in case of SBO are guaranteed for at least two hours. Additionally, in the framework of the licensing process it could be shown that even a total loss of all active core cooling components would not lead to fuel damage. According to the RSK the required criteria are met, no further improvement is necessary.

3.2.5. Robustness of preventive measures

The robustness of a suite of preventive measures has been analysed by the RSK:

- Measures against fire: the RSK concludes that fire cannot endanger the vital safety functions of the FRM II.
- Measures against blocked cooling channels (beyond design base): these are mainly based on passive measures like several grids to stop migration of small particles in the primary cooling loop. Even a failure of these preventive measures would not lead to radiologically required evacuation of the general public in the surroundings of the FRM II.
- Measures against loss of the integrity of the reactor pool leading to loss of pool water: the concept of – at least – double barriers has been used throughout. Additionally, heavy lifts in the vicinity of the pool or delicate installations like the cold source with its D_2 contents are only allowed after additional measures are in place (e. g. the reactor is shut down and the D_2 removed).
- Internal flooding: water is drained in such a way that safety relevant functions cannot be affected. The RSK considers the required criteria as more than met.
- Measures against improper reactivity changes: the overall reactivity coefficients of the FRM II are negative with increase in temperature. Postulated release of 3 $ reactivity has been investigated in the process of the FRM II licensing. No need for additional measures could be deduced.

3.2.6. Aggravated boundary conditions

Several emergency measures (draining of the D2O moderator, sealing of the reactor building ventilation systems against the environment, measures to maintain the pool-water-level and emergency fuel unloading, installation of a backup 400 V electric power supply) are described in the FRM II operating manual (BHB). There is an emergency control room and sufficient room for emergency first responders. The functioning of communication lines under such conditions could not be verified by the RSK. The existing instrumentation is robust against seismic events and airplane crashes. Some measures, however, require access to the reactor hall. The RSK recommends implementing measures that do not require such access since it might no longer be possible under some circumstances. Additional emergency drills and the availability of the required personnel in case of such events should be verified.

3.2.7. Airplane crash

No additional measures are required to withstand the impact of even a large commercial aircraft.

3.2.8. Release of gas

The effects of explosions are covered by the robustness of the FRM II towards seismic events and the crash of even a large commercial aircraft.

In the vicinity of the FRM II no significant supply of burnable gas exists, therefore no additional measures are required (but could be handled regardless by the design of the FRM II site).

Toxic gas might affect the availability of personnel but not compromise the vital safety functions of the FRM II.

4. Evaluation of the measures taken by FRM II until 2017

As a follow-up, the open points mentioned above have been re-evaluated by the RSK in 2017 [2]. The conclusions can be summarized as follows:

4.1. Emergency drills

The FRM II has significantly revised its emergency concept and mostly implemented the RSK recommendations. Some recommendations have not been addressed in full detail yet: The RSK recommends that the FRM II should enlarge its concept of emergency drills. The internal emergency organisation as a whole should train at least once yearly, the relevant external authorities should be included in these exercises at least every five years.

At the time of writing, however, the internal emergency exercise concept is fully functional and even an external exercise has been done. These measures, though, have not been evaluated by the RSK yet.

4.2. Emergency measures to supply water to the reactor pool

The RSK recommends having a system in place to supply water to the reactor pool in case of a failure of the relevant barriers. While this recommendation has not been addressed explicitly by the FRM II yet, at FRM II already now with existing measures or minor changes it would be possible to supply water to the pool in case of emergency without access to the reactor hall. Since no explicit evidence has been provided by FRM II yet there is also no evaluation of the RSK.

4.3. Robustness of the emergency data acquisition systems

The RSK recommends an analysis on the availability of the relevant DAQ systems in case of beyond design base accidents, since emergency measures require reliable information especially on the pool water level and temperature. While such information – mainly pool level and temperature – can be acquired easily by rather primitive means the recommended prove has not yet been provided by the FRM II.

4.4. Emergency communication

The FRM II is well equipped with several independent and diverse communication channels. On top of that, the RSK recommends the FRM II emergency communication should have priority over other's communication needs. This recommendation has not yet been implemented. However, the relevant communication channels (e. g. land line telephone service) have large reserves and therefore the safety gain through priority might be negligible.

4.5. Seismic robustness/implementation of an additional system to maintain long term undercriticality

Additional analysis confirmed that the earlier only assumed robustness of the building and the reactor pool even towards magnitude VIII (MSK) earth quakes. Such a beyond design base event might impede the proper functioning of the primary (control rod) and secondary (four out of five shut down rods) shut down system. Therefore the implementation of an additional system to maintain long term undercriticality is recommended by the RSK.

The FRM II is exploring several options to implement such a system. Ideas include diluting the D_2O with H_2O in the moderator or adding Boron to the primary cooling loop. No final design has been drawn up yet.

5. Conclusion

After the events in the Fukushima-I NPP the RSK has analysed the robustness of the German nuclear reactors in general and also the FRM II with respect to beyond design base accidents. Already the analysis in 2012 [3] had given a positive result and only few recommendations to even further improve the overall safety of the FRM II were presented. Mainly “soft” measures like additional calculations or improved overall emergency procedures were required to meet them. In its 2017 re-analysis [2] the RSK confirmed that most recommendations were met by the FRM II. The FRM II is working to answer the last open points and to reach full compliance with all the RSK recommendations in the near future.

6. References

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

[2] RSK-Stellungnahme, 492. Sitzung der Reaktor-Sicherheitskommission (RSK) am 22.03.2017

[3] Stellungnahme der RSK „Anlagenspezifische Sicherheitsüberprüfung (RSK-SÜ) deutscher Forschungsreaktoren unter Berücksichtigung der Ereignisse in Fukushima-I (Japan)“, Anlage 1 zum Ergebnisprotokoll der 447. Sitzung der Reaktor-Sicherheits-kommission (RSK) am 03.05.2012

[4] „Rahmenempfehlungen für die Planungen von Notfallschutzmaßnahmen durch die Betreiber von Kernkraftwerken“, Empfehlungen der Strahlenschutzkommission und der Reaktorsicherheitskommission, gebilligt in der 244. Sitzung der Strahlenschutz-kommission am 03. November 2010, zum Zeitpunkt der RSK-SÜ-FR gültig, mittlerweile abgelöst durch [5]

[5] „Rahmenempfehlungen für die Planung von Notfallschutzmaßnahmen durch Betreiber von Kernkraftwerken“, Empfehlung der Strahlenschutzkommission und der Reaktor-Sicherheitskommission, verabschiedet in der 242. Sitzung der Strahlenschutz-kommission am 01./02. Juli 2010, gebilligt in der 244. Sitzung der Strahlenschutz-kommission am 03. November 2010, verabschiedet in der 429. Sitzung der Reaktor-Sicherheitskommission am 14. Oktober 2010. Ergänzung verabschiedet in der 468. Sitzung der RSK am 04.September 2014 und in der 271. Sitzung der SSK am 21.Oktober 2014

7. Abbreviations

BMUB	German Federal Ministry of the Environment
DAQ	data acquisition
LOCA	loss of coolant accident
MSK	Medwedew-Sponheuer-Karnik-Scale for the magnitude of earthquakes (I - XII)
NPP	Nuclear power plant
RSK	Reaktorsicherheitskommission (Reactor safety commission that advises the BMUB)

RR	Research Reactor
SBO	Station Black Out
TSO	Technical Support Organisation