

FRM II: LESSONS LEARNED FROM THE REPORTABLE INCIDENT “RELEASE OF C-14 ABOVE DISCHARGE AUTHORISATION”

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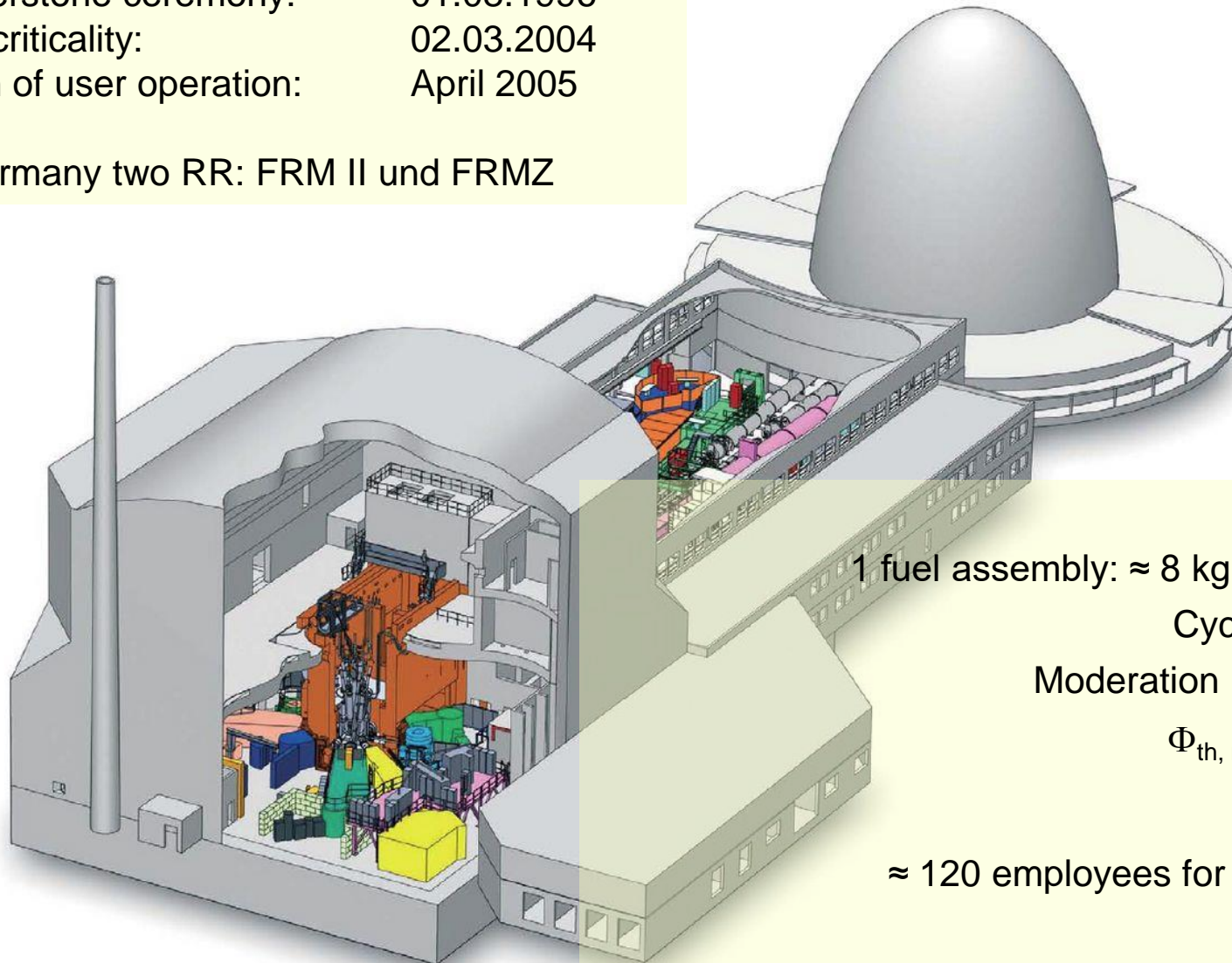
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- The FRM II
- Production of C-14
- Reportable incidence:
release of C-14 above authorized limits
 - Sequence of events
 - Lessons learnt
- Overall conclusion

Cornerstone ceremony: 01.08.1996
First criticality: 02.03.2004
Begin of user operation: April 2005

In Germany two RR: FRM II und FRMZ



P_{th} 20 MW

1 fuel assembly: ≈ 8 kg U, $> 90\%$ U-235

Cycle length 60 days

Moderation D_2O , cooling H_2O

$\Phi_{th, max}$ $8 E14$ n/cm²/s

$T < 50$ °C

$P < 10$ bar

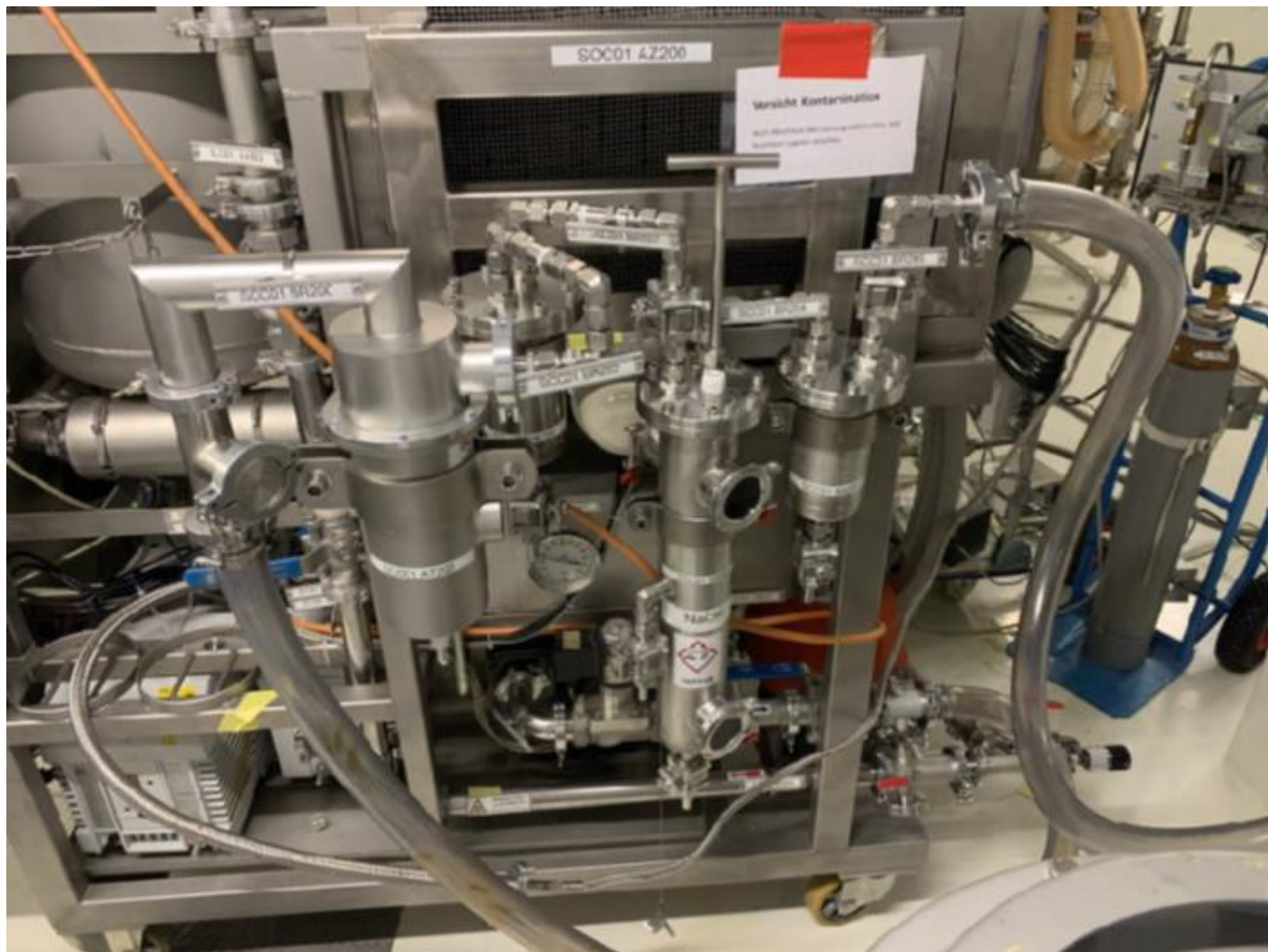
≈ 120 employees for reactor operation

≈ 150 scientists

≈ 1200 users from all over the world annually

- The isotope C-14 is mainly produced e. g. through the reactions
N-14 (n, p) C-14 or
O-17 (n, α) C-14.
These are natural processes, happening on a large scale in the atmosphere with cosmic neutrons.
- C-14 is well known to the wider public through the radio carbon method for age determination of organic artefacts (wood, bones, tissue etc.).
- Because of the high neutron flux and the presence of O und N these processes also happen at the FRM II. Main production path is O-17 (n, α) C-14 in the D2O of the moderator.
- The annual authorized discharge limit is only 2E10 Bq of C-14.
- The Radiation Protection Ordinance provides for an exemption limit of 1E11 Bq.
- C-14 is a weak beta-emitter, similar to H-3. Since the H-3 background is orders of magnitude above the C-14 signal, a direct measurement of C-14 is impossible. Therefore, C-14 is not directly measurable but can only be balanced.

- In the D₂O, the C-14 is present in the form of carbonic acid and is being removed on ion exchange resins.
- Once exhausted, the resins need to be dried for further treatments. During this process, inevitably C-14 will be released.
- Without filtering, the C-14 in the form of (C-14)O₂ would be released into the atmosphere.
- To prevent this from happening, a device using NaOH to remove this radioactive CO₂ had been retrofitted in 2013.



- In 2020, during the first of anticipated four drying cycles the CO₂-removal device had not been installed (in spite of a detailed checklist on how to use it).
- The second cycle was done with the device installed, by precaution and as requested by the regulator, cycles 3 and 4 have not been carried out.
- This continuation was justified by
 - the excellent overall experience
 - earlier, before the removal device had been retrofitted, never more than 50 % of the annual release limit had been reached when completely drying these resins
 - the proven 100 % efficiency during commissioning
 - Investigations by the radio chemistry department that the C-14 release would mainly happen towards the end of the drying process.
- Nevertheless, 115 % of the permissible limit were released, the FRM II had to suspend reactor operation and all work with potential C-14 release for the calendar year.

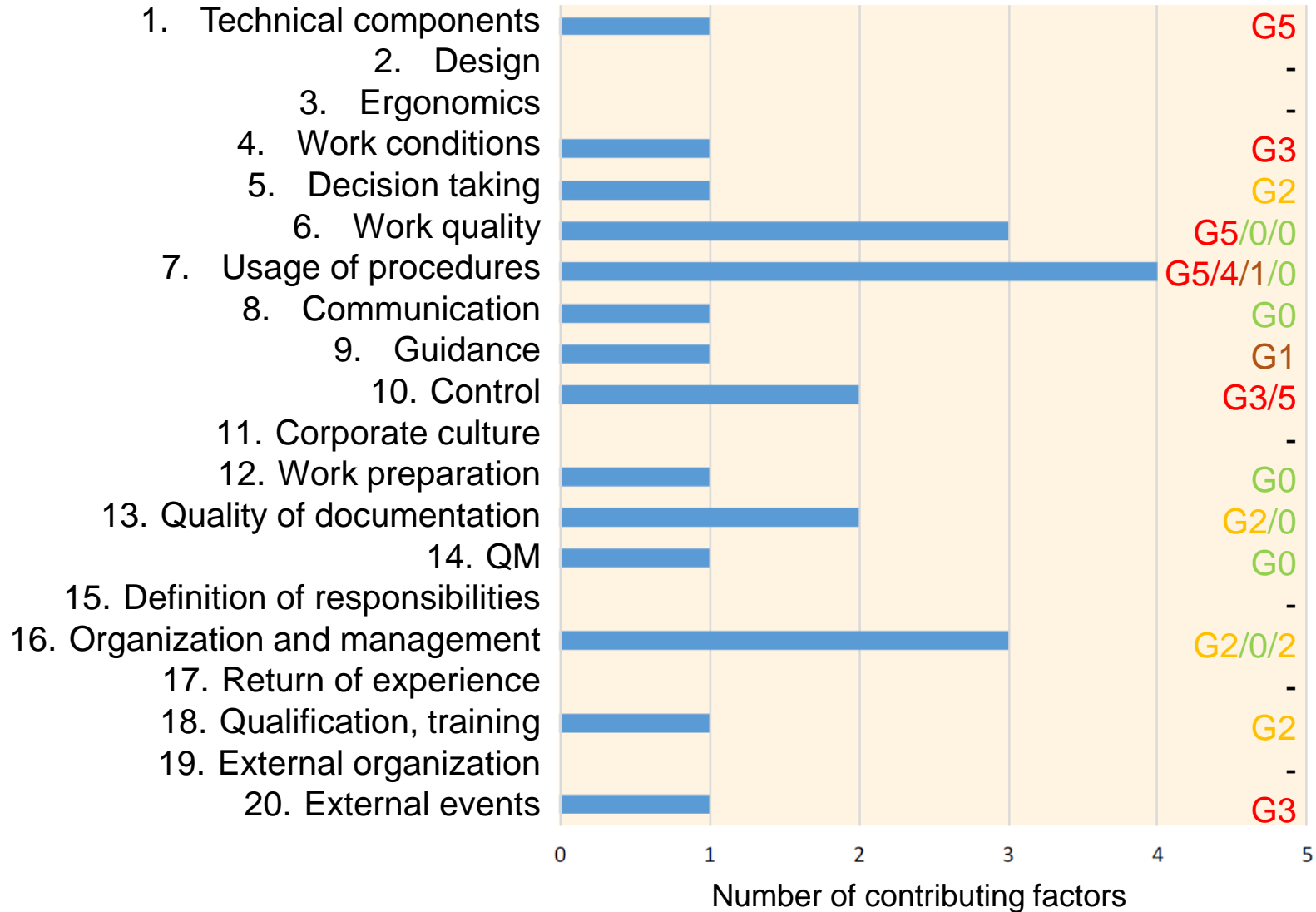
Three main consequences:

- Reactor operation suspended for more than one year
- Complete new construction of the C-14 removal device (ongoing)
- Root cause analysis was done, the main conclusions lead to:
 - Training of the personnel on communication and improved professional behavior (HPO, first and second round completed for 100 % of employees)
 - New construction of the C-14 removal device (cf. above, confirmed by the root cause analysis)
 - Several minor changes concerning e. g. review of the management system, handling of procedures, organization of recruitment.

- Done with external support by professional service provider
- Duration of the analysis: December 2020 to March 2021
- Approach
 - 28 interview with 19 persons on all levels (from operator to upper management)
 - Divide event into small “construction blocks”
 - Identify the contributing factors
 - Weight the contributing factor from G0 (no contribution) to G5 (very important contribution)
 - Presentation of results
 - Define and execute the action plan

- Contributing factors and weight

weight



- The FRM II has an extremely low authorized limit for C-14 emissions.
- It appears manageable to meet this limit, but it takes an ongoing big effort to do so.
- In the wake of the event, a new device to remove C-14 from the exhaust-air has been constructed. Internal procedures have been reviewed and the training program in line with German and international regulations was improved.
- Although technically a minor affaire, the public echo was significant.
- There is always room for improvement for every organization, also at the FRM II.