Safety Reviews of Research Reactors in Germany – Graded Approach for the periodic safety review according to § 19a of the Atomic Energy Act

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Outline

• Legislative and Regulatory Framework
  ✓ Guides for the Periodic Safety Review of NPPs

• Research Reactors Facilities
  ✓ Classification of Research Reactors

• Graded Approach for the periodic safety review of RR
§ 7 Licensing of nuclear installations

- construction and operation (not granted for NPP any more)
- essential modification of installation or its operation
- decommissioning

§ 19 Supervision

- continuous supervision during entire lifetime

§ 19a Verification, evaluation and continuous improvement of the installation

- since 2002 mandatory for NPPs
- since 2010 mandatory for all nuclear installations, including RR
Legislative and Regulatory Framework:

Regulatory Body

Federal Ministry for the Environment, Nature Conservation Building and Nuclear Safety (BMUB)

Federal Office for Radiation Protection (BfS)

**Federal oversight** of the lawfulness and expediency of the actions of the Länder, federal regulatory directive issues in single cases

**Co-operation** of federal and Länder governments with the aims to develop and uniformly apply regulations and to achieve an equal level of precaution throughout the federation

**Länder Committee for Nuclear Energy**

Land ministry - responsible for licensing and supervision of nuclear installations

Subordinate Land authorities

Advisory committees and independent authorised expert organisations, e.g.:
- Reactor Safety Commission (RSK)
- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)

Independent authorised technical expert organisations, e.g. TÜV
Guides for the Periodic Safety Review of NPPs

• Current description of the facility
  ✓ an up-to-date survey of the safety concept, the facility's design features and of all substantial measures important for safety
  ✓ description of the structures, systems and equipment important for safety

• Deterministic safety status analysis
  ✓ accident analysis and protection goal oriented review of the systems (availability and effectiveness)
  ✓ systems important for safety, including these for the very rear events and (severe) accident management (e. g. its availability, function, structure, spatial arrangement, operating mode, efficiency and reliability)
  ✓ operational management and evaluation of operating experience

• Probabilistic safety analysis
  ✓ supplementary to the deterministic assessment of the facility's safety status and its operational safety
  ✓ determination of the necessity and urgency of safety improvements

• Deterministic analysis on physical protection
  ✓ overview on an overall condition associated with security aspects of a facility, refers to technical, personal and administrative - organizational measures

• In-depth analyses of individual aspects
  ✓ scenarios and event sequences of special interest
In total 46 RR were built

Presently

- 7 in operation
- 10 permanently shut down or in decommissioning:
  - 4 permanently shutdown
  - 6 under decommissioning
- 29 decommission finished and released from nuclear regulatory control
FRM II: Munich High-flux Neutron Source

- First criticality in 2004
- Thermal power: 20 MW
- Compact core with a single cylindrical fuel element
  - Actually HEU in a $\text{U}_3\text{Si}_2\text{-Al}$ dispersion fuel with 93 % enrichment
    - (To be converted to $\leq$ 50 % U 235 by end of year 2018)
- Pool type
- Reactor cooling
  - Light water cooled and heavy water moderated
  - Operational cooling system
  - Passive residual heat removal system
- Approximated activity inventory
  - I-131: $2.0\times10^{16}$
  - Cs-137: $1.6\times10^{14}$
BER II – Berlin Experimental Reactor Unit II

- First criticality in 1973
- Thermal power: 10 MW
- Reactor core
  - U$_3$Si$_2$-Al dispersion fuel
  - LEU fuel elements with 20% enrichment
- Pool reactor
- Reactor cooling
  - Light water cooled and moderated
  - Operational cooling system
  - Passive residual heat removal system
- Approximated activity inventory
  - I-131: 1.0E+16
  - Cs-137: 4.2E+14
FRMZ – TRIGA Mark II Reactor of the Mainz University

• First criticality in 1965
• Thermal power: 100 kW
• Pulsed operation: Peak 250 MW (0.03 s)

• Reactor core
  ✓ Uranium as fuel and
    zirconium hydride as moderator
  ✓ LEU fuel elements with 20 % enrichment

• Reactor cooling
  ✓ Light water cooled and moderated
  ✓ Passive operational cooling system

• Approximated activity inventory
  ✓ I-131: 1.0E+14
  ✓ Cs-137: 1.9E+13

www.kernchemie.uni-mainz.de
Zero-power Research Reactors

Siemens Training Reactor (SUR 100) (Stuttgart, Ulm and Furtwangen)

- First criticality in ’60s
- Thermal power: 100 mW
- Reactor core
  - U₃O₈ as fuel and
  - Polyethylene as moderator
  - LEU with 20 % enrichment
- No cooling system
- Approximated activity inventory
  - I-131: 1.0E+08
  - Cs-137: 5.1E+07

Training Reactor AKR 2 (Dresden)

- First criticality: 2005
- Thermal power: 2 W
- Reactor core
  - U₃O₈ as fuel and
  - Polyethylene as moderator
  - LEU with 20 % enrichment
- No cooling system
- Approximated activity inventory
  - I-131: 2.0E+09
  - Cs-137: 1.0E+09
Classification of RR - Criteria

- **Thermal power**
  - ✓ Nearly zero thermal power ($\lesssim 1 \text{ kW}$)
  - ✓ Small thermal power ($\lesssim 100 \text{ kW}$)
  - ✓ Medium thermal power ($\lesssim 1 \text{ MW}$)
  - ✓ Large thermal power ($\gtrsim 1 \text{ MW}$)

- **Hazard potential**
  - ✓ Most relevant radioactive materials: I-131 and Cs 137

- **Safety relevant systems**
  - ✓ No cooling
  - ✓ Operational cooling
  - ✓ Passive residual heat removal
  - ✓ Active residual heat removal
Classification of German RR - Results

- **10^8**
- **10^10**
- **10^12**
- **10^14**
- **10^16**
- **10^18**
- **10^20**

**I - 131** equivalent [Bq]

**P_{th} [MW]**

- Typical German NPP
- TRIGA Mark II; operational cooling
- Larger reactors; passive residual heat removal
- Zero power reactors; no cooling

**Bundesamt für Strahlenschutz**
## Graded Approach for the periodic safety review of RR

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>FRM II, BER II</th>
<th>FRMZ</th>
<th>AKR-2, SURs</th>
</tr>
</thead>
</table>
| 1.   | Current facility and systems description  
- an up-to-date facility description  
- description of systems and components (e.g. its safety function, design and configuration)  
- technical documentation | ✓              | ✓    | ✓           |
| 2.   | Operational management and experience  
- reactor organization  
- applications for the modification  
- operational documentation  
- deviations from normal operation  
- in-service maintenance and maintenance procedures  
- experiences from other reactors and research findings  
- operating and inspection manuals  
- quality assurance  
- maintenance of technical competences and knowledge  
- radiation protection  
- occupational safety  
- handling of irradiated samples | ✓              | ✓    | ✓           |
| 3.   | Deterministic safety status analysis  
- accident analyses und protection goal oriented system inspection (incl. availability and effectiveness)  
- ageing management of safety equipment  
- safety precautions (e.g. specific accident instrumentation, measures against internal and external events, measures against human factors, combination of different incidents)  
- concept of severe accident management (incl. measures for rare events) | ✓              | ✓    | - 1         |
| 4.   | Probabilistic safety analysis (supplementary to the deterministic assessment in case of external events) | ✓              | -    | -           |
| 5.   | Physical protection\(^2\)  
\(^2\) Has to be agreed with the department responsible for nuclear security. | ✓              | ✓    | ✓           |
| 6.   | IT-Security\(^2\)  
\(^2\) Has to be agreed with the department responsible for nuclear security. | ✓              | - 1  | - 1         |

\(^1\) May be included under pt. 1 to an adequate extend.

\(^2\) Has to be agreed with the department responsible for nuclear security.
Conclusions

✓ According to the legislative framework the periodic safety reviews in Germany are obligatory for all research reactors facilities (including zero-power facilities)

✓ German research reactors in operation may be classified into three groups according to their risk potential

✓ Framework for the periodic safety review of German research reactors specifies the requirements for individual risk potential group based on the principle of graded approach
Thank you for your attention!