

# International Conference on Research Reactors: Safe Management and Effective Utilization Rabat, 14 – 18 November 2011

## Safe Operation of Research Reactors in Germany

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# Outline

1. Introduction to the Use of Nuclear Energy in Germany
2. Legislative and Regulatory Framework
3. Operation of Research Reactor Facilities
4. Conclusion



# Introduction

- 1957: Research Reactor Munich (FRM) reached criticality
- In total: 46 research reactors (RR)
- 1998: Germany decided to phase out of nuclear power
- 2002: Amendment of the Atomic Energy Act  
“Phase out the use of nuclear energy for the commercial generation of electricity”  
**→ Refers to NPP, not to RR**
- Actually: No change to RR by subsequent amendments of the Atomic Energy Act in 2010 and 2011  
**→ Safe operation of RR in Germany still has to be assured for a longer time in the future**

# Legislative and Regulatory Framework

- Legal level: Atomic Energy Act and associated ordinances
  - Directly binding to all kind of nuclear facilities, including RR
- Sublegal level: Nuclear Safety Regulations
  - Mainly developed for NPP
  - Applied by analogy for RR, in accordance with the potential hazard of the specific facility by means of a graded approach
- Operator has prime responsibility for safe operation
  - Operation license is granted unlimited in time
  - Safe operation over the entire lifetime
  - Safety reviews and safety upgrades

# Safety Reviews and Safety Upgrades

- Safety upgrades in a licensing procedure (§ 7 Atomic Energy Act)
  - Essential modification of installation or its operation
  - Licence granted by the licensing authority
  - Necessary precautions against damage according to the state of the art in science and technology
  - Demonstrated by safety analyses of the operator and reviewed by licensing authority and authorized experts
- Safety upgrades within continuous regulatory supervision
  - Approval by the supervisory authority
  - Based on a safety analysis and its review

# General Safety Reviews

- Periodic Safety Reviews (PSR)
  - Mandatory for NPP, but not for RR
  - Required for specific facilities, e.g. FRM-II or BER II
- Additional safety reviews in special circumstances
  - After Fukushima accident
  - Systematic plant specific safety reviews for all 17 NPP
  - Performed by Reactor Safety Commission (RSK)
  - Especially against severe accidents
  - Review results, among others, basis for the phase out policy concerning NPP in Germany in 2011
  - Recently, systematic plant specific safety reviews have also been started for RR → FRM-II, BER II and FRMZ

# Research Reactor Facilities in Germany

- In total 46 RR
- Broad range of different types
  - Large pool or tank reactors,  $P_{th}$  several tens of megawatts
  - Small educational reactors, “zero power”
- Actually
  - 38 permanently shut down, in decommissioning or already dismantled and released from regulatory control
  - 8 still in operation
    - 3 “larger” facilities: FRM-II, BER II and FRMZ
    - 5 “smaller” educational reactors: e.g. AKR

# FRM-II – Munich High-flux Neutron Source



- Newest RR in Germany
- First criticality in 2004
- Replaced the old FRM, called “Atomic Egg”



# FRM-II: Plant Characteristics

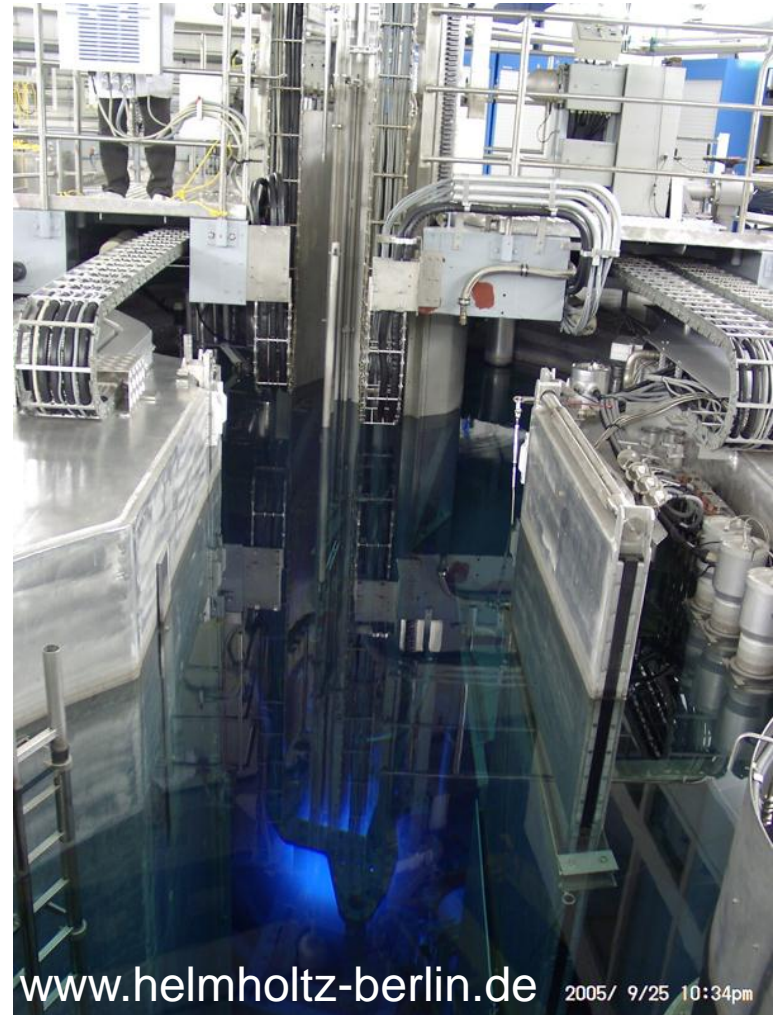
- High-flux neutron source:  $\Phi_{th} \approx 8 \cdot 10^{14} \text{ n}/(\text{cm}^2 \cdot \text{sec})$
- Thermal power: 20 MW
- Pool type, light water cooled, heavy water moderated
- Compact core with a single cylindrical fuel element
  - Actually HEU in a  $\text{U}_3\text{Si}_2$ -Al dispersion fuel
  - To be converted to MEU ( $\leq 50\%$  U 235) by end of year 2018
- Designed to withstand
  - earthquake
  - high speed military aircraft

# FRM-II: General Safety Reviews

- Periodic Safety Review
  - Fixed as an obligation in the operation licence from 2 May 2003
  - First safety review in 2015
  - 10 years after beginning of routine operation in 2005
- Additional safety review due to Fukushima accident
  - Recently started by RSK
  - Especially against severe accident scenarios

# BER II – Berlin Experimental Reactor Unit II

- Pool reactor
- Light water cooled and moderated
- First criticality in 1973
- Thermal power: 10 MW
- $\Phi_{th} \approx 1,5 \cdot 10^{14} \text{ n}/(\text{cm}^2 \cdot \text{sec})$
- Reactor core
  - 30 MTR fuel elements
  - $\text{U}_3\text{Si}_2$ -Al dispersion fuel
  - LEU



# BER II: Power Uprate

- 1985 to 1991: Power Uprate from 5 MW to 10 MW
- Licensing procedure (§ 7 Atomic Energy Act)
  - Involving of public, including public hearing
  - 2 partial licenses for the construction work in 1985 and 1988
  - 1 operation license in 1991
- Safety Assessment (according to the state of the art in science and technology)
  - Overall safety concept
  - Reactor core
  - Core cooling system
  - Reactor protection system
  - Installation of a cold neutron source

# BER II: Conversion from HEU to LEU

- Reducing proliferation risk
- Licensing procedure (§ 7 Atomic Energy Act)
  - Essential modification of installation or its operation
- **Safety Assessment** (according to the state of the art in science and technology)
  - Safety analysis for comparison of source terms for HEU and LEU core
  - Severe accident by a postulated crash of a military aircraft
  - No significant differences to the radiological impact on the environment
- Operation licence in 1994
- Following mixed loadings, first pure LEU core in 2000

# BER II: General Safety Reviews

- Periodic Safety Review
  - Fixed by a provision in the operating manual
  - First safety review completed in 2004
    - Including - Update of plant description
      - Assessment of operating experience
      - New accident analysis
  - ➔ Improved measures in irradiation devices including documentation
- Additional safety review due to Fukushima accident
  - Recently started by RSK
  - Especially against severe accident scenarios

# FRMZ – Research Reactor of the Mainz University

- TRIGA reactor Mark II
- Light water cooled and moderated
- First criticality in 1965
- Thermal power: 100 kW
- Pulsed operation: Peak 250 MW
- Reactor core
  - 60 homogenous fuel moderator elements
  - uranium as fuel and zirconium hydride as moderator
  - LEU



# FRMZ: Safety Upgrade

- Large safety upgrade of the reactor water systems in the beginning of the 1990s
- Licensing procedure (§ 7 Atomic Energy Act)
  - Essential modification of installation or its operation
- **Safety Assessment** (according to the state of the art in science and technology)
  - Reconstruction of primary and secondary circuits
  - Reconstruction of condenser between primary and secondary circuit
  - Implementation of own cleaning circuit, hence separated from primary circuit
  - Modifying electronic systems for measuring and control
- Operation licence in 1992



# FRMZ: General Safety Reviews

- Periodic Safety Review
  - Mandatory for NPP, but not for RR
  - Not required for FRMZ
- Additional safety review due to Fukushima accident
  - Recently started by RSK
  - Especially against severe accident scenarios

# AKR – Training Reactor of the Technical University Dresden

- Zero power reactor
- Example for 5 training and educational reactors still in operation

## AKR-1

- Commissioned in 1978



## AKR-2

- Complete refurbishment of AKR-1  
- Recommissioned in 2005



# AKR: Plant Characteristics

- Thermal power: 2 W
- Cylindrical core
  - Disk-shaped fuel elements
  - Homogenous dispersion of uranium as fuel and polyethylene as moderator
  - LEU
  - 2 separate cylindrical sections with subcritical mass
  - Operation by lifting up lower section
- No cooling necessary and inherent safety features
  - ➔ **Ideal tool for training and educational purposes**

# AKR-1: History

- Sited in Dresden
  - Build, commissioned and operated within the legislative and regulatory framework of the former GDR
- Safety Review in 1989 after 10 years of operation
  - Including all operational and safety systems and of the reactor administration procedures
  - Licence renewed unlimited in time
- Reunification in Germany in 1990
  - Atomic Energy Act of the Federal Republic of Germany
  - New § 57a: Licenses from the former GDR expires on 30 June 2005
  - New license according to § 7 of the Atomic Energy Act



# AKR-2: Complete Refurbishment of AKR-1

- Licensing procedure started in 1998 (§ 7 Atomic Energy Act)
- **Safety Review** (according to the state of the art in science and technology)
  - Extensive refurbishment of facility is necessary
  - Reactor building, auxiliary systems, and instrumentation and control equipment
- Licence granted in March 2004
- Reconstruction from April to December 2004
  - Construction works at the reactor building
  - New installation of electrical systems and room ventilation
  - Modernization of the entire instrumentation and control system
- Recommissioning March 2005

# Conclusion

- ✓ Five decades of safe operation of RR
- ✓ Phase out the use of nuclear energy just for NPP, but not for RR
- ✓ Safe operation of RR in Germany still has to be assured for a longer time in the future