Operational Decommissioning Experiences in Germany

Operational Issues in Radioactive Waste Management and Nuclear Decommissioning
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Jorg Kaulard
Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) mbH
Germany
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Overview on Decommissioning Projects in Germany

Decommissioning of nuclear facilities in Germany – experiences since 1970th

- Prototype or commercial reactors: 19
- Research reactors: 36
- Fuel cycle facilities: 11

Recent (newer) decommissioning projects

- Stade NPP (PWR) (since 2005)
- Obrigheim NPP (PWR) (since 2008)

Decommissioning projects in preparation

- Dismantling of remaining part of Lingen NPP currently in safe enclosure
- FRM Research Reactor (Pool type)
- FRJ-2 Research Reactor (DIDO type)
- FRG-1 Research Reactor (Pool type)
Overview on Decommissioning Projects in Germany

Prototype / Commercial Reactor
- shut down / under decommissioning
- decommissioning completed

Research Reactor
- shut down / under decommissioning
- decommissioning completed

Nuclear Fuel Cycle Facility
- shut down / under decommissioning
- decommissioning completed
Overview on Decommissioning Projects in Germany

- Past and current decommissioning projects of Prototype or Commercial Reactors
  - Total: 19
  - Removed: 3
  - Under dismantling: 14
  - Safe enclosure: 2
  - Final shut down / application for license: 0
  - Reactor types: PWR, BWR, Fast Breeder, High Temperature Gas Cooled, Heavy Water Gas Cooled

- Outlook for Prototype or Commercial Reactors
  - Dismantling of Lingen NPP, currently in Safe Enclosure
  - 8 NPPs finally shut down due to changed atomic law as a consequence of Fukushima accident
    - But: **timeframe completely open**!
Overview on Decommissioning Projects in Germany

- Past and current decommissioning projects of Research Reactors
  - Total: 37
  - Removed: 28
  - Under dismantling: 2+1
  - Safe Enclosure: 2
  - Final Shut down / application for license: 3 + 1
  - Variety of types of Research Reactors
    - Argonaut type
    - Critical assembly
    - Educational reactors
    - Liquid homogenous reactor
    - Propulsion reactor
    - Pool reactor (incl. TRIGA type)
    - Heavy Water reactor (incl. DIDO type)

- Outlook for Research Reactors: FRJ-2, FRM, SUR AC and FRG-1 (in planning)
Overview on Decommissioning Projects in Germany

- Past and current Decommissioning projects of Nuclear Fuel Cycle Facilities
  - Total: 11
  - Removed: 7
  - Safe Enclosure: 0
  - Under dismantling: 4
  - Final Shut down / application for license: 0

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Former storage building for vitrification waste at WAK with additional building for remote dismantling and packaging of decommissioning waste

Slave support system for remote dismantling at WAK
The German Regulatory System

- Understanding the regulatory systems requires understanding the different definitions of “Decommissioning” in Germany
  - 7 (3) of AtG ("Decommissioning in the narrow sense")
    The decommissioning of an installation as defined in para. (1), sentence 1, as well as the safe confinement of an installation, or the dismantling of an installation or of parts thereof shall require a license. Para. (2) shall apply accordingly.
  
  - “Decommissioning in the broaden sense”
    (used in the (Federal) Decommissioning Guide and practice)
    Decommissioning is a general term, which covers all measures which are taken after final cessation of operation, aimed at the safe confinement or dismantling of the facility or dismantling of parts of the facility, including occupancy of the safe confinement.
The German Regulatory System

- German Regulatory Pyramid – Regulatory basis for decommissioning in Germany

Note: the sub legal level is mainly prepared for operation of nuclear power plants and thus needs an analogous application during decommissioning.
The German Regulatory System

- Regulations relevant for decommissioning (excerpt)

**German Laws**
- Atomic Energy Act (AtG)
- Environmental Impact Assessment Act (UVPG)
- Conventional Construction Act (BauGB)

**Ordinances**
- Ordinance on Radiation Protection (StrlSchV)
- Ordinance on the Nuclear Licensing Procedure (AtVfV)
- Ordinance on the Nuclear Financial Security (AtDeckV)

**BMU Regulations / Recommendations / KTA Technical Rules**
- Guideline relating to Emission and Immission Monitoring of Nuclear Facilities (REI)
- Guideline for Radiation Protection during Inspection, Maintenance, Repair and Dismantling of NPPs (IWRS II)
- ESK Guideline on Decommissioning (2011)

High importance for decommissioning
The German Regulatory System

- Basic requirements
  - The atomic energy act allows either
    - to **immediate dismantle** or
    - to dismantle after a **safe enclosure**
  - a nuclear facility
    *Note: no entombment* (near surface disposal) is allowed
  - The **operator** of a nuclear facility is **fully responsible** for the decommissioning and dismantling of a nuclear facility
    - He decides on the decommissioning strategy and the timeframe
    - He decides on the scope of a license he applies for
      *Note: the operator has to ensure at any time the safety of the facility and any precautionary measures are taken*
  - Decommissioning and Dismantling are subject to **one or more licenses**
  - Decommissioning activities are subject to an **intensive regulatory supervision**, involving technical experts and on-site presence during the full project
The German Regulatory System

- Process of licensing

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

Advisory bodies

Experts and expert organizations

Other authorities of the Land (Federal State)

Experts and Expert organizations

General public

Other federal offices

Applicant / Licensee

Licensing authority of the Land (Federal State)

Application documents

- Draft of the license
- Application documents
- Evaluation reports by the authorized experts

Opinion of BMU on the draft of the license “Agreement on the license”
Examples of Decommissioning Projects – No. 1

- A typical & recent decommissioning project – decommissioning of Stade NPP
  - Design features
    - Reactor type: PWR
    - Electrical power: 662 MWe
    - Operator: Kernkraftwerk Stade GmbH & Co. KG
  - Decommissioning “features”
    - Decommissioning due to economic reasons
    - 4 phases approach on immediate dismantling
    - End-state: release of the site for unrestricted use, proposed for 2015
    - Inventory: total of $10^{17}$ Bq, mobile contamination of $10^{13}$ Bq

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Examples of Decommissioning Projects – No. 1

- 4 Phases @ Stade NPP

- Operational phase
- Post-Operational phase
- Residual operations and dismantling management

Liability and supervision on the decommissioning

Phase 1
Phase 2
Phase 3
Phase 4

Release from regulatory control

Conventional dismantling

Dismantling of non-nuclear facilities

Construction & Operation of an interim storage facility for rad. waste

Milestones

November 2003
Final shutdown

September 2005
First decommissioning license

2015 (proposed)
Release from reg. control

January 2011
Forth decommissioning license
Examples of Decommissioning Projects – No. 1

- Stade NPP Decommissioning: Content of the phase 1
  - Removal of contaminated systems and components
  - Objectives:
    - Free space for later dismantling work
    - Preparation of later dismantling work
    - Removal of systems and components

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Examples of Decommissioning Projects – No. 1

- Stade NPP Decommissioning: Content of the phase 2
  - Removal of large components, including
    - Pipes and pumps of the primary circuit
    - Steam generator (transfer to Studsvik for processing)
Examples of Decommissioning Projects – No. 1

- Stade NPP Decommissioning: Content of the phase 3
  - Removal of activated systems and components
    - Core internals
    - Spent fuel pond internals
    - in-situ dismantling of reactor vessel
      - cutting of large parts
      - drum size cutting in former spent fuel pond
    - Biological shielding
    - ...

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Examples of Decommissioning Projects – No. 1

- Stade NPP Decommissioning: Content of the phase 4
  - Removal of remaining systems and components
    - Fuel load machine
    - Reactor crane
    - Ventilation system
    - Water treatment system
  - Preparation for clearance for unrestricted use

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Examples of Decommissioning Projects – No. 2

- An example for the safety enclosure – Decommissioning of the THTR-300 in Hamm-Uentrop
  - Design features
    - Prototype reactor of type: HTR
    - Electrical power: 308 MWe
    - First criticality: 1983
    - Operator: Hochtemperatur-Kernkraftwerk GmbH (HKG)
  - Decommissioning “features”
    - Decommissioning due to economic and political reasons
    - Partial dismantling performed, currently in safe enclosure, end of safe enclosure still open
Examples of Decommissioning Projects – No. 2

- THTR 300 Decommissioning – safe enclosure

© Hochtemperatur-Kernkraftwerk GmbH (HKG)
Decommissioning Experiences – Phased Approach

- Typically large decommissioning projects
  - are divided into phases (corresponding to large work packages)
  - work from “outside to inside”
    - Phase 1: blue
    - Phase 2: yellow / orange
    - Phase 3: red

- A phase
  - corresponds to a large work package
  - can be reflected by an individual license

- Advantages
  - allows structure large complex technical systems
  - allows to gain further information needed for later work packages
  - allows flexibility in adapting changes in future phases not licensed yet
Decommissioning Experiences – Phased Approach

Example of 4 Phases @ Stade NPP

- Operational phase
- Post-operational phase
- Residual operations and dismantling
- Licensing of and supervision on the decommissioning
- Dismantling of non-nuclear facilities
- Construction & operation of an interim storage facility for rad. waste

Year of decommissioning

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Decommissioning Experiences – Large Component Dismantling

- Dismantling of large components – German practice shows following options
  - in-situ dismantling
  - partial in-situ dismantling
    - post-processing on-site or off-site
  - removal and ex-situ dismantling (typically for components of metal)
    - on-site dismantling
      - immediate dismantling
      - deferred dismantling
        (if appropriate: dismantling after decay storage)
    - off-site dismantling
      - at external service providers
        (cutting, decontamination / melting, clearance – in a foreign country: still according to German requirements, return of material and radioactive waste)
Decommissioning Experiences – Large Component Dismantling

- Examples of large component removal for off-site dismantling

**Intended steam generator removal at Obrigheim NPP**

© H. Starke, Babcock-Noell  
KONTEC 2011

**Reactor vessel removal and interim storage at Greifswald NPP**

© R. Borchardt, G. Hillebrecht, EWN,  
2010 Annual Meeting of German Nuclear Society
Decommissioning Experiences – Use of Remote Systems

- Practice shows a wide use of remote systems when the radiological conditions do require this
- Before use of the systems, intensive cold testing is performed

Dismantling of activated concrete of the biological shield of prototype reactor MZFR
(left: cold test rig, right: biological shield)

© E. Prechtl et al, WAK GmbH, W. Huber et al, Simpelkamp Nukleartechnik GmbH
KONTEC 2011
Decommissioning Experiences – Radioactive Material Management

- General radioactive material flow according to sec. 9a (1) of the AtG (and related regulations)

- Residual radioactive material
- Disassembled radioactive components
- Dismantled radioactive components

- Utilization without detriments
- Direct final disposal
- Clearance
- Re-use or utilization
- Interim storage
- Delivery to Land Collecting Facility
- Final disposal

Note: no reprocessing of fuel from 2005 onwards allowed

Note: delivery to Land Collecting facility not allowed for NPPs
Decommissioning Experiences – Radioactive Material Management

- Typical processing scheme for material subject to dismantling
  - Based on categorization of material with respect to contamination / activation

  *cat. I*  no contamination possible  
  *cat. II*  contamination possible  
  *cat. III*  contamination

- activated material → remote cutting → conditioning → interim storage / final disposal
- contaminated material (cat. II, III) → dismantling → cutting, decontamination → clearance
- not contaminated material (cat. I) → dismantling → cutting → unrestricted use

RWM Summer School 2011, Decommissioning Experiences in Germany, J. Kaulard
Decommissioning Experiences – Radioactive Material Management

- Clearance of radioactive material
  - Basic radiological concept: 10 µSv concept
  - Clearance options
    - unconditional clearance (“use as you like”)
    - conditional clearance (“the use is predicted”)
  - Typical process for clearance (partially iterative)
    1. dismantling, cutting
    2. decontamination
    3. preliminary / orientation testing by operator
    4. final clearance testing by operator
    5. optional: control measurement by operator
    6. submission of documents to regulators body
    7. possible: control measurement by regulatory body
    8. removal from regulatory control (if compliant with conditions of license)
Decommissioning Experiences – Radioactive Material Management

- Clearance – As an example: estimated flow of radioactive waste at Stade NPP

<table>
<thead>
<tr>
<th>Area</th>
<th>Clearance (restricted and unrestricted)</th>
<th>Controlled re-use</th>
<th>Radioactive waste</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>in Mg (megagrams)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear area</td>
<td>124,005 (97.2%)</td>
<td>545 (0.4%)</td>
<td>2,990 (2.4%)</td>
<td>127,540 (100%)</td>
</tr>
<tr>
<td>Non-nuclear area</td>
<td>272,100</td>
<td></td>
<td></td>
<td>272,100</td>
</tr>
<tr>
<td>Total</td>
<td>396,105</td>
<td>545</td>
<td>2,990</td>
<td>399,640</td>
</tr>
</tbody>
</table>
Decommissioning Experiences – Radioactive Material Management

- **Interim storage** of radioactive waste
  - Obligation for NPPs to directly deliver radioactive waste to disposal
    - if disposal is not available: storage of radioactive waste required
  - Decommissioning without a disposal site is possible, but waste conditioning might be lacking of reliable waste acceptance criteria
  - As an example: Stade NPP site interim storage facility

![Diagram](image-url)

- Storage area
- Loading area
- Operation building
- Shielding wall
Decommissioning Experiences – Work Permit System

- In addition to the Safety Assessment during licensing:
  
  Safety Assessment during work planning  
  (kind of “μ-Safety Assessment”)

  Work Permit System

- Depending on the safety relevance of the work step intended, a dedicated safety assessment is performed:
  
  • Overall safety is already analyzed and demonstrated during licensing
  • Systems and component are safety classified in the license
  • All work steps have to be planned and prepared using the work permit system, but for those in which safety relevant (classified) systems and components are effected approval of plans and measures
    - by external expert and / or
    - by the supervision regulatory body
  is required
Decommissioning Experiences – Work Permit System

- Safety relevant systems
  - Are needed to ensure safety during normal and abnormal decommissioning operation
  - Are needed to avoid or mitigate consequences from accidents
  - Are identified during safety assessment
    - existing / new systems and component can be re-classified, i.e. gain or lose safety relevance
  - Examples for safety relevant systems
    - venting system
    - fire system
    - radiological monitoring system
    - crane, if drop of waste drums can result in severe radiological consequences
    - in case, spent fuel is still at the facility: e.g. system for residual heat removal
Summary

- In Germany a large number of decommissioning projects was successfully performed
  - majority of projects: immediate dismantling
- Recent decommissioning experiences relate among others to
  - phase approaches
  - large component removal
  - use of remote systems when radiological conditions do require (cold tests to qualify the systems)
  - management of radioactive material, including
    - clearance of material
    - interim storage
  - work permit system (μ-safety assessment during conduct)
- Experiences are reflected in the regulatory system
Thank you for your attention! Any Questions?
Auxiliary Slides
The German Regulatory System

- Brief overview on the (Federal) Decommissioning Guide
  - Objective:
    - harmonize the procedures among all Länder authorities (see later)
  - Comprehensive collect of existing requirements and recommendations on the decommissioning of nuclear facilities in German
    - Jointly applied by all “Länder” authorities (see later)
    - Strong focus on procedural licensing and supervisory aspects
  - Contains among others
    - Comprehensive list of individual elements of the sublegal regulatory system to be applied
    - Description of fundamental factors to be considered during determining the decommissioning strategy
    - Aspects to be considered during the safety assessment
  - Available also in English language

(Federal) Decommissioning Guide represents good practice in Germany from regulatory point of view
The German Regulatory System

Brief overview on the ESK Guideline on Decommissioning

- Objective:
  - Technical guideline for members of German Commission on Waste Management, Decommissioning and Disposal (“Entsorgungskommission”, ESK)
  - "working material" for ESK, but of relevance also outside ESK
  - Focus on technical safety related aspects
  - Complementing the (Federal) Decommissioning Guide

- Contains recommendations on following aspects
  - Decommissioning aspects during design and operation of a nuclear facility
  - Technical measures in preparation of a decommissioning project
  - Plan for decommissioning (corresponds to IAEA concept of final decommissioning plan)
  - Conduct of decommissioning
  - Safety assessment for decommissioning (as part of the licensing process)
  - Operational instructions during decommissioning