Waste management during decommissioning of nuclear facilities in Germany

Seminar on regulations and technology of waste management and disposal in Germany

March 28th, 2018 in Taipei

Dr. J. Shang
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1. Introduction
2. Waste management during decommissioning
3. New development of dismantling & decontamination
4. Concept and technologies of nuclear waste treatment
5. Conclusion
## Contents

1. Introduction
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4. Concept and technologies of nuclear waste treatment
5. Conclusion
Our heritage: 150 years of business success

1866 Establishment of a Mannheim-based steam boiler inspection association by 21 operators and owners of steam boilers, with the objective of protecting man, the environment and property against the risk emanating from a new and largely unknown form of technology

1910 First vehicle periodic technical inspection (PTI)

1926 Introduction of the “TÜV mark / stamp” in Germany

1958 Development of a Bavaria-wide network of vehicle inspection centres in the late 1950s

1990s Conglomeration of TÜVs from the southern part of Germany to form TÜV SÜD and the expansion of business operations into Asia

2006 Expansion of services in ASEAN by acquiring Singapore-based PSB Group

2009 Launch of Turkey-wide vehicle inspection by TÜVTURK

Today TÜV SÜD continues to pursue a strategy of internationalisation and growth
TÜV SÜD in numbers: Growing from strength to strength

1. One-stop technical solution provider

150+ years of experience

1000 locations worldwide

2,300 million Euro in sales revenue 2016

24,000 employees worldwide

Note: Figures have been rounded off.
TÜV SÜD nuclear presence worldwide

Business Unit Nuclear Energy
Approx. 1000 Experts
H.-M. Kursawe

Quality Assurance

TÜV SÜD Industrie Service Energy and Technology
250 experts
MUNICH, GERMANY
S. Kirchner

TÜV SÜD Energietechnik
200 experts
FILDERSTADT, GERMANY
H.-M. Kursawe

Nuclear Technologies
90 experts
GLOUCESTER, UK
S. Browning

Business Support

TÜV SÜD KOCEN SERVICES
360 experts
SUNGNAM, KOREA
S.-S. Cha

Nuclear Services

Map showing locations:
- Dounreay
- Sellafield
- Warrington
- Gloucester
- Harwell
- Winfrith
- Mannheim
- Munich
- Filderstadt

Further locations:
- Seoul
- Daejeon
- Busan
- Kori
Our heritage: more than 60 years of nuclear business success

1955
Middle of the fifties
TÜV-participation in evaluating and examination of research centres and nuclear facilities

1960
Sixties
Foundation of nuclear departments in the TÜV, TÜV-participation in evaluating and examination of construction of several research reactors and pilot power reactors

1970
Middle of the seventies
Foundation of the association of the „Nuclear“ TÜV which is responsible for exchange of experience and technical guidelines for the TÜV activities

Today
Participation in licensing and supervision procedures of the construction, operation and decommissioning &dismantling of Nuclear Power Plants, research reactors, conditioning installations, waste storage and waste disposals.
BUNE Services During the Life Time Cycle of a NPP

1. Planning and Preparation
- Technical and environmental Due Diligence
- Preparation of technical specifications
- Engineering services for design review of systems and materials
- Consulting support
- Review of concept design

2. Design
- Examining conformity with regulation
- Finite Element Analysis
- Supplier specification check
- Risk Assessment
- Safety Justifications
- Development and evaluation of safeguards (e.g. fire, explosion, lightning, flooding etc.)

3. Component Manufacturing
- Pre-selection and auditing of Manufacturers
- Manufacturing supervision
- QA/QC on behalf of the client
- Notified Body Services, Third-Party inspection, Type approval (e.g. Manufacturer certification as per international rules and standards, such as PED, ASME, ISO 9001:2008 acc. ISO/IEC 17020)

4. Construction
- Site Supervision
- Expediting
- QA/QC on behalf of the client
- Site Management, health and safety coordination
- Notified Body Services, Third-Party Inspection

5. Commissioning
- Acceptance and Performance tests
- Warranty Demonstration test
- Emission measurement
- Leak Testing

6. Operation
- Failure investigation, analysis and optimisation concepts / Accident Management
- Stress Test / Special Reviews (e.g. QA-Systems)
- Life time assessment / Plant Inspections
- Rehabilitation and upgrading
- Risk oriented inspection and Maintenance

7. Decommissioning
- Feasibility studies for decommissioning concepts of nuclear facilities.
- Characterization of radioactive waste with mobile measuring equipment on-site
- Radiological protection.
- Assessment of concepts for intermediate and final waste storage
- Assessment and documentation for radioactive material transportation

Slide 10
2016-04-07
The nuclear power plant life cycle

Licensing for nuclear power plants (NPP)

Design and construction of NPPs

Nuclear power plant operation

Nuclear decommissioning

Additional nuclear services provided by TÜV SÜD:
• Safety assessment of nuclear installations
• Radiation protection
• Nuclear fuel supply, waste management and disposal
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4 Concept and technologies of nuclear waste treatment

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Nuclear waste management in Germany

Nuclear power plants and their corresponding disposal facilities in Germany

- Nuclear power plant
- Authorisation for electricity production expired in 2011 according to the last revised German Atomic Act Amendment
- Nuclear power plant shut down
- Nuclear power plant completely decommissioned
- Research facility with waste treatment facility
- Waste treatment facility
- Central interim storage facility
- Repository

1. Exploration
2. Emplacement completed
3. Construction

Source: VGB
**Technical Support for Licensing Authority in the federal states of Germany**

<table>
<thead>
<tr>
<th>Nuclear Power Plant</th>
<th>Type</th>
<th>Nominal Output (Gross) MW</th>
<th>In Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GKN-1 Neckar</td>
<td>PWR</td>
<td>840</td>
<td>NO</td>
</tr>
<tr>
<td>GKN-2 Neckar</td>
<td>PWR</td>
<td>1,395</td>
<td>YES (until 2022)</td>
</tr>
<tr>
<td>KBR Brokdorf</td>
<td>PWR</td>
<td>1,440</td>
<td>YES (until 2021)</td>
</tr>
<tr>
<td>KKB Brunsbüttel</td>
<td>BWR</td>
<td>806</td>
<td>NO</td>
</tr>
<tr>
<td>KKE Emsland</td>
<td>PWR</td>
<td>1,400</td>
<td>YES (until 2022)</td>
</tr>
<tr>
<td>KKG Grafenrheinfeld</td>
<td>PWR</td>
<td>1,345</td>
<td>No</td>
</tr>
<tr>
<td>KKI-1 Isar</td>
<td>BWR</td>
<td>912</td>
<td>NO</td>
</tr>
<tr>
<td>KKI-2 Isar</td>
<td>PWR</td>
<td>1,475</td>
<td>YES (until 2022)</td>
</tr>
<tr>
<td>KKK Krümmel</td>
<td>BWR</td>
<td>1,316</td>
<td>NO</td>
</tr>
<tr>
<td>KKP-1 Philippsburg</td>
<td>BWR</td>
<td>926</td>
<td>NO</td>
</tr>
<tr>
<td>KKP-2 Philippsburg</td>
<td>PWR</td>
<td>1,458</td>
<td>YES (until 2019)</td>
</tr>
<tr>
<td>KKU Unterweser</td>
<td>PWR</td>
<td>1,410</td>
<td>NO</td>
</tr>
<tr>
<td>KRB B Gundremmingen</td>
<td>BWR</td>
<td>1,344</td>
<td>No</td>
</tr>
<tr>
<td>KRB C Gundremmingen</td>
<td>BWR</td>
<td>1,344</td>
<td>YES (until 2021)</td>
</tr>
<tr>
<td>KWB A Biblis</td>
<td>PWR</td>
<td>1,225</td>
<td>NO</td>
</tr>
<tr>
<td>KWB B Biblis</td>
<td>PWR</td>
<td>1,300</td>
<td>NO</td>
</tr>
<tr>
<td>KWG Grohnde</td>
<td>PWR</td>
<td>1,430</td>
<td>YES (until 2021)</td>
</tr>
</tbody>
</table>
Organizations & regulations for waste management

• EURATOM is an independent organisation beside the EU, but shares all important institution like the European Commission

• ENSREG
  – Advisory group of European Commission
  – has established 4 working groups (Nuclear Safety, Radioactive Waste Management, Spent Fuel and Decommissioning and International Cooperation)

• WENRA
  – Is an advisory body from regulatory authorities from countries using nuclear energy
  – has established 3 working groups (Reactor Harmonisation, Waste and Decommissioning and WENRA Inspection)
Organizations & regulations of waste management

- **IAEA**
  - Political decision making
  - Development of safety standards

- **WENRA**
  - Supports Euratom
  - Development of guidelines

- **BSS**

- **Euratom**
  - Institution of the EU
  - Gives recommendations

- **ENSREG**
  - Implementation in national law

- **Members of the EU**
Management of radioactive waste

Standards for implementation of an adequate management of radioactive waste:

http://www-ns.iaea.org/standards/
New development after Fukushima accidents

➢ 08.2011: Acceleration of phase out of nuclear energy
➢ 07.2013: Act to site selection for repository
➢ 01.2014: The Federal Office for the Safety of Nuclear Waste Management (BfE)
➢ 06.2015: National action plan for nuclear waste management
➢ 12.2016: German court decision: Compensation for ESC
➢ 01.2017 Agreement between government and ESC
➢ 06.2017 I. Reorganization in field of nuclear disposal
   II. Reorganization of responsibilities in nuclear disposal
   III. Modification of Act to site selection for repository
New development of regulations for nuclear disposal

Legal and regulatory demands on nuclear waste management:

I. Reorganization in field of nuclear disposal

Federal Office for the Safety of Nuclear Waste Management (BfE)

Federal Company for Radioactive Waste Disposal (BGE)

Federal Office for Radiation Protection (BfS)
Responsibility for nuclear disposal:

II. Reorganization of responsibilities in nuclear disposal

Financial responsibility for decommissioning and disposal

Responsibility for conditioning and packaging acc. the repository conditions

Responsibility during transition from interim storage to repository

Delivery right of spent fuel and vitrified waste from reprocessing for operators (01.01.2019)

......
Financial responsibility:

- Establishment of a fund for nuclear disposal
  Basic amount: costs of interim and final storage
  Actuarial assumptions:
    “Interest“ 4.58 %,
    “general inflation“ 1.6 %,
    “nuclear cost increase“ 1.97 %

Finance fund:

- Basic amount approx. 17.53 (17.4) billion Euro
- risk premium approx. 6.22 (6.2) billion Euro
- total amount approx. 23.75 (23.6) billion Euro

The operators paid the total amount in due time on July 3, 2017 into the fund.
New development of regulations for nuclear waste disposal
New development of regulations for nuclear disposal

Modification of Act to site selection for repository:

III. Modifications


- Reversibility (forward error correction)
- Retrievability & Recoverability
- Ban on exports of nuclear waste

……

Full participation of the general public on local and national level
### Nuclear waste management in Germany

<table>
<thead>
<tr>
<th>Nuclear Facility</th>
<th>Decommissioning</th>
<th>Operation</th>
<th>Dismantled</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPP</td>
<td>22</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Research Reactor</td>
<td>8</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>Fuel Cycle</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

### Nuclear Waste in Germany

<table>
<thead>
<tr>
<th>Heat Generating Waste</th>
<th>Negligible Heat Generating Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>28,000 m³</td>
<td>Ca. 300,000 m³</td>
</tr>
<tr>
<td>Activity &gt; 99%</td>
<td>Activity &lt; 1%</td>
</tr>
</tbody>
</table>

Source: GRS
Repositories for nuclear waste in Germany

**National action plan:**

Nuclear waste disposal: National responsibility (domestic)

Spent fuel from research reactor: Return to country of origin.

Two repositories in Germany: Repository KONRAD and repository according to StandAG

Waste from ASSE II and uranium enrichment have to be considered by construction of repository

Repository KONRAD for nuclear waste with heat Generation < 2 kW/m³: Commissioning 2027

Repository for nuclear waste with heat Generation > 2 kW/m³: Site 2031, Commissioning 2050

Waste from reprocessing in interim storage for nuclear waste with heat Generation > 2 kW/m³ on site

Decommissioning MORSLEBEN
Strategies of decommissioning:

- **Post-operational phase**: 5 - 6 y for planning and licensing
- **Dismantling**: 10 - 15 y
- **Safe enclosure**: 30 - 35 y
Decommissioning strategies & licensing & supervision procedure

Strategies of decommissioning:

- Operation
  - Post operational phase
  - Immediate dismantling
  - Safe enclosure
  - Deferred dismantling

Time frame

I. Post-operational phase: 5 - 6 y for planning and licensing

II. Dismantling: 10 - 15 y

III. Safe Enclosure: 30 - 35 y
Immediate dismantling

**Decommissioning steps:**

2006 : 4 Licenses for decommissioning

0. Post-Operational Phase

1. Dismantling of components within the monitored in-plant area

2. Dismantling of contaminated components within the hot zone

3. Dismantling of activated components

4. Dismantling of the rest components

2015 : 2 Licenses for decommissioning

2017: 1 License for decommissioning
# Licensing & supervision procedure

## Civil participation in the licensing & supervision procedure

<table>
<thead>
<tr>
<th>NPP</th>
<th>Shut down</th>
<th>Application</th>
<th>Scoping</th>
<th>Public Notice</th>
<th>Public Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isar 1</td>
<td>06.08.2011</td>
<td>04.05.2012</td>
<td>16.04.2014</td>
<td>05.03.2014</td>
<td>22.07.2014</td>
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<td>Biblis A</td>
<td>06.08.2011</td>
<td>06.08.2012</td>
<td>22.01.2013</td>
<td>28.04.2013</td>
<td>11.11.2014</td>
</tr>
<tr>
<td>Biblis B</td>
<td>06.08.2011</td>
<td>06.08.2012</td>
<td>22.01.2013</td>
<td>28.04.2013</td>
<td>11.11.2014</td>
</tr>
<tr>
<td>Brunsbüttel</td>
<td>06.08.2011</td>
<td>01.11.2012</td>
<td>18.12.2013</td>
<td>16.02.2015</td>
<td>06.07.2015</td>
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<tr>
<td>Neckarwestheim I</td>
<td>06.08.2011</td>
<td>24.04.2013</td>
<td>04.07.2013</td>
<td>09.01.2015</td>
<td>16.06.2015</td>
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<td>Philippsburg 1</td>
<td>06.08.2011</td>
<td>28.01.2014</td>
<td>01.06.2013</td>
<td>30.01.2015</td>
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<td>Krümmel</td>
<td>06.08.2011</td>
<td>24.08.2015</td>
<td>27.06.2016</td>
<td></td>
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</tbody>
</table>
## Licensing & supervision procedure

### Civil participation in the licensing & supervision procedure

<table>
<thead>
<tr>
<th>NPP</th>
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<th>Application</th>
<th>Scoping</th>
<th>Public Notice</th>
<th>Public Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafenrheinfeld</td>
<td>18.06.2015</td>
<td>28.03.2014</td>
<td>19.03.2015</td>
<td>09.05.2016</td>
<td>25.10.2016</td>
</tr>
<tr>
<td>Grohnde</td>
<td>31.12.2021</td>
<td>27.10.2017</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gundremmingen C</td>
<td>31.12.2021</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isar 2</td>
<td>31.12.2022</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dismantling and disassembling techniques

Operative range of the mean dismantling and disassembling techniques

- Plasma arc cutting
- Torch cutting
- Laser cutting
- Electro discharge machining
- Sawing
- Waterjet cutting

The graph shows the operative range of each technique in millimeters, with two conditions: atmosphere and under water.
Dismantling progress

- Design
- Documentation
- Radiation protection
- Laboratory
- Occupational health and safety
- Transport
- Decontamination
- Scaffolding
- Infrastructure

Disassembly and documentation: 20%
Dismantling on site: 10%

© EnBW Kernkraft GmbH
Reduction of radioactive inventory - full system decontamination (FSD)

Druckwasserreaktor Neckarwestheim I: Primärkreis-Dekontamination

- Umsetzung April/Mai 2013
- Oberflächenreinigung des nuklearen Primärkreislaufs
- Gesamtöberfläche rund 16.000 Quadratmeter
- Reduktion der Aktivität um ca. 99 Prozent

Siedewasserreaktor Philippsburg 1: System-Dekontamination

- Umsetzung November/Dezember 2013
- Oberflächenreinigung von Reaktordruckbehälter (RDB), RDB-Einbauten und Reaktorwasserreinigungssystem
- Gesamtöberfläche rund 8.500 Quadratmeter
Reduction of radioactive inventory - full system decontamination (FSD)
The excellent cooperation between teams and fantastic contributions such as these from the operating personnel of these plants made all these projects so successful!
Decontamination methods and waste Management

before decontamination: 393 µSv/h
Positive sign for the success of RPV decontamination
(not representative for the whole radiological situation in the RPV)

after decontamination: 12 µSv/h
Decontamination methods and waste management

Completion of the results of the TC and RPV decontamination measures, estimation:

Dismantling of the TC system    Duration: ~ 6000 man-hours

Before deco:  average local dose rate: ~ 115 µSv / h → collective dose: 690 mSv
After deco:   average local dose rate: ~ 5 µSv / h  → collective dose: 30  mSv
              saving:                  660 mSv
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4. Concept and technologies of nuclear waste treatment

5. Conclusion
Where is waste produced in Germany?

Radioactive residual products and waste are mainly produced:
- in connection with power generation by nuclear power plants
- during research and development activities
- during decommissioning and dismantling of nuclear facilities
- in industry and, small quantities, also in the medicine sector

Producer (waste producer/producer liable for disposal) of radioactive waste in Germany are divided into the following groups:
- Nuclear power plants
- Decommissioned nuclear power plants
- Nuclear industry (e. g. manufacturing of fuel elements)
- Reprocessing (Reprocessing facility Karlsruhe)
- Federal state collecting facilities (including central collecting facilities for radioactive waste of the Bundeswehr (German Federal Armed Forces))
- Research facilities
Established management of radioactive waste:
Treatment & conditioning of radioactive waste

Requirements on waste containers
(handling, transport, temporary and final disposal)

ALARA ⟷ Minimize dose rate and avoid potential release into environment

- Dimension and mass
- Resistance to mechanical impact
- Radionuclide containment
- Compressive strength (stackable)
- Fire resistance and combustibility
- Corrosion properties
- Radiation dose rates and radiation resistance
- Labelling
Waste Treatment

Type of waste

Solid waste

- Metal parts, debris, i.a.
- Metal parts, insulation, i.a.
- Paper, plastics, textiles, i.a.

Liquid waste

- Oil
- Sludge
- Evaporator concentrate
- Filter concentrate
- Ion-exchange resin

Raw waste

Conditioning

Compression

Waste products

- Solid waste
- Pellet

Final storage container

- e.g. container
- Salt rock, granulate, powder, cement block
- e.g. container, cast-iron packaging

© VGB
Treatment of radioactive waste

Comparison of volume reduction factors

- Raw waste: 1/1
- High force compaction: Up to 1/5
- Incineration: Up to 1/50
- Incineration + high force compaction: Up to 1/100

Source: VGB PowerTech e.V.
Treatment of radioactive waste

Compaction

Drum filled with mixed metal scrap before high force compaction

Drum after compaction (1500 t)

Source: NUKEM
Treatment of radioactive waste

**Compaction:** cross section cut of several pellets after compaction
Note: Removal = In Germany removal refers to a proceeding for the release of non-contaminated and non-activated substances as well as movable goods, buildings, facilities or part of facilities (in this section shortly referred to as “substances”) from nuclear supervision, unless the substances stem from the controlled area.
Waste management – disposal concept BWR

- **Total mass BWR**: 397,400 Mg
  - **Mass control area**: 222,500 Mg
    - **Mass buildings**: 200,100 Mg
    - **Radioactive residuals from dismantling**: 27,750 Mg
    - **Clearance on non-dismantled buildings**: 194,700 Mg
    - **Additional masses**: 500 Mg
    - **Nuclear material cycle**: 500 Mg
  - **Plant components mass to be dismantled**: 22,400 Mg
  - **Radioactive waste from dismantling**: 1,150 Mg
  - **Clearance acc. to §29 StrSchV**: 24,950 Mg
  - **Disposal as radioactive material**: 4,300 Mg
  - **Radioactive waste from dismantling**: 1,150 Mg
  - **Non-radioactive residuals from dismantling**: 7,800 Mg
  - **Clearance/removal on non-dismantled buildings**: 166,000 Mg
- **Mass outside control area**: 174,900 Mg
  - **Mass buildings**: 166,000 Mg
  - **Clearance on non-dismantled buildings**: 166,000 Mg
  - **Secondary waste**: 350 Mg

**Note:** Removal = In Germany removal refers to a proceeding for the release of non-contaminated and non-activated substances as well as movable goods, buildings, facilities or part of facilities (in this section shortly referred to as “substances”) from nuclear supervision, unless the substances stem from the controlled area.

© EnBW
Waste management – disposal concept PWR / BWR

<table>
<thead>
<tr>
<th>[Mg]</th>
<th>Total mass</th>
<th>Rad. waste</th>
<th>Clearance</th>
<th>Clearance/Removal Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWR</td>
<td>397,400</td>
<td>4,300 [1.1 %]</td>
<td>24,950 [6.3 %]</td>
<td>360,700 [90.8 %]</td>
</tr>
<tr>
<td>PWR</td>
<td>330,900</td>
<td>2,800 [0.8 %]</td>
<td>9,700 [2.9 %]</td>
<td>305,500 [92.3 %]</td>
</tr>
</tbody>
</table>
Packaging example of radioactive waste - PWR

<table>
<thead>
<tr>
<th>Type of repository container</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSAIK Container</td>
<td>245</td>
</tr>
<tr>
<td>Konrad-Container Typ III</td>
<td>117</td>
</tr>
<tr>
<td>Konrad-Container Typ IV</td>
<td>206</td>
</tr>
<tr>
<td>Konrad-Container Typ V</td>
<td>28</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>596</strong></td>
</tr>
</tbody>
</table>

2,800 Mg

© EnBW
Preparation for Repository KONRAD

According to the German waste disposal concept, separate radioactive waste repositories are envisaged for:

- Heat-generating wastes (final storage still open)
- Wastes with negligible heat production (LAW, MAW)
Containers for repository Konrad

D=560 mm
H=890 mm
V=0,2 m³
Treatment & conditioning of radioactive waste

**Waste containers:** steel drums (200 – 580 liters)

In-liner for high force compaction

Source: Eisenwerk-Bassum
# Casks & Containers for rePOSITORY Konrad

<table>
<thead>
<tr>
<th>Cask/Container</th>
<th>Length or Diameter (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete packaging I</td>
<td>1060</td>
<td>-</td>
<td>1370¹</td>
<td>1,2</td>
</tr>
<tr>
<td>Concrete packaging II</td>
<td>1060</td>
<td>-</td>
<td>1510²/³</td>
<td>1,3</td>
</tr>
<tr>
<td>cast-iron packaging I</td>
<td>900</td>
<td>-</td>
<td>1150</td>
<td>0,7</td>
</tr>
<tr>
<td>cast-iron packaging II</td>
<td>1060</td>
<td>-</td>
<td>1500⁴</td>
<td>1,3⁴</td>
</tr>
<tr>
<td>cast-iron packaging III</td>
<td>1000</td>
<td>-</td>
<td>1240</td>
<td>1,0</td>
</tr>
<tr>
<td>Container I</td>
<td>1600</td>
<td>1700</td>
<td>1450⁵</td>
<td>3,9⁵</td>
</tr>
<tr>
<td>Container II</td>
<td>1600</td>
<td>1700</td>
<td>1700</td>
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<td>Container III</td>
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<td>Container IV</td>
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<td>1450⁶</td>
<td>7,4⁷</td>
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<td>Container V</td>
<td>3200</td>
<td>2000</td>
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<td>Container VI</td>
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<td>2000</td>
<td>1700</td>
<td>5,4</td>
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</table>
Containers for repository Konrad

CYLINDRICAL CONCRETE CONTAINER TYPE I

D =1060 mm
H=1370 mm
V=1,2 m³
Containers for repository Konrad

CYLINDRICAL CAST CONTAINER TYPE II (Mobiler Sammelcontainer im Kraftwerk – MOSAIK)

D=1060 mm
H=1500 mm
V=1,3 m³
Containers for repository Konrad

STEEL CONTAINER TYPE I

L = 1600 mm
W = 1700 mm
H = 1450 mm
V = 3.9 m³
Containers for repository Konrad

CONCRETE CONTAINER TYPE IV

L = 3000 mm
B = 1700 mm
H = 1450 mm
V = 7.4 m³
Treatment & conditioning of radioactive waste

**Waste containers:** Cladded Concrete Shielding cask (UBA), IP-2

Material:
- cylindrical cask body consisting of an outer and inner **steel jacket**
- space between the two **jackets filled with concrete**; different densities available

Type of waste:
- **dry solid**, Intermediate Level Waste (ILW)
- Suitable for repository KONRAD

Source: GNS
Treatment & conditioning of radioactive waste

**Waste containers:** MOSAIK® cask

**Material:** ductile cast iron

**Type of waste:**

- **Intermediate Level Waste (ILW)** occurring during the operation and shutting down of nuclear facilities (ion exchange resins, evaporator concentrate, core components)
- Suitable for final disposal (**dry solid waste**)
Treatment & conditioning of radioactive waste

**Waste containers:** steel container, IP-2

- Example here: Type V container, L x W x H = 3.2 m x 2 m x 1.7 m, V = 10.9 m³
- Additional shielding made of concrete, steel or lead can be added
- Suitable for final disposal

Source: Eisenwerk-Bassum
Conditioning of radioactive waste
Example Facilities for treatment and interim storage

Replacement of the container lid on a container filled with concrete

Source: WAK GmbH
Example Facilities for treatment and interim storage

Interim storage II (interior view): full storage building (46 x 7 x 8 containers)

Source: WAK GmbH
Treatment & conditioning of radioactive waste

**Waste containers:** dimension and mass

- The container dimensions must be **compatible** with the requirements of existing or anticipated handling and storage arrangements, transport systems and disposal facilities.

Source: GRS
Castor for spent fuel and vitrified Canister

Source: GNS
Interim storage of heat-generating radioactive waste

German concept for dry interim storage in casks

- Accident-proof metal casks (above all GNS mbH CASTOR® type)
  with licence for transport and storage
  double-lid system;
  permanent leakage monitoring;
  vacuum-dried, helium-filled cask interior;
  type B(U) and/or B(U)F certification.

- Casks in reinforced concrete building
  for additional radiation shielding
  as well as mechanical barrier
  and for weather protection
Nuclear Waste Management in Germany

Status of interim storage in Germany

Central interim storage

Site interim storage

Around 850 casks will still be added until the final exit from the nuclear energy of Germany

© GRS

<table>
<thead>
<tr>
<th>Interim Storage</th>
<th>Vessels</th>
<th>In Operation since</th>
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<tbody>
<tr>
<td>TBL Ahaus</td>
<td>329</td>
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<td>TBL Gorleben</td>
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</table>

*Note: '02.05.2006' for Brunsbüttel KKB could be a typo or specific date notation.
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2. Waste management during decommissioning
3. New development of dismantling & decontamination
4. Concept and technologies of nuclear waste treatment
5. Conclusion
Conclusion

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   - IAEA, EURATOM, WENRA, ENSREG (BSS)

2. **New development of regulations for nuclear disposal in Germany**
   - I. Reorganization in field of nuclear disposal
   - II. Reorganization of responsibilities in nuclear disposal
   - III. Modification of Act to site selection for repository

3. **New development of dismantling & decontamination**
   - Strategy, Licensing and supervision procedures
   - Optimization in decommissioning and decontamination

4. **Concept and technologies of nuclear waste treatment**
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   - Conditioning of nuclear waste, Casks and containers for repositories…
Thank you for your attention