8th US/German Workshop on Salt Repository Research, Design, and Operation

Workshop Images By Holger Wirth

Compiled by Laura A. Connolly
Sandia National Laboratories
Contributed by Holger Wirth, BMWI

COVRA
Middelburg, The Netherlands
September 5-7, 2017
COVRA Meeting Room Wall, September 2017
COVRA Offices Entrance, September 2017
Met ingang van 2009 worden enkele hallen in dit Laagradioactief afval Opslag Gebouw ingezet voor museaal medegebruik.

Door de bouwkundige constructie van dit gebouw is langs de wanden ruimte over, die niet door COVRA wordt gebruikt voor de opslag van radioactief afval. COVRA stelt de ruimte langdurig en zonder kosten beschikbaar aan de Vereniging van Zeeuwse Musea als centrale depotvoorziening voor museumcollecties. Een bijzonder voorbeeld van museale sponsoring en een unieke samenwerking voor Nederland!


www.zeelandmuseumland.nl
Flood Museum Outside, September 2017
Flood Museum, September 2017
Flood Museum, September 2017
Middelburg Drawbridge, September 2017
Repository Design for 4 Emplacement Alternatives

Type: flat bedded salt
1. Drift disposal of POLLUX® Casks
2. borehole disposal (horizontal) of canisters (BSK-H)

Type: salt pillow
3. borehole disposal (vertical) of canisters (BSK-V)
4. Direct disposal of CASTOR® Casks

Tasks:
• design temperature calculations (max. 200°C)
• design of the repository mine
• Transport and emplacement technology and -systems
• backfilling and sealing concept
Thank you for your attention!
Thank you for your attention!
WP 1: Deformation behavior at small deviatoric stresses

Comparison of different investigations

Dead weight setup

Sample size: d(h) 100 mm L = 140 m

Berest et al. (2015): Salt mine Varangerfell
Type: Avery Island salt, t = 15°C

Berest et al. (2017): Salt mine Alaussee
Type: Avery Island, Heilbronn, Gohobor
1 = 2 a

3D-simulation of salt dome uplift

BGR (2018): Type ERAM salt, d(h) 100 mm L = 200 m, t = 1, 4 a
New results of the KOSINA project
- Generic geological models / Integrity analysis
Till Popp (IfG), Tatjana Kühnlenz (BGR) & KOSINA-Team

KOSINA:
FuE-Projekt: Konzeptentwicklung für ein generisches Endlager für wärmendische Abfälle in flach liegenden Sediolithen in Deutschland sowie Entwicklung und Überprüfung eines Sicherheits- und Nachweiskonzeptes

R&D Project: Concept development for a generic repository for heat generating waste in shallow salt formations as well as development and review of a safety and safety demonstration concept (KOSINA)
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Participants</th>
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</thead>
<tbody>
<tr>
<td>12:30-13:30</td>
<td>Lunch</td>
<td></td>
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<tr>
<td>13:30-14:00</td>
<td>PA Codes and PA Codes &amp; PERTTRAN &amp;</td>
<td>D. Becker, GRS, J. Frederick, SNL</td>
</tr>
<tr>
<td></td>
<td>RepoTools</td>
<td>D. Becker, GRS</td>
</tr>
<tr>
<td>14:00-14:30</td>
<td>Uncertainty</td>
<td>G. Freeze, D. Sevougian, SNL, J. Wolf, GRS</td>
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<tr>
<td>14:30-15:00</td>
<td>FEP, etc</td>
<td></td>
</tr>
<tr>
<td>15:00-17:00</td>
<td>Tour of SNL</td>
<td></td>
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<tr>
<td>18:00</td>
<td>Workshop &amp; Presentation by Plant Vierbanne</td>
<td></td>
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Ewoud Verhoef, September 2017
Thilo von Berlepsch
September 2017
Berest, September 2017

10^{-10} \text{s}^{-1}

Strain

Test at Rangéville Mine

200°C

15°C

10 \text{ MPa}

Deviatoric stress

AVERY ISLAND SALT (RESPEC)
Thank you for your attention!
Regulatory Steps to Recertify WIPP

Every 5 Years - DOE is required to submit to EPA a Compliance Recertification Application (CRA) with a Performance Assessment (PA) for WIPP

- March 26, 2014 - DOE submitted 3rd WIPP CRA PA to EPA for recertification
PFLOTRAN-RepoTREND Code Inter-comparison: 
Inter-comparison Plan & First PFLOTRAN Results

Jennifer M. Frederick, Emily R. Stein, and S. David Sevougian
Sandia National Laboratories
Middelburg, The Netherlands
September 5-7, 2017
SAFETY CASE EXPERIENCES IN THE NETHERLANDS

Grupa, Jaap Hart, Hans Meeussen, Rosca-Bocancea, Thomas Schröder

Odenberg (TNO)

Alexander Becker, Dieter Buhmann, (GRS Braunschweig)

De Vries, Joan Govaerts (SCK-CEN)
Joint Project WEIMOS

Work Packages

WP 1: Deformation behavior at small deviatoric stresses

WP 2: Influence of temperature and stress state on damage reduction

WP 3: Deformation behavior resulting from tensile stresses

WP 4: Influence of inhomogeneities (layer boundaries, interfaces) on deformation

WP 5: Virtual demonstrator

WP 6: Administrative work
Basic assumptions for the damage reduction process:
- Long-term change in stress conditions in the near field of sealing structures as a result of convergence process
- Creeping of the rock salt mass on the sealing structure (hard inclusion) / on the backfill material (soft inclusion) with increasing contact pressure
- Reduction of the damage and permeability development as a result of crack closure and healing effects

WEIMOS-Approach:

Healing tests with different stress states and temperatures
Qualification and improvement of material models based on lab tests
Simulation of a complex model to demonstrate the improved modeling
Safety Demonstration – Model

- GRS-own software package RepoTREND (Transport and RETention of Non-decaying and Decaying contaminants in final Repositories)

RepoTREND

BioTREND
radioactive exposure in the biosphere

GeoTREND
transport through the host rock

NaTREND
mobilisation and release of contaminants from the repository

CRZ = Containment providing rock zone
Project REPOPERM

Joint project of BGR, DBT, and GRS

Mechanical and hydraulic behaviour of compacting crushed salt backfill at low porosities
WIPP Hydrogeology

- Repository in Salado bedded salt formation
  - >500-m thick salt unit
- Hydrogeology of formations above salt
  - Rustler Formation
    - Culebra dolomite
    - Magenta dolomite
    - Anhydrite
    - Mudstone/Halite
  - Dewey Lake Red Beds
    - Silt/sand stones + clay
  - Dockum Group
    - Silt/sand stones + clay

Diagram showing layers and formations including:
- Gatuna Formation
- Surficial Deposits
- Rustler-Salado Contact
- Rustler Formation
- Salado Formation
- Dockum Group
- Culebra
- Castile Formation
- Bell Canyon Formation
- McEwen Potash Zone
- Land Surface

Legend:
- Sand and Sandstone
- Siltstone and Sandstone
- Mudstone and Siltstone
- Anhydrite
- Halite
- Limestone

Elevation (m)
Preliminary Disposal Concepts for a Salt Repository: Salt Geologic Setting

- Plastic formation
  - Creep behavior impacts concept of operations
  - Excavations will close due to creep
  - Just-in-time drift construction
  - Self-healing
- Geochemical environment
  - Brine pore water
- Virtually impermeable media (diffusion dominated)
- Repository Access
  - For bedded salt, shaft access only
  - For domal salt, shaft or ramp access
Short Report on Salt Club Meeting

Jörg Mönig
GRS

Middelburg, The Netherlands
September 5-7, 2017
Offsite monitoring data
Punam Thakur (CEMRC)

On site and Off Site Monitoring Stations

- Receipt: 115 μg/g m³ of 137Cs Amm: 81.4 μg/g m³
- No off-site high-volume sampler detections were positively attributable to the NNX06-026A event.
Current research on deep borehole disposal of nuclear spent fuel and high-level radioactive waste - considerations within a German research project

Tino Rosenzweig
TU Bergakademie Freiberg
Middelburg, The Netherlands
September 5-7, 2017
d³f++: distributed density-driven flow

- density-driven groundwater flow
- salt and heat transport
- fluid density and viscosity depending on salt concentration and temperature
- porous and fractured media
- free groundwater surface – levelset function
- sources and sinks
- transport of radionuclides
- decay and ingrowth
- equilibrium and kinetically controlled sorption
- precipitation/dissolution
- diffusion into immobile pore water
- colloid-borne transport

- numerics based on UG, G-CSC, Frankfurt University
- finite volume methods
- geometric and algebraic multigrid solvers
- completely parallelized (UG: scaling invest. some 100,000 proc.)
FEP Catalogue, Database, and Knowledge Archive

Geoff Freeze, David Sevougian, Mike Gross, and Kris Kuhlman
Sandia National Laboratories (SNL)
Jens Wolf and Dieter Buhmann
Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)

8th US/GER Workshop
Nieuwdorp, The Netherlands
September 5, 2017
Discontinuities in salt

- Influence of nonhomogeneities in repository performance identified as 1 of 4 key areas of the research agenda
- Examples include bedding interfaces, boundary shear planes, joints, and seams of non-halite material such as anhydrite
- Does shear strain create a permeable flow path along an interface or premature salt failure?
- Little existing lab or in situ data to characterize shear strength of salt interface and effects of shear on interface displacement and permeability
- 2 nuclear power plants
  - 1 operating (500 MWE)
  - 1 shut down (GKN 1997)
- 2 research centers
- U-enrichment plant
- Mo-production
- industry
- medicine
- research
RADIOACTIVE WASTE STRATEGY IN THE NETHERLANDS

Ewoud Verhoef

COVRA

US-German Workshop 2017, Nieuwdorp
German Waste Management Strategy

US / German Workshop on Salt Repository Research, Design, an Operation

Dr. Thilo v. Berlepsch
DBE TECHNOLOGY GmbH
September 5th, 2017
Reconsolidation of crushed salt backfill – review of existing experimental database and constitutive models and need for future R&D work

Klaus Wieczorek (GRS), Ulrich Heemann, Dieter Stührenberg (BGR), Christian Lerch, Nina Müller-Hoppe (DBE TECHNOLOGY), Christoph Lüdeling, Till Popp (IfG), Uwe Düsterloh, Ralf Wolters (TUC)

8th US/German Workshop on Salt Repository Research, Design, and Operation Middelburg, The Netherlands, September 5-7, 2017
Ideas for a project (compiled by GRS, BGR, DBE TEC, IfG, TUC, SNL)

- A project aimed at clearing the deficits in prediction capability should include all three issues and their interrelation
  - Modelling
  - Experimental investigations
  - Process understanding
- Complementary idea: Tune backfill material to attain high performance characteristics early in a salt repository lifetime
SaltFEP Database and Salt Knowledge Archive

- www.saltfep.org
- Incorporation of new FEPS and Associated Processes into database
  - Complete list of new FEPS fully incorporated into electronic database
  - Mapping of prior (UFD, VSG) salt FEPS to new FEP structure
- New database search and evaluation functions added
- Addition of references for FEP-based salt knowledge archive
  - Replaces SNL’s SITED on-line archive
    - SITED has been taken offline and would require significant effort to comply with SNL network security requirements
### FEP list: External factors

<table>
<thead>
<tr>
<th></th>
<th>External factor</th>
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<tbody>
<tr>
<td>0.1.1</td>
<td>Interruption of Operations</td>
</tr>
<tr>
<td>0.1.2</td>
<td>Power Failure</td>
</tr>
<tr>
<td>0.1.3</td>
<td>Earthquake</td>
</tr>
<tr>
<td>0.1.4</td>
<td>Human Error</td>
</tr>
<tr>
<td>0.1.5</td>
<td>Mine Flooding</td>
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<tr>
<td>0.1.6</td>
<td>Aircraft Crash</td>
</tr>
<tr>
<td>0.1.7</td>
<td>Impacts from Hazardous Substances</td>
</tr>
<tr>
<td>0.1.8</td>
<td>Shockwave from Chemical Reactions</td>
</tr>
<tr>
<td>0.1.9</td>
<td>Lightning Strikes, Storm, Ice, Snow</td>
</tr>
<tr>
<td>0.1.10</td>
<td>Impact from Exterior Fire and other Site-specific Impacts</td>
</tr>
</tbody>
</table>

- mainly derived from regulations for nuclear facilities.
- external = outside the mine (ground surface), not within the facility.
Interaction between Operational Safety and Long-Term Safety (Project BASEL)

Wolf, J.\textsuperscript{1}, Bertrams, N.\textsuperscript{2}, Bollingerfehr, W.\textsuperscript{2}, Buhmann, D.\textsuperscript{1}, Fahrenholz, C.\textsuperscript{1}, Filbert, W.\textsuperscript{2}, Lommerzheim, A.\textsuperscript{2}, Noseck, U.\textsuperscript{1}, Prignitz, S.\textsuperscript{2}

\textsuperscript{1}GRS gGmbH, \textsuperscript{2}DBE Technology GmbH

Middelburg, The Netherlands
September 5-7, 2017
Thank you for your attention!
September 4 – Monday, NEA Salt Club Meeting same venue

September 5 - Tuesday

Day 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>8:00-8:30</td>
<td>Registration</td>
</tr>
<tr>
<td>08:30-08:45</td>
<td>Kick off and organizational details</td>
</tr>
<tr>
<td>08:45-09:00</td>
<td>Welcome COVRA</td>
</tr>
<tr>
<td>09:00-09:15</td>
<td>Welcome BMWi</td>
</tr>
<tr>
<td>09:15-09:30</td>
<td>Short Report on SC meeting</td>
</tr>
<tr>
<td>09:30-10:00</td>
<td>IAEA repository studies</td>
</tr>
<tr>
<td>10:00-10:30</td>
<td>Break and Group Photo</td>
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Developments in National Programs (chair: S. Meyer-IAEA)

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>10:30-11:00</td>
<td>Dutch Waste Management Strategy</td>
</tr>
<tr>
<td>11:00-11:30</td>
<td>Welcome DOE and Summary of US WM status</td>
</tr>
<tr>
<td>11:30-12:00</td>
<td>German Waste Management Strategy</td>
</tr>
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Safety Case Issues (chair: W. Steininger, KIT)

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<tr>
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<tbody>
<tr>
<td>12:00-12:30</td>
<td>Netherlands Safety Case experiences OPERA</td>
</tr>
<tr>
<td>12:30-13:30</td>
<td>Lunch</td>
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Key Steps Toward Recovery

- Documented Safety Analysis Revisions
- Safety Management Program Revitalization
- Underground Restoration
  - Re-Establish Degraded Equipment
  - Fire Protection
  - Maintenance and Ground Control
  - Radiological Roll-back
  - Soot cleaning of electrical panels
- Expedite mine stability
- Initial Panel 6 and Panel 7, Room 7 Closure
- Interim Ventilation