UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201
703-235-4473

AGENDA

Workshop on Recent Advances in Repository Science and Operations from International Underground Research Laboratory Collaborations

Embassy Suites by Hilton San Francisco Airport Waterfront
150 Anza Boulevard, Burlingame, CA 94010

Wednesday, April 24, 2019 (Ambassador Ballroom)

8:00 a.m. **Call to Order and Introductory Statement**
Jean Bahr (Board Chair)

8:15 a.m. **Underground Research Laboratories: Purposes, Types, and Activities**
Michael Apted (INTERA)

QUESTIONS TO BE ADDRESSED:

- What is an underground research laboratory (URL) and what purposes are they serving in national nuclear waste disposal programs?
- Where are the major URLs located, and in what types of potential repository host rocks are these constructed?
- What are the characteristics of these types of host rocks that (1) are advantageous for a mined geologic repository and (2) might be disadvantageous to a mined geologic repository?
- What are some key uncertainties that remain with respect to processes in these host rock environments?
- The Nuclear Energy Agency of the Organization for Economic Co-operation and Development distinguishes between “generic” and “site-specific” URLs. What are the features and advantages of each of these?
- What types of research, development, and demonstration activities are undertaken at URLs (e.g., site characterization, experiments on host rock and engineered barrier behavior, and demonstration of disposal concepts)?
- Can you describe a few key processes and uncertainties for repository safety cases that are being or have been investigated in URLs?
- Can you provide examples of URL observations or experiments that have been successful in discriminating between competing hypotheses or conceptual models for repository performance?

Note: The questions have been provided to the speakers in advance of the meeting to convey the Board’s primary interests in the agenda topics and to aid in focusing the presentations.

8:45 a.m. *Questions, discussion*

9:00 a.m. **International Programs, Part 1 – each speaker has 30 minutes**
Irina Gaus (Nagra, Switzerland)
Patrik Vidstrand (SKB, Sweden)

10:00 a.m. **Break**

10:10 a.m. **International Programs, Part 2 – each speaker has 30 minutes**
Daniel Delort (Andra, France)
Simon Norris (Radioactive Waste Management, United Kingdom)

QUESTIONS TO BE ADDRESSED BY EACH INTERNATIONAL SPEAKER:

- Please begin by briefly describing the geologic/hydrologic setting of your country's expected repository and the key components of your safety case.
    - What is the role of your URL research and development (R&D) program in your country's repository program?
- How were the objectives of the URL R&D program initially defined and how have the R&D activities evolved?
    - What key parameters needed for the safety case were defined?
    - Was the R&D prioritization done based on conceptual models and/or features, events, and processes?
    - Describe successes to date, particularly experiments that discriminated between competing hypotheses.
    - What was the most unexpected thing learned from the URL program?
- How are the results of the URL R&D incorporated into repository performance assessments (e.g., as parameter values in performance assessment models, model validation, etc.) and the safety case (e.g., confirmation of predicted system behavior)?
- What are the most important R&D activities related to demonstrating repository operations?
- What R&D activities have proven most helpful for performance confirmation monitoring and waste retrievability/reversibility?
- How effective have URLs proven to engendering stakeholder confidence and public acceptance of a repository?

11:10 a.m. **Facilitated Panel Discussion**
Panelists: *Michael Apted* (INTERA), *Irina Gaus* (Nagra, Switzerland), *Patrik Vidstrand* (SKB, Sweden), *Daniel Delort* (Andra, France), *Simon Norris* (Radioactive Waste Management, United Kingdom)

11:55 a.m. **U.S. Department of Energy's (DOE) Collaborations and Underground Research Program: Overall Program and Approach**
William Boyle (DOE Office of Nuclear Energy)

QUESTIONS TO BE ADDRESSED:

- What are the main objectives and mission of DOE's Disposal R&D Program within the Office of Spent Fuel and Waste Science and Technology?
- What are the main components of the program?
- What are the priority R&D areas and associated questions/challenges?
- How do these priorities relate to key uncertainties associated with each of the generic host rock environments (crystalline, clay/argillite, salt)?

12:15 p.m. *Questions, discussion*

12:30 p.m. **Lunch Break (1 hour)**

1:30 p.m. **DOE's Specific Research and Development Activities Related to International URLs**
Jens Birkholzer (Lawrence Berkeley National Laboratory)

QUESTIONS TO BE ADDRESSED:

- Summarize the DOE portfolio of URL collaboration efforts in the context of the overall disposal research program.
- What are the key processes and uncertainties in the disposal research program that can be addressed in URL collaborative research?
- How are these questions similar to or different from those other countries are attempting to address?
- What policy, logistical, and technical issues were considered by DOE in selecting its URL participation?
- How have the results obtained to date informed and challenged assumptions of DOE modeling (conceptual and numerical)?
- How are these activities integrated into and supporting DOE's generic disposal efforts related to its generic disposal safety assessment and direct disposal of dual-purpose canister efforts?

2:10 p.m. *Questions, discussion*

2:30 p.m. **DOE's Near-Field Natural Barrier Perturbation Activities: Talk 1 Thermo-Hydro-Mechanical (THM) Perturbations in Bentonite/Argillite Repositories: Heater Tests at Mont Terri and Bure**
Jonny Rutqvist (Lawrence Berkeley National Laboratory)

QUESTIONS TO BE ADDRESSED:

- Describe the conceptual model for near-field perturbations in a bentonite/argillite repository.
- What are the key unknowns (knowledge gaps) and uncertainties in the conceptual model?
- What has been learned to date from the heater tests?

    - How important is the near-field damage to a host rock (such as clay and salt) due to initial mechanical and thermal perturbation, and how effective is healing and sealing of the damage zone in the long term?
    - Describe the constitutive models used to capture coupled heat transfer and water flow in deformable, unsaturated geomaterials, and their calibration. How reliable are available constitutive models for capturing the thermal volume change of unsaturated bentonites under high temperatures? Are sufficient data available in the literature to calibrate advanced constitutive models, or are additional testing programs needed to understand the behavior of these geomaterials?
- How do the small-scale element tests performed in the laboratory for calibration of constitutive models address uncertainties in the values of key parameters in the constitutive model?
- How can small-scale physical-modeling experiments (i.e., experiments that measure variables during coupled heat transfer and water flow processes in deformable geomaterials) be upscaled to repository-scale predictions?
- How are the repository-scale heater tests integrated into and supporting DOE's generic disposal R&D efforts for:
    - different host rocks and the engineered barrier system
    - the generic disposal safety assessment tool
    - direct disposal of dual-purpose canisters?
- Specific to the FE Heater Test as a demonstration experiment:
    - Can the behavior of an entire repository system, including all engineered and natural barriers and their interactions, be demonstrated, and is the planned construction and emplacement method feasible?
    - How suitable are the monitoring methods employed in the FE test to performance confirmation monitoring?

3:10 p.m. *Questions, discussion*

3:30 p.m. **Break**

3:45 p.m. **DOE's Engineered Barrier Integrity Activities: Talk 1**
Understanding Engineered Barrier System Coupled Processes and Mineral Alterations at High Temperatures: From Full-Scale Engineered Barrier Experiment-Dismantling Project (FEBEX-DP) to High Temperature Bentonite Project (HotBENT)
Liange Zheng (Lawrence Berkeley National Laboratory)

QUESTIONS TO BE ADDRESSED:
- Please explain why an engineered barrier/backfill is important and what aspects of the barrier are essential.
- Explain the conceptual model for engineered barriers, specifically for bentonite, in different host rocks
- What are the key unknowns and uncertainties in the conceptual models and how do they vary with host rock?

- What has been learned to date from the experiments?
    - What is the long-term stability and retention capability of backfills and seals?
    - What is the impact of elevated temperature on bentonite properties (thermo-elasto plastic model parameters, hydraulic properties, thermal properties)?
    - What is the impact of different bentonite compaction/placement strategies and initial conditions (i.e., distributions in initial density, initial gravimetric water content)?
    - Can we achieve temperatures approaching 200 °C, and are current constitutive models representative of this regime?
    - How relevant are interactions between engineered and natural barrier materials, such as metal-bentonite-cement interactions?
- Describe any research focusing on the effects of the change from partially saturated to saturated conditions with time, especially as the temperature decreases. Are the models that will be used to make forecasts for thousands or tens of thousands of years capable of modeling reactions in unsaturated conditions; for example, are reaction kinetics known for systems where the environmental conditions vary from unsaturated to saturated conditions?
- Do any experiments or simulations address the effect of vapor or steam on mineralogy (i.e., for early time periods where conditions are unsaturated)?
- How are these activities integrated into and supporting DOE's generic disposal R&D efforts for:
    - different host rocks and the engineered barrier system
    - the generic disposal safety assessment tool
    - direct disposal of dual-purpose canisters?

4:25 p.m. *Questions, discussion*

4:45 p.m. **Public Comments**

4:59 p.m. **Adjourn Public Meeting**

5:00 p.m. **Poster Session (Diplomat A & B)**
– 6:15 p.m. DOE posters and program posters from international speakers

Thursday, April 25, 2019 (Ambassador Ballroom)

8:00 a.m. **Call to Order and Introductory Statement**
Jean Bahr (Board Chair)

8:15 a.m. **DOE's Engineered Barrier Integrity Activities: Talk 2**
Thermal Implications on Transport in Bentonite: Using Full-Scale Engineered Barrier Experiment-Dismantling Project (FEBEX-DP) Samples for Laboratory Studies and Model Testing
Carlos Jove-Colon (Sandia National Laboratories), with help from *Patricia Fox* (Lawrence Berkeley National Laboratory) and *Florie Caporuscio* (Los Alamos National Laboratory)

QUESTIONS TO BE ADDRESSED:

- Explain the conceptual model for transport in bentonite.
- What are the key uncertainties and unknowns in transport properties and processes?
- What has been learned to date from the URL experiments?
    - What is the effect of high temperature on the swelling, sorption, water retention, hydraulic conductivity, and thermal conductivity characteristics of clays (i.e., considering the heat load from dual-purpose canisters)?
    - What is the role of thermal volume change over a wide range of temperatures in unsaturated bentonite?
    - How relevant are interactions between engineered and natural barrier materials, such as metal-bentonite-cement interactions?
    - How can the diffusive transport processes in nanopore materials, such as compacted clays and bentonites, best be described?
- How are these laboratory studies integrated into and supporting DOE's generic R&D disposal efforts for:
    - different host rocks and the engineered barrier system
    - the generic disposal safety assessment tool
    - direct disposal of dual-purpose canisters?

8:55 a.m. *Questions, discussion*

9:15 a.m. **DOE's Engineered Barrier Integrity Activities: Talk 3**
Gas Migration in Clay-Based Materials — International Collaboration Activities as Part of the DEvelopment of COupled models and their VALidation against EXperiments (DECOVALEX) Project
Jonny Rutqvist (Lawrence Berkeley National Laboratory)

QUESTIONS TO BE ADDRESSED:

- Describe the gas generation process in nuclear waste repositories, including the rate of gas generation, the expected pressure range, and gas composition, and explain the relevance of gas migration to repository performance.

- Comment on the available laboratory experiments on gas migration in various host rocks and engineered barrier materials and how they represent the expected initial saturation conditions and stress state in a repository.
- How are heterogeneities and construction seams in the bentonite pellets or blocks considered in the gas migration processes?
- Under what conditions do unsaturated conditions occur? How important is the role of unsaturated conditions in the bentonite and homogeneity of hydration in the engineered barrier system on gas migration?
- How does the total stress distribution in the engineered barrier system during partial hydration affect gas migration, and is this captured in simulations?
- How does the relationship between dilation and boundary conditions affect gas migration?
- How do deformation effects on the hydraulic properties of bentonite (permeability and water retention curve when the material is unsaturated) relate to gas migration?
- How important is the temperature distribution on the gas intrusion process?
- What is the effect of high temperature on gas formation and behavior?

9:45 a.m. *Questions, discussion*

10:00 a.m. **Break**

10:15 a.m. **DOE's Flow and Radionuclide Transport Activities: Talk 1**
Flow and Transport in Fractured Granite: Modeling Studies Involving the Bentonite Rock Interaction Experiment (BRIE) and the Long Term Diffusion Experiment (LTDE)
Hari Viswanathan (Los Alamos National Laboratory)

QUESTIONS TO BE ADDRESSED:
- What are the key uncertainties associated with predicting radionuclide transport in fractured crystalline rock?
- What has been learned from the experiments to date?
    - Can the active fracture network be identified and characterized adequately to predict near field and farther field transport?
    - How relevant are interactions between flowing fractures and bentonite (e.g., bentonite erosion, homogeneity)?
- For each of the experiments:
    - What questions does the experiment address?
    - How is the experiment designed and how are experimental conditions expected to evolve over time?
    - How does modeling of the experiment contribute to improved understanding of processes and parameter identification/quantification?
    - What has been learned to date from the results of the experiment (if it has been completed)?

10:45 a.m. *Questions, discussion*

11:00 a.m. **DOE's Flow and Radionuclide Transport Activities: Talk 2**
Colloid-Facilitated Transport: Studies Related to Colloid Formation and Migration (CFM) Project at Grimsel Test Site
Hakim Boukhalfa (Los Alamos National Laboratory)

QUESTIONS TO BE ADDRESSED:

- Colloidal transport in both unsaturated and saturated porous media has been extensively studied. However, in the context of media such as rocks and clay, the mechanisms of colloidal transport can be fundamentally different because of the presence of fractures and very small permeabilities. Describe the conceptual model for colloid-facilitated transport in the host rocks under consideration.
- What is the most likely source of colloids and what is the potential for transport of radionuclides by colloids in any of the host rocks under consideration?
- In conventional settings, transport of dissolved solutes is modeled by parameterizing the diffusivity, the permeability, the dispersivity, and the chemical reactions. What parameters are needed to characterize colloid-facilitated transport in host rocks? What are the unknowns and uncertainties for the key parameters controlling colloid-facilitated transport, and how do these uncertainties vary with host rock type?
- Will colloid transport be the same or different in different geomedia? What is the state of models that are used to simulate colloid associated transport in porous media? Can these models be applied with confidence to host rock conditions at URLs? With expected uncertainties in obtaining parameters for models, what is the level of confidence in predictions in URL settings?
- Describe the CFM project—the geometry, measurements, interpretation, rationale, and underlying assumptions. What has been learned to date from the experiment?
- What experimental data are available or what experiments are under way to generate data at URLs with different host rocks that will benefit DOE's R&D efforts to support generic disposal models? Please describe data that will help to address issues related to safety assessment of disposal systems, engineered barriers, and direct disposal of dual-purpose canisters.

11:30 a.m. *Questions, discussion*

11:45 a.m. **Lunch Break (1 hour)**

12:45p.m. **DOE's Salt Research and Waste Isolation Pilot Plant (WIPP) Activities: Understanding Heat-Driven Brine Migration in Salt: From Collaborations with the German Salt Program to the Planned WIPP Heater Test**
Kristopher Kuhlman (Sandia National Laboratories) and *Philip Stauffer* (Los Alamos National Laboratory)

QUESTIONS TO BE ADDRESSED:

- What is the significance of heat-driven brine migration to overall performance of a salt repository?
- What is the conceptual model for heat-driven brine migration in salt?
- What are the key unknowns and uncertainties in the conceptual model?
- What has been learned from the experiments to date?
    - How relevant are thermally-driven brine migration processes? Can they be predicted with confidence?
    - How important is the near-field damage to salt due to initial mechanical and thermal perturbation, and how effective is healing and sealing of the damage zone in the long term?
    - How reliable are existing constitutive models for the deformation of elastoplastic and plastic geomaterials as affected by temperature and water-content changes?

1:40 p.m. *Questions, discussion*

2:05 p.m. **Geologic Disposal Safety Assessment (GDSA): How GDSA Benefits from International Collaborations**
Emily Stein (Sandia National Laboratories)

QUESTIONS TO BE ADDRESSED:

- In which general ways does GDSA benefit from international collaboration (e.g., use of international datasets, development of post-closure PA models, confidence enhancement)?
- How have the individual international activities presented before supported GDSA developments and safety assessments?

2:45 p.m. *Questions, discussion*

3:00 p.m. **Break**

3:15 p.m. **Closing Facilitated Panel Discussion**
Panelists: *Michael Apted* (INTERA), *Irina Gaus* (Nagra, Switzerland), *Patrik Vidstrand* (SKB, Sweden), *Daniel Delort* (Andra, France), *Simon Norris* (Radioactive Waste Management, United Kingdom), *William Boyle* (DOE Office of Nuclear Energy), *Peter Swift* (Sandia National Laboratories)

4:45 p.m. **Public Comments**

5:00 p.m. **Adjourn Public Meeting**