Work Plan for UFD R&D Tests at KAERI Underground Research Tunnel (KURT) Site

Fuel Cycle Research & Development

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Appendix E
FCT Document Cover Sheet

Name/Title of Deliverable/Milestone	Work Plan for UFD R&D Tests at KAERI Underground Research Tunnel (KURT) Site (M4FT-12SN0811036)
Work Package Title and Number	UFD Natural System Evaluation & Tool Development
Work Package WBS Number	FT-12SN081103
Responsible Work Package Manager	Yifeng Wang (Name/Signature)

Date Submitted 7/31/2012

Quality Rigor Level for Deliverable/Milestone	☐ QRL-3	☐ QRL-2	☐ QRL-1 ☐ Nuclear Data	☒ N/A*

This deliverable was prepared in accordance with Sandia National Laboratories
(Participant/National Laboratory Name)

QA program which meets the requirements of
☒ DOE Order 414.1 ☐ NQA-1-2000

This Deliverable was subjected to:

☐ Technical Review

Technical Review (TR)

Review Documentation Provided

☐ Signed TR Report or,
☐ Signed TR Concurrence Sheet or,
☐ Signature of TR Reviewer(s) below

Name and Signature of Reviewers

N/A

☐ Peer Review

Peer Review (PR)

Review Documentation Provided

☐ Signed PR Report or,
☐ Signed PR Concurrence Sheet or,
☐ Signature of PR Reviewer(s) below

*Note: In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity along with the Document Cover Sheet is sufficient to demonstrate achieving the milestone. QRL for such milestones may be also be marked N/A in the work package provided the work package clearly specifies the requirement to use the Document Cover Sheet and provide supporting documentation.

Work Plan for
UFD R&D Tests at KAERI Underground Research Tunnel (KURT) Site

Yifeng Wang (Sandia National Laboratories)

Deep borehole disposal in crystalline rock and a mined repository in granite are two of the four disposal options that the Used Fuel Disposition Campaign (UFDC) is currently evaluating for high level radioactive waste disposition (Nutt, 2011). The Blue Ribbon Commission (BRC) explicitly recognizes that deep borehole disposal may hold promise but it is less well understood and thus recommends that further research, development & demonstration be needed to fully assess its potential advantages and disadvantages (BRC, 2012). In its research & development (R&D) roadmap (Nutt, 2011) and the related implementation plan for natural system study (Wang, 2011), the UFDC has identified the following key technical issues related to deep borehole disposal and granite repository concept development:

- Lack of predictive tools for subsurface flow and transport pathways in generally fractured crystalline media;
- Lack of understanding of physical and chemical conditions in deep boreholes, especially the evolution of excavation-disturbed zone (EDZ) around a borehole up to 5 km deep.
- Lack of data and modeling tools for predicting waste and engineered material behavior in deep borehole relevant environments.

To address these issues, in-situ testing in underground research labs (URLs) is required.

Korea Atomic Energy Research Institute (KAERI) Underground Research Tunnel (KURT) is a generic underground research laboratory, and it intends to obtain information on the geological environment and the behavior and performance of engineered barriers under repository conditions. It is located in a mountainous area inside the KAERI, Daejeon, Korea. It has a total length of 255 m with a 180 m long access tunnel and two research modules with a total length of 75 m. The maximum depth of the tunnel is 90 m from the peak of the mountain. The horseshoe shape tunnel is 6 m wide and 6 m high. The host rock is granite. KAERI is in the process to expand the research modules to include a major fracture zone for flow and tracer testing. KURT plays a significant role in developing and demonstrating the repository disposal concept in Korea. Currently, KAERI has planned or are conducting the following tests: (1) geological investigations, (2) solute migration experiments, (2) EDZ characterization, (3) borehole heater tests, (4) long-term monitoring, (5) tracer tests, and (6) redox chemistry tests. Importantly, within the site, there is a 1 km deep borehole (DB-2) all in granite that has been drilled and maintained to be accessible.

The KURT site offers the following unique capabilities and advantages:

- The existing deep (1 km) borehole in granite provides a unique site for testing and developing deep borehole disposal concept. To our knowledge, this is one of very few deep boreholes in a crystalline rock in the world. The diameter of the bottom part of the borehole is 3 inches. Given the small diameter of the borehole, this deep borehole is suitable for in-situ hydrological and geochemical testing and related technique development. KAERI is also interested in the deep borehole disposal concept. Dr. Kyung Su Kim has recently submitted a proposal on deep borehole disposal to his organization.

- The geology of the site is well characterized and the tunnel and borehole facilities are well developed, making the tests relatively easy to be conducted. Importantly, KAERI is very open for collaboration and is looking for new ideas and experimental designs for future tests, which makes it possible to design UFDC-specific experiments. Furthermore, unlike other sites, KURT does not require entrance fee. In addition, the cost for setting up and maintaining a test is relatively inexpensive.
- Under other programs, Sandia National Laboratories (SNL) currently has on-going collaboration projects with KAERI at the KURT site, including streaming potential (SP) testing for groundwater flow and cubic law testing for flow in a single fracture, both directly relevant to DOE UFD activities (Figure 1). These tests can provide critical data for the parameterization and validation of the discrete fracture network model currently under development for the UFD natural system work package.

Figure 1. Experimental setup for streaming potential testing

During April 23-26, Yifeng Wang of Sandia National Laboratories visited the KURT site and the adjacent deep borehole, and the 1st KAERI-SNL technical meeting was held. At this meeting, the following research items were identified for potential collaborations between UFDC and KAERI:

Item #1 - Testing in-situ measurement equipment for characterization of deep geologic conditions in a deep borehole

- In-situ measurement equipment will be developed and tested by SNL or jointly by KAERI and SNL. The size of equipment should be smaller than the diameter of borehole (~ 3 in).
- The tests will be focused on non-destructive techniques.
- Testing technique development will be focused on in-situ hydrological/geochemical measurements.

- The tests will use borehole DB-2.
- KAER and SNL will evaluate the current hydrological/geochemical data, discuss target investigation item(s), and develop new techniques as needed.

Action items:

- KAERI will provide borehole specification and hydrological/geochemical data from DB-2 (KAERI point of contact: KW Park).

Item #2 - Streaming potential (SP) experiments to quantify the correlation between SP signal and ground water flow in a fractured rock (including the chemical effect on SP Signal)

- The experiments will focus on potential applications of SP techniques to in-situ characterization of EDZ and deep borehole.
- Specifically, the SP experiments will investigate the chemical effect on SP signal.
- The initiation of the experiments will depend on the schedule of KURT next phase expansion (starting in April or May, 2013).
- SNL will discuss more internally on the ongoing SP experiments.
- SP experiments can be a part of research item #1 (e.g. SP experiments for deep borehole EDZ characterization).

Action items:

- Yifeng Wang will discuss with Bwalya Malama (SNL-Carlsbad) on the on-going SP tests.

Item #3 – Tracer tests in fractured geologic media, validation of discrete fracture network model using KURT geological data, and investigation of the effect of a stagnant zone on solute transport in a fracture (Lab. Test)

- The schedule of tracer test is set at the end of 2013 (or the start of 2014) at the KURT site
- SNL will identify the research items.
- SNL will develop a discrete fracture network model and will use KURT data for a model demonstration at the end of fiscal year 2013.

Action items:

- During the design of tracer tests, KAERI will perform borehole investigations of major water conductive fracture (MWCF).
- SNL will provide the key objectives of the discrete fracture network model developed for the UFDC.
- KAERI will provide the fracture maps (figures/tables) around the KURT site (KAERI point of contact: KW Park).

Item #4 – Heater tests for quantifying interactions between bentonite and rock under thermal-hydraulic-mechanical conditions

- The design of the testing system will start 2013-2014.

- The system will be installed in 2015-2016.
- The in-situ test will start March 2016.

Action items:

- Yifeng Wang will discuss with Carlos Jove-Colon on a joint effort between the Natural System (NS) Work Package and the Engineered Barrier System (EBS) Work Package on the tests.
- KAERI point of contact: HJ Choi

Item #5 – Development of high performance chemical/thermodynamic database (especially for clay and cement materials)

- The database will be shared between KAERI and UFDC.
- UFDC is developing a database for clay and cement materials FY 13 and will communicate with KAERI on the progress.

Action items:

- SNL will include this item for discussion at the US-ROK Joint Fuel Cycle Study (JFCS) working group meeting in May, 2012.

Item #6 – Performance Assessment (PA) framework development

- KAERI is developing its own PA framework. KAERI is interested in the development of advanced PA framework that can account for multiple couplings among various thermal-hydrologic-mechanical-chemical processes.
- SNL has already started the development of an advanced PA framework and will communicate with KAERI on the progress.

Action items:

- SNL will provide interim milestones to KAERI by September 2012.

Item 7 – Modeling of redox chemistry at KURT

- SNL has developed biogeochemical models for WIPP and Yucca Mountains. KAERI is interested in the modeling approach.

Action items:

- KAERI will provide the geochemical dataset of crystalline rock and a modeling research plan on deep borehole to SNL.
- SNL will provide references on biogeochemical modeling of deep geologic repositories.

Item #8 – *Long-term evolution of repository materials (cement, canister, clay etc) and their impact on groundwater chemistry*

- KAERI has ongoing experiments in the tunnel for testing long-term performance of engineered materials. Both SNL and KAERI have expressed their interest in developing

a joint testing program.

Action items:

- KAERI and SNL will discuss further.

The research items identified above should be pursued as soon as possible to meet both UFDC and KAERI programmatic schedule. The relevance of the research items and the tentative schedule are summarized in Table 1.

Table 1. Summary of research items for potential collaboration and their relevance to UFDC

Research item	Description	Relevance to UFDC	Schedule
1	Testing in-situ characterization techniques in deep borehole	Address natural system R&D topics S5, S6, S7, P17, and P18; support deep borehole work package.	Plan to start in FY13.
2	Streaming potential (SP) experiments	Address natural system R&D topics S5, S6, S7, P1, P17, and P18. The data obtained will used for the validation of discrete fracture network (DFN) model.	Ongoing under other funding source. UFDC work will take over the work in FY13. Need to accommodate the schedule of KURT next phase expansion.
3	Tracer tests in fractured media	Address natural system R&D topics P1, P9, and P12. The data obtained will used to directly support DFN model development.	Fracture data will be used for DFN model demonstration in FY13. UFDC will participate in the design of tracer testing in late 2013 or early 2014.
4	Heater tests on bentonite-host rock interactions	Address natural system R&D topics P14, P17 and P18, especially the issues related to technical basis for thermal limits. This will be a joint effort between the NS work package and the EBS work package.	TBD UFDC will participate in the design of the experiments.
5	Development of high performance chemical/thermodynamic database	Address natural system R&D topic S4. This activity will support both NS and EBS work packages.	Initiated in FY12 under JFCS and will continue in FY13 and beyond.
6	PA framework development	Enhance UFDC PA model credibility.	Technical exchange was initiated in FY12 under JFCS and will continue in FY13 and beyond.
7	Modeling of redox chemistry at KURT	Address natural system R&D topic P8.	Data exchange will start in FY13.
8	Long-term evolution of repository materials	Directly support EBS work package.	TBD

References

BRC (Blue Ribbon Commission on America's Nuclear Future) (2012) Report to the Secretary of Energy. Department of Energy.

Nutt, M. (2011) Used Fuel Disposition Campaign Disposal Research and Development Roadmap. FCR&D-USED-2011-000065 REV 0.

Wang, Y. (2011) Research & Development (R&D) Plan for Used Fuel Disposition Campaign (UFDC) Natural System Evaluation and Tool Development.