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CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

REVISED
TRIP REPORT

SUBJECT: DECOVALEX III Workshop 2 (20.01402.671)

DATE/PLACE: June 6–9, 2000
Hotel du Sauvage, Meirengen, Switzerland

AUTHOR: Ronald T. Green

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PERSONS PRESENT:

Workshop was attended by R. Green, CNWRA; M. Nataraja, NRC; and approximately 50 representatives from other participating organizations (SKI, SKB, ENRESA, CEA, ANDRA, NAGRA, STUK, AECL, JNC, AECB, NIREX, and DOE).

BACKGROUND AND PURPOSE OF TRIP:

The purpose of the trip was to participate in the second workshop of the international thermal-hydrological-mechanical modeling DECOVALEX III Project. DECOVALEX III is the third in a series of modeling projects initiated in 1992. The Nuclear Regulatory Commission (NRC) participated in DECOVALEX I, did not participate in DECOVALEX II because of budget constraints, and resumed participation in DECOVALEX III. A workshop, or task group meeting, is usually held twice a year to allow participants an opportunity to present results and plan future activities. Two new teams have asked to join the DECOVALEX III Project, CEA and the German Federal Institute of Geosciences and Natural Resources.

The DECOVALEX III Project is divided into several test cases referred to as Tasks. Each Task has a sponsoring organization, typically the organization responsible for the conduct of the subject test case. It is the responsibility of the sponsoring organization to define the test case, provide characterization information, and define the target modeling objectives. For example, the DOE is the sponsoring organization of Task 2, the drift-scale heater test (DST) at Yucca Mountain. DOE has provided a description of the DST, characterization information, and stated what test result data are available; however, the test measurement data have not been disclosed to the DECOVALEX III Project. Typically, not all DECOVALEX teams participate in all Tasks.

SUMMARY OF PERTINENT POINTS:

The workshop was organized into three days of presentations and discussions and a one-day field trip to the Grimsel Test Site (GTS). There are four Tasks in DECOVALEX III: Task 1–FEBEX *in situ* experiments; Task 2–Yucca Mountain drift-scale test (DST); Task 3–Three benchmark tests (BMT)—BMT1 near-field safety, BMT2 upscaling and homogenization, BMT3 glaciation; and Task 4–Forum and questionnaire on

THM processes in performance assessment. NRC direct participation is limited to Tasks 2 and 4; however, comments on other Tasks are included in this report.

Task 1 is the examination of the FEBEX *in situ* experiment at the Grimsel Test Site (GTS). A description of the multi-national team working on FEBEX was made by J. Audstillo, ENRESA. A summary of the test was presented by F. Kautsky, SKI, managing director of DECOVALEX III program. The objectives of the FEBEX project are to understand (i) the engineered barrier system (EBS), (ii) THM processes, and (iii) THC processes. Task 1 update was presented by E. Alonso of ENRESA, the managing organization of Task 1. Only two of the nine teams participating in the Task provided predictions of THM processes in time for preworkshop comparison, although several presented prediction results at the workshop. The participants were asked to predict the rate of water flow at one point in the tunnel and water pressure in a borehole near the FEBEX tunnel as a result of excavation of the tunnel. Results from the SKB team and one of two analyses by ANDRA were submitted prior to the workshop. The SKB results were very close (i.e., within two percent) to those measured by ENRESA. Results by all others varied as much as one order of magnitude from the measured values. The approaches by the different teams varied considerably. Some teams used the characterization data explicitly, while other teams calibrated their models by allowing some data to vary. This methodology was useful, particularly for data that appeared to be disparate.

In conjunction with the team presentations, P. Zuidema, NAGRA, presented a discussion on the Swiss involvement in the FEBEX program. In particular, he discussed performance assessment (PA) in terms of FEBEX THM issues. Key issues addressed in FEBEX include: stress fields, stability, conventional mine safety, excavated damage zone (EDZ), mining precision (i.e., emplacement of bentonite blocks), retrievability, coupled phenomena, convergence of disposal tunnels, and self healing (i.e., EDZ). Zuidema concluded that THM is important to PA, but highly system-dependent and that PA differs during construction and operation phases. He appealed to THM investigators to interact with those involved with PA. He also noted the need to identify which components are important to PA. The importance of monitoring waste was discussed. It was noted that waste cannot be simply buried and forgotten; the importance of monitoring buried waste is emphasized.

Zuidema concluded with general statements on the Swiss HLW disposal program. The Swiss have decided to abandon granite as the medium for HLW disposal and have opted to explore the Opalimus Clay for disposal. Several criteria were cited for this decision: the target granite formations are either too deep or too close to country borders; the performance of crystalline rock is hard to predict; the characterization of crystalline rock is highly challenging; contrary to crystalline rock, clay is self healing; and the age of groundwater in the Opalimus Clay is of the order 10^6 years.

Task 2 on the Yucca Mountain DST has been divided into four subtasks:

- Task 2a—To model the TH response of the DST
- Task 2b—To model the TM response of the DST using results from the TH simulations
- Task 2c—To model the TM response of the DST using measured TH values of the DST
- Task 2d—To model the THC response of the DST and predict gas and water chemistries

Task 2d is a newly assigned subtask. It was added in response to a request by the JNC team. Several other teams, including the NRC, expressed a potential interest in participating in Task 2d.

The number of teams participating in Task 2 has increased since the start of the project. Current participating teams include NRC, SKI, ENRESA, and JNC. CEA, if accepted into the DECOVALEX III project, expressed their intention to participate in Task 2. The CEA team lead for this task will be Christophe Grenier.

R. Green, CNWRA, was the first presenter for Task 2. His presentation was a status report for the NRC/CNWRA team. R. Green discussed the general framework of the NRC plan for Tasks 2a, 2b, and 2c. The TH response of the DST will be simulated using MULTIFLO as part of Task 2a. The predicted TH simulated responses will be provided as input for the TM simulations to be conducted as part of Task 2b. The NRC/CNWRA model was described. The description included the model setup, including element construction, boundary and initial conditions; and additional model parameters, in particular, parameters associated with the dual continuum model conceptualization. Preliminary model results were presented. Model predictions for temperature were compared at 1.0 and 1.9 yr after heating along Borehole 158, which is vertically oriented midway down the heater drift and placed in the drift ceiling. As illustrated in the results, a much stronger heat pipe was predicted in the model results than has been observed in the DST. The source of this discrepancy was discussed in some detail. R. Green noted that the use of large-sized blocks was necessitated to be able to predict reasonable steady-state ambient saturations, but in doing so, may have modified the energy and mass transfer between the matrix and fracture continua. B. Bovardsson, LBL, and R. Datta, DOE, concurred that this is the probable source of the discrepancy. DOE also noted that the NRC/CNWRA results, although not consistent with observed results from the DST, are consistent with the DOE pretest predictions.

Additional comments were directed at the use of the van Genuchten model to represent the fracture continuum capillary pressure/saturation relationship. Although results of DOE were neither discussed nor presented at the meeting, it was noted that DST modeling results by Birkholzer and Tsang (2000) applied the van Genucthen relationship to liquid relative permeability, but the Brooks-Corey relationship to gas relative permeability.

S. Olivella, University de Barcelona, discussed the status of the ENRESA team. Olivella has recently initiated work on this task. ENRESA plans to participate in Tasks 2a, 2b, 2c, and possibly 2d. His efforts to date entail a theoretical examination of the DST problem (examination of capillary and relative permeability relationships in unsaturated media) and a one-dimensional simulation of the single-heater test at Yucca Mountain. The ENRESA team plans to accelerate their participation in Task 2. ENRESA will use the nonisothermal unsaturated soil approach to investigate the problem using CODE_BRIGHT, a fully coupled THM code, although the TH and TM processes will be decoupled for the DST analyses.

J Rundquist, LBNL, discussed the SKI team status for Task 2. Rundquist stated that the SKI team was not participating in Task 2a, modeling TH response of the DST, but would participate in Tasks 2b and 2c. Rundquist intends to use the fully coupled THM code ROCMAS for his analyses. He will have to use predetermined or measured values for temperature because ROCMAS is not capable of calculating temperature for above-boiling regimes.

T. Fujita, JNC, detailed their approach to the DST problem. Their interest encouraged them to recommend the inclusion of Task 2d, analysis of coupled THC processes at Yucca Mountain. They have not yet initiated detailed analyses of the THC system at the DST.

C. Greiner, CEA, stated that CEA has applied for membership in the DECOVALEX III program. If accepted, CEA stated that they intend to participate in Task 2. Greiner explained that there are three components to the

French HLW program: (i) long-term disposal of HLW to be conducted by ANDRA; (ii) intermediate disposal of HLW to be conducted by CEA and DCC (the division in charge of the combustible fuel cycle); and (iii) transmutation of HLW, to be conducted by CEA. All three of these divisions are on the licensee side of the French program. Identification of an intermediate site in the unsaturated zone led to the recent interest of CEA in Task 2 of DECOVALEX III.

Benchmark Test 1 (BMT 1) of Task 3 addresses near-field safety issues related to THM processes. The Kamaishi mine experiments are used as the test cases. S. Nguyen, AECB, presented a detailed discussion of the mine experiments and proposed problems. Three teams (S. Nguyen, AECB; J. Rundquist, LBNL for SKI; and M. Chijimatsu, JNC) presented results of their modeling efforts. These modeling results are still early in development.

Benchmark Test 2 (BMT 2) of Task 3 addresses upscaling/homogenization of THM processes at the Sellafield site in England as the test case. L. Knight, NIREX, made opening remarks of BMT2. The task is currently planned to continue until 2002. A total of five teams made presentations on BMT2 (A.Sahuquillo, University de Valencia for ENRESA; G. Bodvardsson, LBNL for DOE; T.Fugita, JNC; T. Chan, OPG; and L. Jing, SKI).

The consensus of all discussions on BMT 2 was that the task is not yet sufficiently defined. There was a general sense stated that there is no formally accepted method to upscale THM processes. It was noted that informal methods, such as engineering judgment, may be acceptable. At the conclusion of the presentations and discussions the following required actions were identified to provide coherency to BMT 2:

- finalize the problem description
- provide a reference problem (preferably with a deterministic solution)
- provide a synthetic data set
- identify specific performance measures

G. Bodvardsson recommended the following as specific examples for performance measures for BMT 2: (i) long-term seepage for H; (ii) temperature history for T; (iii) radionuclide transport for C; and long-term displacement for M. C-F Tsang recommended that integral quantities (i.e., travel times) are better measures of performance than point measures (i.e., arrival times) due to heterogenieties.

J. Andersson, consultant to the DECOVALEX Secretariat, presented a discussion on the responses to a questionnaire sent to all participants inquiring about the effects of THM processes on performance assessment. A total of six participating teams (including the NRC/CNWRA) responded to the questionnaire. The compiled results were distributed in a draft document. The questionnaire asked how each team viewed the importance of THM on performance assessment and how each team currently incorporates THM processes in their performance assessments. In response to a question by M. Nataraja, NRC, the participating teams were assured that each team would have an opportunity to review/edit the draft prior to release of a final document. The final review would allow the teams an opportunity to pass their comments through their respective organization's review processes.

SUMMARY OF ACTIVITIES:

The workshop included DECOVALEX III task sessions with presentations by participating teams. R. Green made a presentation on the status of Task 2 DST numerical model. The DECOVALEX III steering committee meeting was attended by M. Nataraja of the NRC.

There was a field trip to the Grimsel Test Site (GTS) on Friday. The FEBEX experiment and other *in situ* experiments were visited on the last day of the workshop. Of additional interest to the FEBEX experiment is a silo experiment under construction at the GTS. A vertically oriented ~5 m diameter, ~5 m deep shaft has been excavated into the host granodiorite. Eventually, a heater will be placed in the shaft and encased in bentonite. Currently, evaluation of the loss of moisture from the host rock is ongoing. Two sets of measurements are being made, both based on relative humidity. In the first method, a disc has been attached to the recently exposed silo wall. The movement of moisture out of the rock and through the disc is estimated by measuring air flow and relative humidity. In the second method, the access drift to the silo has been sealed off. The flow rate and relative humidity into and out of the sealed off access drift and silo area are measured. The loss of moisture out of the exposed rock surface is calculated from the measured moisture removal through the sealed bulkhead. This measurement system is of interest because it is similar to what was suggested to the DOE at the April 28, 1999, TEF Appendix 7 meeting as a way to measure mass loss through the bulkhead at the DST. DOE had responded that the air flux rate at the DST was too great to allow meaningful measurement of negligible changes in relative humidity between the inflowing and outflowing air.

R. Green participated in additional meetings with J.C. Major, ENRESA, and ENRESA contractors to discuss a planned *in situ* ventilation experiment in clay at Monterry, Switzerland, for the upcoming year. The constructed horizontally oriented tunnel is 7 m long and has a diameter of 1.2 m. The specific details of the experiment and its conduct are not yet finalized, but the essence of the experiment will be to instrument the drift to allow mass loss measurements, then subject the drift to drying from air ventilation into and out of a bulkead. Approximately 4–5 other national programs are participating in the experiment.

CONCLUSIONS:

The Task 2 DST presentation by R. Green generated many comments, most from representatives from DOE, the Task 2 sponsoring organization. Presentations on the other tasks illustrated problems encountered and potential approaches to analyzing THM processes in a variety of media. Of common interest were solution techniques, characterization methodologies, continuum versus discrete conceptualizations, calibration methodologies, and coupling versus decoupling approaches used to analyze THM processes. Considerable discussion was devoted to how the success of various approaches should be evaluated. In all cases the success of the exercises was ultimately tied to performance of the repository. The discussions emphasized that processes only need to be evaluated if they have an impact on performance.

PROBLEMS ENCOUNTERED: None

PENDING ACTIONS:

J.C. Major, ENRESA, is to send to R. Green project documents and plans for the *in situ* ventilation experiment. CNWRA is to continue modeling the DST as part of Task 2. NRC/CNWRA should consider whether to participate in the newly defined Task 2d, simulation of coupled THC processes, at the DST.

RECOMMENDATIONS:

It is recommended that NRC/CNWRA continue their participation in DECOVALEX III. The modeling and analysis exercise provides an opportunity to critically compare numerical simulation results to a well controlled, structured field-scale experiment. The NRC/CNWRA program can benefit from the advances of other national programs that address similar challenges facing the proposed repository at Yucca Mountain.

REFERENCE:

Birkholzer, J.T., and YW. Tsang. Modeling the thermal-hydrologic processes in a large-scale underground heater test in partially saturated fractured tuff.. *Water Resources Research* 36(6): 1,431–1,447. 2000.

SIGNATURES:

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