February 26, 2001

MEMORANDUM TO: William F. Kane, Director
Office of Nuclear Material Safety
and Safeguards

FROM: John T. Greeves, Director /RA/
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

SUBJECT: EXECUTIVE SUMMARY OF THE TRIP REPORT FOR THE FOREIGN TRAVEL RELATED TO DECOVALEX PROJECT

Dr. Mysore Nataraja of my staff attended the steering committee meeting and participated in the third workshop of the Development of Coupled Models and Their Validation Against Experiments (DECOVALEX) Project in Japan on January 20-27, 2001. The Nuclear Regulatory Commission (NRC) is a funding organization for this project along with many other countries. The DECOVALEX project is in its third and final phase and is scheduled to run until December 2002 when a final report will be published. Of great interest to the United States Department of Energy (DOE) high-level waste disposal program is the participation of Swedish, Japanese, French, and the Spanish modeling teams (in addition to the NRC and DOE teams) in evaluating the results of the Drift-Scale Heater Test being conducted at the Yucca Mountain site by DOE. Although the teams are still at very early stages of modeling and evaluations of the results, it was evident that the temperature predictions made by most teams agreed well with measured values. However, when thermal impacts are coupled with mechanical and/or hydrological behavior, wide ranges of results were predicted depending on the limitations and capabilities of the models used. The NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) team will continue to actively participate in the project until the final report is published. Our participation in this project directly supports our strategic goal of nuclear waste safety. Mysore Nataraja and Ronald Green of the CNWRA discussed the progress made to date in modeling the thermal-hydrological aspects of the heater experiment during the workshop and worked out details for further work.

After the Workshop, the participants visited Japan's Geological Isolation Basic Research Facility at Tokai, and the Underground Research Laboratory at the Tono Geoscience Center. Both the facilities are run by Japan Nuclear Cycle Development Institute (JNC). Tests and investigations currently in progress include state-of-the-art rock mechanics and geochemistry tests at the Tokai Works Facility and at-depth mechanical-hydrological investigations of the shallow sedimentary hard rocks at the Tono Mines. Future tests are planned for testing granitic rocks at greater depths.

NRC participation in this project has provided very valuable insights into the current capabilities and limitations of coupled models being used by various international high-level waste programs. This knowledge is being used by the staff in developing acceptance criteria for the Yucca Mountain Review Plan under preparation.

A more detailed trip report is attached to this memorandum. Neither this executive summary nor the detailed trip report contains any sensitive information. If you have any questions on the contents, Dr. Nataraja may be contacted at 415-6695 or by e-mail at (msn1).

Attachment: As stated

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TRIP REPORT, THIRD STEERING COMMITTEE MEETING AND WORKSHOP DECOVALEX PROJECT PHASE-III

From January 22 through 26, 2001, Mysore Nataraja of the Division of Waste Management attended the third steering committee meeting and workshop on the coupled thermal-hydrological-mechanical (THM) processes project (phase-III) for waste repositories in Mito and Tokai, Japan. He also visited the test facility at the Japan Nuclear Cycle Development Institute (JNC) on January 23, 2001, and the underground test facility at the Tono Mines on January 27, 2001. This trip report provides some background material and summarizes the highlights of the meeting and the visits.

BACKGROUND

Development of Coupled Models and their Validation Against Experiments (DECOVALEX) is an international cooperative project that supports the development of mathematical models of coupled THM processes in the geosphere and their applications and validation against experiments in the field of nuclear waste isolation. The steering committee for the project is managed by the Swedish Nuclear Power Inspectorate (SKI) through the Swedish Royal Institute of Technology and is chaired by Dr. Chin Fu Tsang of the Lawrence Berkeley National Laboratory. More than a dozen countries participate both by funding and by actual performance of tasks. Phase I and Phase II of the project have been completed and the Nuclear Regulatory Commission (NRC) participated in the first phase between 1992 through 1995. NRC is currently funding the third phase although phase II of the project (1995 through 1999) was not funded by NRC. The workshop he attended was to review the progress to date and approve plans for the future.

DECOVALEX PHASE I

During phase-I of the project, three benchmark tests were studied: (1) BMT1- Far-field model to simulate THM processes in a large volume of rock located at 500 meters depth; (2) BMT2 - Near-field model of a multiple fractured rock mass; and, (3) BMT3 - Near field model of a realistic fracture network around a rock opening 50mX50m, 500m deep. Six test case problems were also studied: (1) TC1 - Study of a coupled shear flow experiment of a single rock joint (Norway); (2) TC2 - In situ Thermal-Mechanical (TM) experiment at Fanay Augeres (France); (3) TC3 - Laboratory experiment of engineered barriers (Japan); (4) TC4 - Hydrological-Mechanical (HM) behavior of rock joints (Finland); (5) TC5 - HM behavior of jointed rocks (USA); and, (6) In situ borehole injection, HM study (Sweden). After the study of benchmark tests and the test cases, it was concluded that: (1) the thermal processes in fractured and continuous media were well understood and that the existing models could be successfully used to predict temperature distributions; (2) mechanical processes such as distribution of stresses around excavations were reasonably predicted using the current models while the reliability of displacement predictions would depend on the extent of fractures and their distribution; and finally, (3) hydrologic processes in fractured rocks were not well understood.

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DECOVALEX PHASE II

During phase II of the project, two field studies were modeled; (1) Kamaishi mine engineered barrier study in Japan; and (2) Sellafield intermediate waste repository in UK. In addition, two studies were undertaken, one on the review of constitutive models for jointed rocks and the other on the review of THM processes that might have an impact on performance assessments. Because the Sellafield shaft construction was canceled, many of the "blind" predictions made by participating organizations using different conceptual models and numerical codes could not be verified. The results of the Kamaishi experiment showed different degrees of agreement with actual measured/observed behavior. The lessons learned during phase II are summarized in the following main conclusions: (1) a THM predictive capability is required to support repository design because there is no past experience in this area; (2) many aspects of THM processes and modeling are now well understood and there is a variety of numerical codes available to provide solutions for different host rock and repository conditions; (3) modeling all the THM mechanisms in space and time is extremely complex and therefore, simplifications will have to be made; (4) it is not always possible to obtain all the necessary detailed supporting information for use in the modeling studies; (5) the THM modeling requirements and the supporting data needs should be defined in the context of performance assessment; and, finally, (6) a transparent audit trail should be developed to help documentation of all testing, modeling and analyses.

DECOVALEX PHASE III

The objectives of DECOVALEX phase III are the same as those for the previous two phases, namely: (1) to increase the basic understanding of THM coupled processes in fractured rocks and buffer materials; (2) to investigate the predictive capabilities of different codes by comparison of results with field test data; (3) to exchange experimental data and improve understanding of constitutive laws for rock masses and buffer materials; and (4) to review the state of the art in coupled THM issues in performance assessment. The steering committee has agreed to conduct four tasks under phase III and they are: (1) modeling of a field test conducted in Switzerland; (2) modeling of Yucca Mountain Drift Scale Heater Test; (3) modeling of selected benchmark test problems for treatment of coupled THM processes in performance assessment; and, (4) establishing a forum to discuss and document methodologies for the treatment of THM processes in performance assessment. NRC has committed to participate in Task-2, modeling of the drift scale heater test at the Yucca Mountain site and Task-4.

PROCEEDINGS OF THE WORKSHOP

As a prelude to the workshop various task forces met separately to develop strategies for their work and work out schedules. Teams participating in Task-2 (modeling of Drift-Scale Heater Test (DSHT) at the Yucca Mountain Site) met on January 22, 2001, to discuss details of work in progress. DOE informed the Task Force that the heat input to the rock block was adjusted to keep the limit of maximum temperature to about 200 degrees C. (Originally, this limit was set at 250 degrees C.) There are four subtasks under Task-2: (2-A) simulation of Thermal-Hydrological behavior; (2-B) simulation of Thermal-Hydrological-Mechanical behavior; (2-C) simulation of Thermal-Hydrological-Mechanical behavior using measured Temperature from the test; and finally, (2-D) simulation of Thermal-Hydrological-Chemical behavior. The participating organizations presented progress in their work to date in their respective tasks.

The NRC/Center team approach consists of performing T-H analyses using a code developed at the Center (MULTIFLO) and the output will be used as input for T-M analyses to be performed using UDEC computer program. Equivalent Continuum Models used earlier have yielded reasonably good predictions of temperature field while prediction of saturation have been less successful under two-phase activity. Dual Permeability models are being tested out and numerical experiments are being conducted to study efficient ways of linking the matrix and fracture continua for predicting saturation and temperature fields. Although some comparisons of actual measurements and computed results were presented, more work needs to be done before making definitive conclusions on the acceptability of the model and the code.

The Spanish and Swedish teams are attempting a fully coupled formulation of T-H-M behavior while the DOE team is using JAS3D and TOUGH2 and coupled codes such as ROCKMASS. The French team is pursuing some simple closed form elastic solutions as a starting point to verify some of their own bench-scale tests and would eventually intend modeling the DSHT. The Japanese team is the only one interested in simulating quantitatively the chemical interactions along with T-H-M coupling because of their design concepts which include a buffer material like bentonite.

J. Anderson, a consultant who is working on Task-4, presented his compilation of answers to the questionnaire circulated among the participants. The report he is preparing for the project will highlight the approaches being used by various high-level waste management projects in dealing with the issue of coupled thermal effects in conducting performance assessment. NRC-Center team has provided its input to this report and will review the report before it gets finalized.

Other tasks in which NRC-Center team is involved in a limited way as observers include the study of benchmark problems (such as the Kamaishi mine experiments in Japan and FEBEX experiment in Grimsel Pass underground Facility in Switzerland), a study of upscaling (such as the one for Sellafiled shaft in UK) and a study of Hydro-Mechanical effects under glaciers (such as the Canadian and the Scandinavian shields). The various teams working on these problems also presented the progress made by them.

STEERING COMMITTEE MEETING

The steering committee meeting was held at the end of the workshop to discuss the status of budget, schedule and future activities. SKI pointed out that the financial status was satisfactory. Currently, the project is scheduled to end by December 2002. However, there is a possibility of the report preparation activities spilling into the year 2003. Two new organizations (CEA of France and BGR of Germany) have joined the project. The steering committee welcomed them.

The project has succeeded in obtaining additional funding from the European Union for supporting some of the activities of the project by submitting a proposal. Many members of the steering committee (including NRC) had requested additional information related to the terms and conditions of the agreement with the European Union. SKI provided details of the proposed project commitments and their potential impacts on DECOVALEX III and how the project will be managed without mutual interference or conflict.

After a lengthy discussion, it was decided to hold the next steering committee meeting and the fourth workshop in Finland. The date for the steering committee meeting and workshop was set to be either in mid-September or mid-October of 2001.

SITE VISIT TO JNC TEST FACILITY AT TOKAI

The participants visited the Geological Isolation Basic Research Facility which is the pride of Japan Nuclear Cycle Development Institute. The facility has state-of-the-art equipment for testing and studying rocks, buffer material, evolution of groundwater chemistry and long-term behavior of metals. The laboratory is especially known for its sophisticated measuring techniques for migration experiments.

SITE VISIT TO TONO MINES UNDERGROUND TEST FACILITY

The participants visited the Tono Geoscience Center located at the largest uranium deposit in Japan. The research and development facility consists of two shafts driven to the depths where the sedimentary formations intersect hard granitic rock which is being considered as the medium in which high-level waste would be disposed. A 1,000 meter shaft is being proposed to penetrate the granite to a depth which would be similar to those proposed for a future repository horizon. The experiments are now focusing on effects of mechanical disturbance due to excavation, flow through fractures and seismic investigations.

NEXT STEP

The steering committee will meet in the fall of 2001 to discuss progress and document the status of Phase-III activities. The next step for NRC-Center team is to complete modeling of T-H aspects of the DSHT and prepare input for the T-M modeling. Repository Design Thermal Mechanical Key Technical Issue has appropriated necessary funds for FY 2001 at the Center for conducting the necessary modeling studies. The next deliverable is due before March 2001. T-M analyses will begin shortly and a detailed report on T-H and T-M results will be prepared for presentation and discussion at the Finland workshop in September/October 2001.