March 5, 2003

MEMORANDUM TO: Martin Virgilio, Director
Office of Nuclear Material Safety
and Safeguards

THROUGH: John Greeves, Director **/RA/**
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

FROM: Mysore Nataraja **/RA/**
Program Element Manager
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

SUBJECT: TRIP REPORT ON STEERING COMMITTEE MEETING, FINAL WORKSHOP AND SITE VISIT TO MORSLEBEN, DECOVALEX PROJECT PHASE-III; BERLIN, GERMANY, JANUARY 27-30, 2003

Attached is a trip report documenting the attendance of Mysore Nataraja of the Division of Waste Management (NMSS) and Ronald Green of the Center for Nuclear Waste Regulatory Analyses (CNWRA) at the steering committee meeting and the final workshop in Berlin, Germany on the coupled thermal-hydrological-mechanical (THM) processes project (phase-III) for waste repositories. They also visited the test facility, and low- and intermediate-level repository at Morsleben on January 31, 2003. Highlights of the trip are provided as Attachment 1 to this memorandum while some additional details are provided as Attachment 2 to this memorandum. This report expands upon a "quick look" report prepared on February 6, 2003. DWM believes the content of this report is likely to be of limited interest to the Commission.

Attachments: As stated

cc: J. Craig (OEDO)
J. D. Lee (OIP)
T. Rothschild (OGC)
L. Silvious (ONSIR/INFOSEC)
M. Federline (NMSS)
T. Sherr (NMSS/FCSS)
J. Kennedy (NMSS/DWM)

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NAME	M. Nataraja*	K. Stablein*	J. Schlueter*	J. Greeves
DATE	2/27/03	2/27/03	02/28/03	/ /03

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NRC FOREIGN TRIP REPORT

Subject
Steering committee meeting and final workshop on the coupled thermal-hydrological-mechanical (THM) processes project (phase-III) for waste repositories

Dates of Travel and Countries/Organizations Visited
January 27-31, 2003; German Geological Survey (BGR); Berlin, Germany, and Low- and Intermediate-Level Radioactive Waste Repository at Morsleben, Germany

Author, Title, and Agency Affiliation
Mysore Nataraja, Program Element Manager
High Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Sensitivity
Non-Sensitive

Background/Purpose

DECOVALEX PROJECT: DECOVALEX is the acronym for **DE**VELOPMENT OF **CO**UPLED MODELS AND THEIR **VAL**IDATION AGAINST **EX**PERIMENTS. DECOVALEX is an international cooperative project that supports the development of mathematical models of coupled Thermal-Hydrological-Mechanical (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. 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 to 1995. NRC is currently funding the third phase although phase II of the project (between 1995-1999) was not funded by NRC.

DECOVALEX PHASE III: The objectives of DECOVALEX phase III are: (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, along with the Center for Nuclear Waste Regulatory Analyses (CNWRA) is participating in Task-2 (modeling of the drift scale heater test at the Yucca Mountain site) and Task-4.

Abstract: Summary of Pertinent Points/Issues

Participation in this international project is a continuation of NRC's involvement for the past several years. The project is technical in nature which provides an opportunity for the NRC and CNWRA staff to study the limitations of the numerical codes that are used in the reviews of the Department of Energy's License Application for a high-level waste geologic repository at the Yucca Mountain site. No sensitive information was discussed during this meeting nor any policy decisions affecting NRC were discussed. Staff's participation was worthwhile and if a request for NRC financial support and participation is made by the project for the next phase of the project, we support a favorable consideration by the NRC management.

Discussion

Berlin Workshop: NRC/CNWRA led two discussions at the Task 2 session of the workshop. The first discussion included a summary of the thermal-hydrological (TH) analyses of the Drift-Scale Heater test (DST) performed using the computer code MULTIFLO.

The second discussion included a summary of NRC/CNWRA analyses of the thermal-mechanical (TM) analyses of the DST using the continuum code FLAC. The workshop also included a trip to the German Geological survey (BGR) geologic specimen collection center which houses one of the largest number of rock samples from allover Europe.

Steering Committee Meeting: The steering committee meeting was held at the end of the workshop. The schedule for the final meeting for the current phase of DECOVALEX project was finalized for October 2003 in Stockholm. The funding organizations tentatively expressed an interest in the next phase of DECOVALEX project which is expected to focus on performance confirmation using the cool-down phase of DST at the Yucca Mountain site in addition to considering potentially new experiments being proposed by the French Nuclear Regulatory Agency.

Field Trip to Morsleben Facility: The field trip to the intermediate- and low-level repository at the Morsleben salt dome was extremely informative. The trip allowed an opportunity to visit a geological repository located in a salt dome formation. The Morsleben salt mine was started in the 1890's and was active until the 1920's. It was used as a repository in the 1970's but has been inactive for a number of years pending resolution of the German radioactive waste disposal program plan. Access to the portion of the mine used for disposal of mid- and low-level radioactive waste was discontinued since Sept 2001 due to security reasons.

The Morsleben Repository is located in the Federal State of Saxony-Anhalt. At the site, potassium was mined until the early twenties. Thereafter, rock salt mining went on until 1969, the two operations together leaving open cavities with a volume of approximately 10 million cubic meters. In 1970, the nuclear power plant operator of the former German Democratic Republic bought the mine to convert it into a low-level waste and intermediate-level waste repository. After a licensing procedure, waste disposal started in 1978 using rock cavities below the 500 meter horizon for waste emplacement. Morsleben became a Federal Facility following the German unification, since then the facility is under private contract to operate and maintain the facility. Essentially, low-level waste packed in drums is stacked in chambers, and wastes with higher activity content are delivered to the repository in shielding over-packs. They are then discharged through shielding lock system into closed chambers below a drift.

As of the end of 1998, the total radioactive waste disposal at Morsleben amounted to 36,752 cubic meters of waste and 6,621 sealed radiation sources. The operating license for this facility, originally valid until June 30, 2000, was later extended for five more years but without allowing any increase in the volume of waste to be disposed of at the site. Pursuant to the ruling by an administrative court on September 25, 1998, waste disposal at Morsleben was stopped pending further policy decisions by the government.

Pending Actions/Planned Next Steps for NRC:

NRC will be expected to make a decision regarding its participation in the next phase of the project after a detailed proposal will be submitted for staff review. A recommendation will be made to the Office of Nuclear Material Safety and Safeguards management after reviewing the proposal and evaluating the staff and Center priorities for FY 2004-2008. As with the previous workshops, this workshop too provided an opportunity to subject the NRC/CNWRA analyses to international peer review.

The steering committee will meet in October 2003 to conclude Phase-III activities of the project and begin the next phase. The next step for NRC-Center team is to complete modeling of T-M aspects of the DSHT and prepare input for the T-H-M modeling. Repository Design Thermal Mechanical Key Technical Issue has appropriated necessary funds for FY 2003 and 2004 at the CNWRA for conducting the necessary modeling studies.

Additional information related to this trip may be found in the CNWRA trip report by Ronald Green (Attachment 2 to this memorandum). If there are any questions about this trip or the contents summarized in this trip report, I can be contacted at (301) 415-6695 or though e-mail (msn1). Ronald Green may be contacted at (210) 522-5184 for additional details.

Points for Commission Consideration /Items of Interest

No Commission action is required as a result of this trip.

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: DECOVALEX III Task Force Meeting

DATE/PLACE: January 28-30, 2003, BGR, Berlin, Germany

AUTHORS: Ronald Green

PERSONS PRESENT: Approximately 60 representatives from the participating country organizations.

BACKGROUND AND PURPOSE OF TRIP: Final task force meeting for DECOVALEX III.

SUMMARY OF PERTINENT POINTS:

The meeting opened with remarks by Chin-Fu Tsang. C-F Tsang provided a summary of the ten years of DECOVALEX III. Tsang noted that DECOVALEX III:

- Advanced the state of science and established in-depth international cooperation and mutual peer review. Promoted and facilitated communications between researchers, implementers and regulators.
- Played key role in promoting development of coupled THM codes in many countries and in conducting model testing through code inter-comparison and in modeling laboratory and field experiments.
- Studied and understood the main observations in all major field experiments to date on coupled THM processes. Study sites included the Kamaishi Experiment, FEBEX experiment, and Yucca Mountain Drift Scale Test.
- Performed benchmark and sensitivity studies to understand key THM issues and sensitivity of key parameters.
- Got to know what we know, what we do not know, what we know only moderately
- Produced a series of joint scientific papers, two special issues of International Journal of Rock Mechanics and Mining Sciences and an Elsevier Geotechnical Engineering Monograph. More are planned.

Tsang noted the following motivation for continuation of the international geoscience modeling effort:

- Keep expertise together. He noted there are rare opportunities of having a group of international experts in THM geosciences work and collaborate in continuous close cooperation
- Continue scientific communication between researchers, implementers and regulators.
- Major progress has been made, but significant issues remain, especially concerning the development from THM to THMC.
- Questions on confidence building and confirmation of our understanding and prediction capabilities need to be addressed.
- Need THMC modeling to define what to measure, e.g., saturation, strain and/or chemical changes.
- Need THM modeling to define optimal monitoring locations and timing.

- Optimal test scope, measurement points and duration to obtain unambiguous results with specified uncertainty levels.
- Parallel modeling-measurement activities at specific field testing sites to ensure gaining insight and understanding.

Tsang noted that safety assessment and performance confirmation will have requirements relevant to the objectives of THMC modeling efforts. These requirements were summarized as the following:

- Optimal monitoring design for safety assessment and performance assessment.
- Evaluation of significance of monitoring data being different from model predictions.
- Use of such discrepancies to evaluate implication on processes, features or parameter values.
- Feedback to safety assessment
- Explore scientific feasibility of 'Thresholds' to identify significant discrepancies.
- Strategy for performance confirmation
- Advanced state of science and established in-depth international cooperation and peer review, promoted communication.

Prof Manfred Wallner gave an opening address summarizing the German HLW program. There are 19 nuclear facilities operating in Germany. The election of 1998 resulted in adoption of policies affecting the nuclear industry that reflect the agenda by the Green party. The National Atomic Act specifies that all nuclear power plants should stop by 2020. The BGR is under the Ministry of Economy and Labor. There are four divisions in the BGR, Prof Wallner is the director of the division in charge of engineering geology. General responsibilities of this division include research and development, advisor for other ministries, advisor for German industry, and international interactions. There is to be only one repository, although Prof Wallner noted that safety assessments suggest there should be more than one. The current assignment of responsibilities is as follows:

BGR-geotechnical advisor
State government-licensing
Federal government-provide site
BfS/DBE-planning/construction/operation of repository
Waste producers-cost bearing

There is a committee established for selecting any new repository sites (AkEnd). The selection process includes the following:

Step-wise procedure
Systematic focusing
Geoscientific criteria
Sociological criteria
Evaluation
Proof of suitability
Public interaction (BGR appreciates the importance of having public buy-in)

BGR has contracts and cooperation with DOE and other international groups, using their sites during this period of moratorium. In particular, BGR has interest in the clay environment at Mont Terri in France. There is a series of experiments at this site. BGR has interest in two experiments: (i) observing the effects of a heater placed in the clay and (ii) a saturation experiment conducted by ENRESA in which a canister is placed over bentonite bricks and covered with bentonite pellets. Infiltration tubes are set within the bentonite pellets. The effect of saturation is measured in terms of the resulting pressure build up.

At this time, there is no agency in the German government assigned the role of regulator for the HLW program. Prof Wallner said this is currently under consideration and he anticipates that this will change within the coming year.

There are three principal field study sites in the HLW program: (i) Konrad, an unusually dry iron ore mine; (ii) Gorleben, a salt dome, initiated in 1977, exploration discontinued in 2000; and (iii) Morsleben, dry salt/anhydrite, there are questions of suitability of this site. There is a 3-10 year moratorium on study at the sites.

Final opening remarks by Ove Stevenson and Frtiz Kausty noted that DECOVALEX III is on schedule for completion in October 2003 with a final meeting at the GeoProc conference. There were 143 abstracts accepted by GeoProc of which 31 are from DECOOVALEX III and 7 from Task 2 participants. (NRC/CNWRA submitted abstracts that were accepted for presentation at GeoProc).

Task 2, the Drift-Scale Heater Test at Yucca Mountain, was discussed during the morning session Wednesday January 29. There are four subtasks in Task 2: 2A thermal-hydrological modeling; 2B thermal-hydrological-mechanical modeling using predicted temperatures; 2C thermal-hydrological-mechanical modeling using measured temperatures; and 2D thermal-hydrological-chemical modeling. Teams representing DOE, NRC, CEA (France), ENRESA/UPC (Spain), and JNC (Japan) are active in Task 2.

Sebastia Olivella/UPC discussed his modeling results. Olivella is using his code CODE_BIRGHT to perform the analyses. CODE_BRIGHT is a thermal-hydrological-mechanical finite-element simulator. There were three parts to his analyses: (i) TH modeling using a single porosity model; (ii) THM using a single porosity model; and TH analyses using a double porosity model. His single porosity model is actually an equivalent continuum model (ECM) because he incorporates both fracture and matrix relative permeability properties in the retention curve. Olivella assigned van Genuchten relationships to the liquid permeability and Brooks-Corey relationships to gas permeability for both the matrix and fracture continua. The Olivella model was two dimensional. He assigned a linear model to the canister and wing heaters heat loads. These were reduced by an arbitrary factor to account for heat loss in the third direction. The reduction factor was based on engineering intuition. The canister heat load was applied to the drift wall.

There was no significant heat pipe predicted by the single porosity TH model. Temperatures at large times were over predicted. Shedding of liquid off the boiling isotherm was prominently predicted.

The THM analyses based on a single porosity structure evaluated the effect of several porosity-permeability relationships: (i) Kozeny law, (ii) cubic law; and (iii) exponential law with three choices for the exponent. A reduction of permeability as large as four orders of magnitude is possible for an exponential model that experiences a decrease in fracture porosity from 0.111 to 0.105. Sensitivity analyses indicated that a four order of magnitude reduction in permeability is needed before a significant effect on saturation is observed. He also observed that either increasing or decreasing porosity results in a decrease dry-out. A decrease in dry-out is experienced with an increase in permeability due to an increase in liquid return flow.

Olivella has an operational two-dimensional model with a double porosity structure. This is comparable with a dual continuum model. The matrix and fracture continua are coupled with a 1-m long transfer connection.

The strength of the coupling is modified by changing the length of the connection. Stability difficulties limited simulations to two years. Maximum fracture saturations were 0.6.

Olivella has identified vapor diffusion as a key mechanism in his simulations when both water vapor and air are present. In particular, he is investigating the importance of enhanced vapor diffusion. He is using the inverse of gas saturation as the enhancement factor. With this factor, there is increased diffusion, which results in increased dry-out. This results in less shedding in fractures. Olivella has performed a series of analyses with no enhanced diffusion and maximum diffusion. Minimal diffusion results in a prominent heat pipe and maximum diffusion results in essentially no heat pipe. His opinion is that actual diffusion rates are somewhere between the two extremes.

R. Green discussed the results of the NRC/CNWRA Task 2A and 2C analyses. The TH analyses in Task 2A were performed by R. Green and S. Painter. The THM analyses in Task 2C were performed by S. Hsiung. R. Green reported results of the four-year simulations for the dual continuum three-dimensional model with improved boundary conditions at the drift wall. These results address concerns of early two-dimensional model results that were questioned because of the lack of full dimensionality and the no-flow boundary at the drift wall. THM results for deformation predictions were discussed. Predictions of changes to permeability resulting from deformation were not discussed. It was noted that difficulties were encountered using the DOE provided temperatures, because of data ambiguities. Apparently, temperature from the actual wing heater elements were included in the recorded temperatures. This resulted in skewed temperatures. This skewing resulted in significant effects on modeling predictions. Corrected data sets had been sent to task participants, but not in time to redo the simulations.

Allain Millard/CEA discussed his results of the CEA modeling THM efforts in Task 2C. His model is a two-dimensional half-plane continuum formulation. He evaluated the effects resulting from assuming linear, plastic, and brittle rock properties. Millard performed a parametric study of thermal-elastic rock properties. He also noted the difficulties caused by the skewed temperature measurements. Also similar to analyses by Hsiung, Millard performed both intact rock and rock mass calculations. Millard did not detect any significant changes due to changes in Young's modulus. He concluded that a linear elastic model is mostly acceptable, however non-linear effects are observed at low Young's modulus and alpha.

Chin-Fu Tsang/LBNL discussed modeling results of THM that had been performed by Johnny Rutquist/LBNL. C-F Tsang noted that THM analyses of the DST have been performed by SNL using JAS3D, by LLNL using 3-DEC, and by LBNL using TOUGH-FLAC. JAS3D is a ubiquitous fracture model, 3-DEC assumes discrete fractures, and TOUGH-FLAC models ubiquitous fractures using a dual continuum. Of these models, only TOUGH-FLAC is a fully coupled THM simulator. Rutquist attempted to answer the questions: (i) is a continuum model adequate or is a discrete fracture model needed and (ii) is an elastic or non-linear elastic mechanical model needed. Rutquist analyzed both displacement and the change in air permeability resulting from changes in saturation and mechanical effects. He used an empirical relation to associate air permeability and stress. He defines fracture aperture as equal to a residual aperture plus a maximum aperture times the exponential of stress and alpha. The residual aperture was measured during air permeability tests during the DST and the remainder of the relationship was developed using results from the niche studies. Rutquist determined that plastic behavior is only experienced at the drift wall. This implies that a rock-mass model would be conservative. He concluded that a continuum model looks promising, air permeability changes are due to changes in saturation and mechanical deformation. Lastly, he determined that for large permeability, deformation is small and for small permeability, deformation is large.

JNC is the only participant investigating THC processes at the DST. They are using the THAMES code. The current geochemical system is restricted to SiO2. Future analyses will also include calcium carbonate and gypsum using PHREEQE60. Only a single continuum model is investigated at this time. Current analyses provide predictions of Si contents in the liquid phase.

I had additional conversations with several workshop participants. M Wallner and I discussed earlier conducted heater tests conducted in salt formations. He commented that mechanisms observed during the cool-down phase were not expected. Significant fractures were observed during cooling. The fractures eventually closed by healing.

Another conversation was with JC Mayor/ENRESA. In his opinion, most European HLW programs were looking more at clay and granite as geologic barriers than other media. In his opinion, difficulties in making the safety case for fractured rock, in general, and granite, in particular, pose significant challenges in making the selection of granite the desired geological setting.

There were two field trips offered on Friday January 31. I attended the field trip to the mid- and low-level repository at the salt dome in Morsleben, Germany. The Morsleben field trip was led by Dr. Shao Hu/BGR and attended by 11 meeting attendees. NRC was represented by M. Nataraja and R. Green. BGR provided the site geologist and a site public relations official.