UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D.C. 20555

November 8, 1996

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Chairman Jackson:

Subject: COMMENTS ON COUPLED PROCESSES IN THE NRC HIGH-LEVEL WASTE PRELICENSING PROGRAM

SUMMARY

The Advisory Committee on Nuclear Waste (ACNW) is impressed by the progress that the NRC staff and the Center for Nuclear Waste Regulatory Analyses (CNWRA) have made in developing a strong program to study potential coupled processes at the site of the proposed repository at Yucca Mountain, Nevada. Furthermore, we are pleased with the plans for integrating coupled processes among the vertical slice investigations of key technical issues (KTIs). The Committee has provided observations and suggestions to strengthen NRC's approach to coupled processes.

We want to emphasize the following recommendations:

(1) Performance assessment needs to have a more prominent role in guiding the prioritization of coupled processes studies.

(2) The NRC should revise its decision to not participate in DECOVALEX, a multidisciplinary international program dedicated to the Development of Coupled Models and their Validation against Experiments.

(3) The coupled processes studies are "data starved." Changes are needed in the program to rectify this situation.

(4) The modeling studies in thermal-hydrological (TH) processes need to be expanded.

(5) Greater attention is needed on near-field chemistry, with particular emphasis on thermal-hydrological-chemical (T-H-C) processes that affect contaminant release and transport.

INTRODUCTION

In February 1996, we communicated our recommendations and suggestions on the "Revised Prelicensing Program Strategy for the U.S. Nuclear Regulatory Commission High-Level Waste Repository Program ('Vertical Slice Approach')" and the NRC staff's plans for resolving KTIs dealing with the proposed high-level waste (HLW) geologic repository at Yucca Mountain, Nevada. In that letter, we made suggestions for improving the strategy and investigation of the KTIs, but we were, and continue to be, supportive of the work of the NRC staff in this regard. We see this program as an excellent response to maintaining a prelicensing program focused on critical issues in the face of limited resources. In our February 1996 letter we expressed our concern that within the specified strategy and program, it was unclear if the issue of in situ thermal-mechanical-hydrological-chemical (T-M-H-C) coupled processes was moving toward resolution. This letter provides further comments on that concern.

Construction of the proposed repository will perturb the stress pattern in Yucca Mountain, thus resulting in mechanical deformation of the surrounding rock and the emplaced HLW will cause a significant heat pulse to the rock. The resulting thermal and mechanical effects are interrelated and may significantly affect the movement of water and the nature of related hydrologic properties, as well as the chemical processes acting on the waste, canisters, and surrounding engineered and natural materials of the repository. These coupled processes may have an important impact on the performance of the repository over the course of its history. The algorithms used in modeling the performance of the repository system are influenced strongly by the analytical descriptions of the various coupled relationships among physical and chemical phenomena. The Committee is concerned that the "vertical slice" approach to the KTIs could lead to neglect of interaction of phenomena and their resulting modifications of parameters and processes. To evaluate the current validity of this concern, the ACNW reviewed the status of the investigation of coupled processes by the NRC staff and the integration of these activities among and within KTIs through a working group on T-M-H-C coupled processes at the 85th meeting of the Committee. Comments were made by representatives of the NRC staff, the CNWRA, Lawrence Berkeley Laboratory, the U.S. Geological Survey, the Department of Energy (DOE), academia, and private industry.

The Committee learned of the significant progress in the T-M-H-C coupled processes investigations and was impressed by studies being performed by the NRC and CNWRA. Effort has been put into the related KTI investigations and the integration of elements of the coupled processes among the KTIs. Below are our observations and suggestions regarding coupled processes, which should focus future activities on the potentially most critical elements.

TECHNICAL OBSERVATIONS AND SUGGESTIONS

I. General

(1) The NRC staff, with the support of the CNWRA, has developed a strong program for studying the impact of selected coupled processes on the performance of the potential repository at Yucca Mountain. This is especially true in T-H coupled processes, which have been ranked consistently as high priority in reviews of both the NRC's and the DOE's programs.

(2) A key to coupled processes studies and the development of supporting data is understanding their overall importance to repository performance. The Committee is pleased to see the increasing role of performance assessment (PA) in this regard. It is critical that the PA activity be used to provide the necessary insights and understanding of physical processes to maximize the return on investment of investigative resources. The Committee looks forward to the increased use of PA to guide the scope of analysis and research activities.

(3) We understand the continued need to reassess the allocation of HLW funding in the face of shrinking resources. However, the Committee is concerned about NRC's withdrawal from Phase II of the multidisciplinary international program DECOVALEX. The Committee sees the results of the DECOVALEX project to date as meaningful to the NRC HLW program. The testing of mathematical models and computer codes for predicting the effects of coupled processes, which is the aim of the project, is a most critical aspect of the study of coupled processes. In the tasks outlined for the continuing project, a variety of models and codes, developed largely independently by investigators in several countries, will be tested against each other and against experimental results from international nuclear waste test facilities. Although these test sites will not duplicate exactly the proposed unsaturated-tuff geologic repository at Yucca Mountain, the results should be useful in the NRC scoping studies and testing of models and codes. For these reasons, the Committee urges the staff to reverse its decision to withdraw from the DECOVALEX project.

(4) The coupled processes studies of the NRC and the CNWRA appear to be "data starved." The primary emphasis of the studies has been on developing models and related codes. This is an important element of the program but is only one of the necessary ingredients to bringing the program to fruition. The termination of the HLW research program in this topic apparently has reduced access to experimental and geologic analog information useful in validating the models and codes and in providing bounding data. This is true over a range of processes but is especially important to thermal processes and their effect on properties and other processes. In the face

of this problem. both the NRC and the CNWRA should make specific efforts to obtain all relevant data from the DOE and its contractors. Further, the Committee believes that there is important information to be gained from studies of current and ancient geologic regions, with thermal anomalies for which data are available. For example, existing data from the Nevada Test Site operations may be useful. Also, the Committee has learned of recent studies on the properties, chemistry (mineralogy), and mechanical characteristics of rocks similar to those at Yucca Mountain surrounding an igneous intrusion in the Nevada Test Site. This and similar analogs are potentially a valuable source of T-H-M-C information.

Limitations on data from thermal testing are exacerbated by the current timing of the thermal tests being conducted and organized by the DOE at Yucca Mountain. The high thermal inertia of the rock precludes significant acceleration of the studies. Currently, the single heater test in the Exploration Study Facility and the large block test will provide thermal input before the DOE's Viability Assessment (VA), but these tests will not give the bulk properties of Yucca Mountain. The plan is to obtain these properties from the drift scale thermal tests, but data from this test will not be available in time for the VA decisions. Furthermore, it is unclear how the results of these tests will be used to evaluate alternative models for describing thermally induced phenomena in highly fractured rock. The NRC should consider how these data limitations will affect their response to the DOE's VA.

II. Specific

(1) The Committee concurs with the emphasis placed by the NRC staff on the T-H coupled processes, but we note that in the CNWRA's assessment of the importance of post-closure processes, the combination of T-H processes on chemical processes is deemed most important. We agree with this conclusion because of the potential effect on release, transport, and retardation of radionuclides. However, we note only limited, albeit important, attention directed to the chemical portion of the coupled processes equation. Studies are largely limited to model and code development using simplified matrix mineralogy (chemistry). We believe greater attention is warranted on near-field, contaminant-related chemistry, for example, the effect of temperature on the chemistry of glasses, of sorption of radionuclides by zeolites and other minerals, of redox changes, and so on. We encourage scoping studies to determine the potential impact of temperature and hydrology on chemistry as this will affect NRC decisions that have to be made in the near term related to the VA. For example, mineral precipitation and dissolution may

profoundly alter the rock permeability in the near-field region. The required thermodynamic data at elevated temperatures currently are inadequately known and the effects of such attributes as grain size and fracture filling on chemical reactions need clarification.

(2) The NRC and the CNWRA note potential shortcomings in the Equivalent Continuum Model (ECM), which is the current focus of T-H studies. Of critical concern is the effectiveness of the ECM in predicting flow through fractured rock and the possible development of the "heat pipe" associated with the thermal pulse caused by the decaying HLW. The DOE Peer Review Team on Thermohydrologic Testing and Modeling also identifies potential shortcomings. The Executive Summary of the DOE report states that the ECM quantitative predictions, particularly where they impact design of the underground structures, should be accepted with a great deal of caution. The Executive Summary also states the following:

> The main computational codes. . .have undergone extensive development and verification. The next step in their use, however, should involve investigations, primarily in underground tests, where the efficacy of ECM can be carefully examined. Given the apparent limitations of the ECM, further application of these models would appear to be inappropriate without such confirmation.

We encourage the CNWRA to expand its studies of T-H to include testing the ECM models and codes through studies of current and ancient geothermal regions. These geologic analogs, at a minimum, should identify the effects and relative importance of the principal processes.

(3) We encourage studies of T-H-C processes between the repository and the location of the critical group. We understand that a study has been initiated at the CNWRA to study hydrological chemical (H-C) effects in the Calico Hills formation, which is rich in cation exchange minerals. We believe this and related studies are warranted. The staff needs to be aware of nonreversible processes in the near field, such as thermal effects on permeability, and their impact upon far-field processes.

(4) The program to study the effect of natural disruptive processes, for example, igneous activity, was not the subject of our current review. Nonetheless, we were pleased to learn that the study of the effect of natural disruption of the repository is included in future plans for coupled processes investigations by the NRC.

(5) We believe it is important to conduct scoping studies to aid in the assessment of the potential effects from coupled

processes that are not deemed important on the basis of literature review. Specifically, we suggest that scoping calculations be performed to address the concerns regarding "indirect flow" processes or "Onsager processes."

(6) We believe the mechanical aspects of the T-H-M-C processes are less problematic than the other components, and, thus, at this time, related studies can be minimized or eliminated.

III. Related Issues

(1) Our original concerns about the investigation of coupled processes in the "vertical-slice" approach to key issues during the prelicensing studies by NRC were focused on the integration among the various processes. We are pleased that the NRC management has proceeded beyond the KTI dealing with Total Systems Performance Assessment and Integration by developing a management integration task force. We congratulate the staff on this action, which goes a long way toward alleviating our concern. This "top-down" approach has many advantages. Nonetheless, we encourage the staff at all levels to be sensitive to the need to communicate across discipline and KTI boundaries and thus to implement integration meaningfully and in a timely manner. In addition, we encourage management to continue support of the Integration Task Force in the important studies leading to decisions at the time DOE completes its VA process and in the years beyond the VA in the prelicensing and licensing periods.

(2) We have referred to many of the coupled processes investigations as "data starved." Resource limitations mandate limited opportunity for experimentation and field studies, and, thus, this lack of data is likely to remain unremedied, without special efforts on the part of management. We believe joint programs with other nations that have parallel interests are a worthwhile investment. In addition, every effort must be made to apply the considerable data collected by DOE and its contractors to the NRC programs. Furthermore, we suggest that important data on critical coupled processes problems exist in peer-reviewed journals and industrial and government literature. Management should work toward developing a climate that fosters using these low-cost data in the NRC program.

(3) The Staff is encouraged to be sensitive to the developing DOE strategy for waste emplacement in the repository so that the potential effects on thermal loading are included in scoping and sensitivity studies as part of the coupled processes program. Because of limited thermal testing at the time of the VA, the NRC should evaluate the impact of these studies at that time and develop strategies for minimizing their impact. Limitations imposed by an incomplete understanding of thermal

properties and processes because of restricted in situ testing even in the post-VA period remains a possibility that needs to be considered by the NRC.

We believe the NRC staff has a strong program to examine the importance of coupled processes and trust that these suggestions will be helpful in further focusing the program.

Sincerely,

Paul W. Pomeroy
Chairman