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

August 7, 1997

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

Dear Chairman Jackson:

SUBJECT: COMMENTS ON THE NRC PROGRAM TO PREDICT RISK FROM IGNEOUS ACTIVITY AT THE PROPOSED HIGH-LEVEL WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

This report contains our observations and conclusions regarding the NRC's High-Level Waste (HLW) Igneous Activity Program. The Committee has followed this program for a number of years and has recently determined the current status of studies on the probability and consequences of an igneous event at the potential HLW repository at Yucca Mountain, Nevada. As a result, we offer a number of recommendations to the Commission with regard to the current program and for bringing this key technical issue (KTI) to closure.

RECOMMENDATIONS

1. On the basis of the maturity of the NRC's Igneous Activity Program and the preliminary results of related risk analysis, we recommend that the Commission bring the current activities of this program to an orderly closure within about one year, providing there are no significant changes in the current risk estimates. To achieve this goal, we recommend that the Commission direct the staff to

   a. Develop criteria for making a decision on the closure of the Igneous Activity Program. The staff should also develop specific criteria for making this decision on the other individual KTIs.

   b. Reorder the program to focus on documenting the NRC's studies on the probability and consequences of igneous activity at Yucca Mountain, including quantification of uncertainties and clarification of assumptions used in the studies.

2. The NRC staff should be directed to convey to the Department of Energy (DOE) its concerns with and responses to DOE igneous activity studies, including the probabilistic volcanic hazard assessment (PVHA) in a clear, comprehensive, and timely manner.

The staff should also promptly transmit the results of current NRC field and modeling investigations that may have significant impact on the risk from igneous activity to the DOE for its study and consideration.

3. Technical expertise in igneous activity will be required and should be maintained by the NRC in the prelicensing period after closure of the igneous activity KTI.

COMMENTS AND DISCUSSION

As part of its continuing interest in the Igneous Activity Program, the Advisory Committee on Nuclear Waste devoted a full-day working group meeting to this topic on April 22, 1997. The Committee was briefed by the staff of the NRC and the Center for Nuclear Waste Regulatory Analyses (the Center), the DOE staff and the DOE contractor who conducted the PVHA expert elicitation, and a representative of the State of Nevada. Consultants included igneous activity specialists from the Ohio State University, Johns Hopkins University, and the U.S. Geological Survey.

PROGRESS OF THE PROGRAM

Igneous activity is one of the KTIs identified by the NRC staff because of its potential risk significance in the tectonically active southwestern United States. The presence of the nearby volcano at Lathrop Wells, which was active 100,000 years ago, and the million year-old volcanic vents of Crater Flat that are as close as 8 km to the proposed repository illustrate why igneous activity had to be investigated at this site. The NRC has developed and conducted a high-quality program dealing with assessing the likelihood of an igneous event intersecting the proposed repository and analysis of the consequences of such an occurrence. The Center work has contributed to advancing state-of-the-art methods for assessing the probability of an igneous event, including development of methods that can be used with a limited number of recognized volcanic events and that incorporate the effect of geologic structure and current tectonism. Further, the Center has demonstrated the utility of high-resolution ground magnetic surveys to identify and map volcanic vents buried in the alluvial basins adjacent to Yucca Mountain. This information is useful in establishing a more accurate record of volcanism over the past several million years and improving the knowledge of geologic structural controls on igneous activity over those previously defined by lower resolution DOE aerial surveys.

The estimated risk from the HLW repository posed by igneous activity, and specifically from volcanism, has been a contentious issue among the NRC, the DOE, and the State of Nevada, all of which have had major characterization or research programs focused on this issue. This controversy can be largely attributed to the infancy of the science of predicting the likelihood of an igneous event, especially over a time span measured in thousands of years. Accurate predictions are problematic because of limitations in the knowledge of the relevant basic geologic phenomena and of acquiring fundamental data. Furthermore, the small number of volcanoes in the Yucca Mountain region limits the accuracy of direct statistical estimation of the frequency of occurrence of igneous activity over space and time. In addition, the lack of an analog for investigating the consequence of molten rock intruding into an underground facility limits the predictability of potential consequences of an event at Yucca Mountain.

The lack of a generally acceptable deterministic method for specifying the level of safety at the proposed HLW repository as a result of igneous activity has made it necessary to perform a risk assessment, including a quantification of the uncertainties in the risk measures. Current NRC estimates of the probability of an igneous event intersecting the proposed repository fall within the range of 10^{-7} to 10^{-8} events/year. The staff also has initiated consequence studies with implementation of a model to determine the anticipated dose to the critical group from an ash-forming eruption that entrains waste from the repository. The NRC is continuing to conduct field and modeling studies to reduce uncertainties and to test and evaluate conceptual models.

In contrast to the NRC, the DOE has terminated its characterization studies and probability analyses with completion of the PVHA expert elicitation, which generally was conducted in a manner consistent with the NRC Branch Technical Position on the Formal Use of Expert Elicitation in the High-Level Radioactive Waste Program, NUREG-1563, November 1996. The results of this study, which are an aggregation of the opinion of 10 volcanism experts, is that the mean probability of an igneous event intersecting the proposed repository is 1.5×10^{-8} events/year with bounds of 10^{-7} to 10^{-10}. The staff has informally indicated in technical exchanges with the DOE that it is concerned about two aspects of the PVHA: the impact of the information obtained from ground magnetic surveying subsequent to the PVHA study and the identification of volcanic zones based on the geologic structure of the Yucca Mountain region. With regard to the former concern, DOE's analysis of recent findings from NRC's ground magnetic surveying has not discerned a significant impact from the new survey data on risk from the igneous activity letter of June 4, 1997, from Stephan J. Brocoum, DOE, to John T. Greeves, NRC. In addition, the definition of "volcanic event" as used in the PVHA needs to be agreed upon by the NRC and the DOE. The results of the DOE's consequence studies will be summarized in the volcanism synthesis report, which will be released later this year. Meanwhile, the DOE has announced its intention to use the NRC's ash-forming eruption entrainment model to determine the consequences and, thus, the risk in its Total Systems Performance Assessment--Viability Assessment (TSPA-VA).

NEED FOR CRITERIA TO MAKE A FINDING ON A KTI

The staff should be directed to establish guidance on the criteria that are used to determine the information, both the type and the amount, required to make a finding regarding the Igneous Activity KTI. These criteria should emphasize the quantification of uncertainty in the parameters that are aggregated to form the risk measures. The scope and assumptions forming the basis for the risk estimate should be transparent and well documented and should clearly indicate the quality and source of all the supporting evidence. The importance of this type of guidance is emphasized by the lack of supporting evidence on the uncertainty in the current estimate of risk from igneous activity at Yucca Mountain.

Although this recommendation is directed to the need for guidance on the criteria for closing out the Igneous Activity KTI, we strongly urge that related guidance for closing out the other KTIs be developed promptly.

FUTURE EMPHASIS OF THE PROGRAM

The Committee believes that based on the significant progress made in the Igneous Activity Program, and the low risk calculated by the staff from a volcanic event, the staff should focus on completing the highest priority tasks that are aimed specifically at reducing uncertainty in the results of models used to depict the repository's performance. Upon completion of these studies, the bulk of the program should be brought to closure in about a year, provided there are no significant modifications in the results compared with those of the present.

We recommend that the staff consider including the following tasks in completing and closing out the Igneous Activity Program.

1. Evaluate the impact of unrecognized igneous events. The number, location, and age of unrecognized igneous events such as unobserved near-surface dikes and alluvium-covered volcanic cones and flows introduce uncertainty in the probability models. To minimize this uncertainty and to test the DOE's conceptual models on which probability estimates are based, the staff is mapping unrecognized volcanic features by conducting high-resolution ground magnetic surveys at sites identified as potential igneous event anomalies in data of the aerial magnetic surveys of the Yucca Mountain region. We concur with these activities, but we urge that the staff be directed to test and document the impact of such possible volcanic features on probability estimates with performance assessment using the number of volcanic features suggested by the occurrence of potential igneous-event anomalies observed in the existing data. These scoping studies should be used to determine which, if any, of these anomalies warrant investigation by ground magnetic surveys. Special attention should be given to evaluating anomalies in the immediate vicinity of Yucca Mountain, where their existence may lead to new models and significant revisions in probability. If the ground magnetic surveys lead to the identification of potential volcanic features, these results should be conveyed to the DOE for further analysis. Ground magnetic surveying of anomalies solely for the purpose of studying structural controls on igneous activity is warranted only in specific situations in which the potential connection between volcanism and geologic structure is clear and can lead to refinement in estimating probabilities.

2. Summarize, evaluate, and document the probability estimates. Currently, there is a range of estimates on the probability of an igneous event disrupting the proposed Yucca Mountain repository. Estimates are available from the DOE, the PVHA, the State of Nevada, and the Electric Power Research Institute. All of these have undergone some level of peer review and thus can be accorded a degree of credibility. In addition, the estimates of the Center should be finalized in the near future and their uncertainties defined. The results of the various studies need to be summarized by NRC, perhaps as part of an issue resolution status report. This summary should impartially explain in a simple qualitative manner the differences in the results and the origins of the differences. Special emphasis should be placed on evaluating (a) the assumptions employed in the various methodologies and in calculating the estimates and (b) the quality of the data input and its impact upon results. This documentation should highlight the model uncertainties.

To support this summary and evaluation, we suggest that a comprehensive discussion of models of igneous systems in the Yucca Mountain region be prepared based on the extensive existing information gathered by the DOE and others. These models should integrate the geological, tectonic, geophysical, and geochemical information into a coherent system. The models should rationalize the probable igneous system dynamics in the context of knowledge on the behavior of active igneous systems. Special emphasis should be placed on integrating the igneous system into current information on tectonic models of the region. This synthesis will be valuable in evaluating all existing models of probability or other models that may be developed before licensing review.

3. Further develop and document the consequence analysis. Preliminary analyses show that the expected annual risk over a 10,000-year time period from an ash-forming eruption at Yucca Mountain to an individual located 20 km downwind in Amargosa Valley is less than 1 mrem. This risk appears to be based on conservative estimates of some parameters, but further sensitivity studies are required to evaluate this estimate and related documentation should be prepared. The Committee urges identification through sensitivity studies of those parameters of consequence models, including indirect effects that may have a significant effect on the repository's performance or that are ill defined. Efforts should be made to reduce uncertainties with carefully targeted investigations, if justified by these analyses. The staff is encouraged to give high priority to evaluating the sensitivity of the dose calculation to the location of critical group.

FOLLOW-ON PROGRAM

The science of igneous processes and systems is very dynamic with rapid, continual growth in knowledge of this discipline and methodologies for improving the related data bases. Thus, we can anticipate improvements in the ability to predict igneous events. As a result, the NRC should maintain sufficient expertise in igneous activity to monitor and evaluate DOE's continuing progress in this discipline. In addition, the NRC should monitor the occurrence of precursors to igneous activity in the Yucca Mountain region, such as microseismic activity and elevation perturbations. Finally, technical expertise in igneous activity will be required when the NRC reviews the DOE's TSPA-VA and conducts its own performance assessments.

COMMUNICATIONS

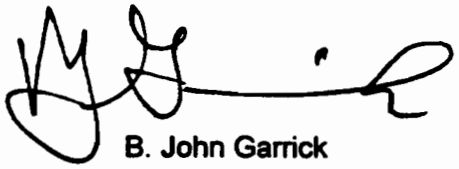
Our review of the NRC's Igneous Activity Program has led us to conclude that although communications have increased and improved between the DOE and the NRC in the past few years, more effective interaction is desirable. NRC should develop its questions, concerns, and conclusions about DOE activities and reports in a timely manner with supporting backup documentation. For example, the Committee urges the staff to document and formally communicate promptly its concerns and the bases for them about DOE's PVHA expert elicitation. In addition, the staff should formally acknowledge and communicate any residual concerns about recent additional probability analyses by the DOE that incorporate new NRC ground magnetic data (letter of June 4,1997, from Stephan J. Brocoum, DOE, to John T. Greeves, NRC). These data identify previously unknown volcanic features in the greater Yucca Mountain region. The NRC also should document its position on the annual probability of

an igneous event intersecting the proposed repository. The NRC staff refers to its estimate of 10^{-7} events /year as a "reasonably conservative upper bound," but the justification of this value is unclear. In addition, neither the uncertainty associated with this estimate nor the assumptions used in its determination have been formally documented and transmitted to the DOE. Presumably, this type of information will be provided in reports being prepared. We urge that these reports be completed in the near term.

CONCLUSION

The maturity and success of the NRC's Igneous Activity program are recognized by the Committee. This recognition, together with the preliminary calculated estimates indicating minimal risk from an igneous event at the proposed Yucca Mountain repository, leads us to the recommendation that the current program be brought to an orderly closure. However, we do make suggestions for modifications and recommend several specific areas for special emphasis in the remaining program. The Committee encourages the use of performance assessment to prioritize activities and the development of guidance to make a decision on terminating a program and closing out a KTI. Although germane to the Igneous Activity Program, this advice applies equally well to the entire prelicensing strategy. Finally, although we recommend the near-term closure of the current Igneous Activity Program, we also encourage the NRC to maintain an expertise within this discipline throughout the prelicensing period of the high-level radioactive waste effort.

Sincerely,



B. John Garrick
Chairman

UNITED STATES
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WASHINGTON, D.C. 20555

October 8, 1997

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

Dear Chairman Jackson:

SUBJECT: Comments on Performance Assessment Capability in the NRC High-Level Radioactive Waste Program

The purpose of this letter is to advise the Commission about the NRC staff's performance assessment (PA) capability in the High-Level Radioactive Waste (HLW) Program. Performance assessment is an important tool in NRC's prelicensing activities, including the following: understanding the importance of specific site characteristics and the design of engineered features to the performance of an HLW repository at Yucca Mountain, prioritizing key technical issues (KTIs) and staff activities, developing revised standards and regulations for licensing, and preparing for review of the Department of Energy's (DOE's) viability assessment (VA) of the proposed repository. The evaluation of staff HLW PA capability continues to be a priority issue of the Advisory Committee on Nuclear Waste (ACNW).

The observations and comments in this letter have been developed, in part, on the basis of the 93rd ACNW Meeting at the Center for Nuclear Waste Regulatory Analyses (hereafter the Center) in San Antonio, Texas, on July 23-24, 1997. The ACNW previously reviewed and commented on staff HLW PA capability in letters dated December 2, 1991, and May 27, 1994.

Recommendations

The Committee makes the following recommendations:

- Selected capabilities should be added to the program to provide further assurance that the staff has the ability to assess the containment capacity of the engineered systems. Support for KTIs relating to the near-field performance of the repository should be restored. Among the disciplines for which the ACNW believes added capability is necessary are engineering analysis, materials science, and chemistry. The crosscutting discipline of corrosion science and engineering is also an essential part of the mix.

- The PA models should be structured to represent repository performance as realistically as possible and thereby provide the necessary information for regulators to make decisions in the context of the full state of knowledge about the performance measures of the repository. Improved coordination and communication between the NRC staff and the Center will be essential.

- Greater emphasis should be given to collecting, organizing, and documenting the supporting evidence for the performance assessments to enhance acceptance of the results. An important element of this is improvement in communicating the abstraction of process models into probabilistic models. Of particular interest to the Committee is visibility of the treatment of such phenomena as chemical and geological processes leading to the mobilization of radionuclides in the near field.

- A working version of the NRC's Total Performance Assessment code, version 3.1 (TPA-3) should be implemented as soon as practicable.

- A program for verifying TPA-3 should be developed. TPA-3 should be benchmarked against other codes for Yucca Mountain. The Committee also encourages exposure of the methods of TPA-3 and associated background information to the scientific community through extensive and timely peer review.

Accomplishments

The Committee commends the staff for its many impressive accomplishments in upgrading and preserving a dedicated HLW PA team in the face of budget cuts and programmatic uncertainties. The organization of the HLW Program around a specific set of KTIs and the grouping of expertise and disciplines within the KTIs provides an important means of focusing the staff's efforts on issues most important to performance of the repository. Performance assessment is important in the staff's efforts to provide integration across disciplines in the KTIs and to set priorities for activities. The Committee was pleased to see the clear integration of PA with other Yucca Mountain activities. This effort has led to the development of sound, near-term plans for prelicensing activities, including resolving outstanding issues and preparing for review of DOE's total system performance assessment supporting the viability assessment (TSPA-VA). The revised and updated TPA-3 code increases the staff's capability in performance assessment modeling. The code should facilitate the KTI investigations with its ability to evaluate the importance of specific site characteristics and the effectiveness of engineered barriers. The ability to conduct sensitivity and uncertainty analyses for subsystems and for the total system is improved. The development of the code is a solid effort and we encourage the staff to pursue aggressively the implementation of TPA-3. Many of these staff activities conform to recommendations contained in the ACNW letter of May 27, 1994, on PA capability.

Engineered Barrier System

The ACNW is concerned about the staff's capability to evaluate quantitatively the engineered barrier system of the proposed Yucca Mountain repository. This concern is punctuated by lessons learned from PA, including the apparently increasing dependence on engineered barriers to demonstrate compliance with a dose- or health-based standard for the repository. With increasing evidence that engineered systems must be an important part of the waste isolation strategy for Yucca Mountain, it is important that these systems receive extensive scientific and engineering scrutiny.

We are concerned about the decision to reduce the effort at the Center on certain KTIs, most

notably those dealing with engineered barriers and radionuclide transport. The shifting emphasis of the DOE to the performance of engineered systems accents the need for the Commission to provide resources to restart work on the KTIs most important to an independent assessment of the performance of engineered systems and near-field radionuclide transport. A concern is that without restarting the work of the NRC staff and the Center, the performance assessment effort, including the TPA-3 code, will not have the scope to assess adequately the DOE work. The Committee urges the Commission to act on this issue as soon as practicable.

Beyond the issue of the scope of the engineered systems assessment capability of the NRC staff, the ACNW believes that added capability is necessary to analyze adequately the engineering design of long-lived, passive high-integrity systems. In particular, additional staff effort is required in engineering analysis, materials science, and chemistry (especially corrosion and colloid chemistry) to have the full capability to assess the engineered systems.

Realistic Performance Assessment Models

The ACNW has three primary points to make regarding the staff's performance assessment modeling activities: (1) the PAs should have a risk-informed perspective; (2) the PAs should be transparent about the supporting evidence (data and information); and (3) the relationship between process model and probabilistic calculations needs to be made clear.

Risk-informed performance assessment provides the opportunity to assess *realistically* the performance of an HLW repository. Our concern is that the TPA-3 activity is relying too much on bounding and worst-case calculations. Although bounding calculations are a very useful part of any technical investigation in providing insights on what is important to the performance measures of a model, such calculations are often of little value in representing what is likely to happen. In the opinion of the ACNW a much preferred approach is to limit bounding and worst-case calculations to the task of scoping the investigation and deciding what may or may not be important to model. Decision making requires more information. The decision-maker needs to know the total range of uncertainty of the performance measures. The primary tool for communicating uncertainty, rather than just an upper bound, for example, is to embed the performance measures in probability distributions so that the full range of values and all their supporting evidence are visible. For example, if the value preferred by the regulator is the 90th percentile value, then it is explicitly clear just how conservative the regulator has chosen to be.

The Committee stresses the importance that the evidence (i.e., data and all other information) that is the basis of the PA model be clearly visible, particularly regarding the abstraction from physical process models to probabilistic calculations. We are especially concerned with the abstraction of information about the engineered systems, especially under the circumstances of not having a fixed design. In addition, supporting evidence for modeling important phenomena such as the chemistry of redox reactions is weak. Our current impression is that more attention is being given to methods than to the required information to support those methods.

Analysis Capability

The ACNW was impressed with the progress in the development of NRC's TPA-3 code. We are anxious to follow the development of TPA-3 and look forward to more discussions with the staff.

The ACNW urges the staff to implement a working code in an expeditious manner so that the code is fully functional as the TSPA-VA analyses are made available to NRC.

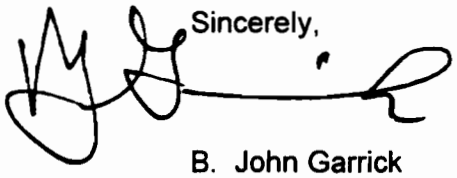
The Commission has indicated an interest in moving toward a risk-informed, performance-based philosophy of regulation. Of concern to us is whether the TPA-3 effort is keeping pace with the development of methods and ideas on how to implement such a philosophy.

An issue with TPA-3 is how to verify the code. The problem as stated by the staff is that because the code is designed specifically for the Yucca Mountain site, international bench marking is almost impossible. It is true that parts of the code, such as NEFTRAN (**NE**twork **F**low and **TRAN**sport), have been benchmarked. The NRC staff must see that TPA-3 is benchmarked against applications of other codes to Yucca Mountain. The ACNW also believes that the NRC staff should pursue other avenues of peer criticism of its codes, such as publication in refereed engineering and scientific journals.

Although the ACNW believes that it is important to develop a PC compatible version of the code to reach more users, we would not like to see other important activities compromised to reach this goal. A PC compatible version should not be created at the risk of oversimplification. Meanwhile, to conduct a full range of analyses in reviewing DOE's TSPA-VA, the staff requires the NMSS Advanced Computer System or a suitable alternative.

We believe that these comments provide constructive guidance on the future direction of the performance assessment effort and look forward to following NRC staff progress in this important activity.

Sincerely,



B. John Garrick
Chairman