ACNWR-0197

June 12, 2003

The Honorable Nils J. Diaz
Chairman
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: TOTAL SYSTEM PERFORMANCE ASSESSMENT WORKING GROUP SESSION, MARCH 25-26, 2003

Dear Chairman Diaz:

At its 140th meeting on March 25–26, 2003, the Advisory Committee on Nuclear Waste (ACNW or the Committee) held a working group session (WGS) on performance assessment for the proposed high-level waste repository at Yucca Mountain, Nevada. The session included a panel of five distinguished scientists and engineers from academia and research institutions renowned in the fields of geosciences, corrosion science, and engineering.[1] Representatives of the U. S. Department of Energy (DOE), the U. S. Nuclear Regulatory Commission (NRC), and the State of Nevada made presentations, as did various other stakeholders.

The primary purposes of the working group session were to (1) better understand the principal issues of performance assessment that might affect the licensing process, (2) review the NRC staff readiness to evaluate a total system performance assessment, and (3) assess the level of realism in the modeling of the repository. The principal bases of the discussions were the performance assessment models of the NRC and DOE identified as Total-system Performance Assessment (TPA) and Total System Performance Assessment (TSPA), respectively. While the TSPA was part of the discussions, the focus of the session was on the "near-field," by which is meant the drip shield, the waste package, the radionuclide source term, and the geosphere in the immediate vicinity of the repository drifts. In particular, the discussion emphasized the "source term" and "source term uncertainty."

The rationale for the emphasis on the source term is that it is the principal boundary condition for assessing the performance of the natural setting. One view is that if a strong scientific basis can be established for the argument that not much radioactive material escapes from the waste, any impact of uncertainties about the performance of the geosphere may be of limited concern. Thus, a better understanding of the near-field containment capability may reduce the need for additional characterization of the site.

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[1]Two of the panel members serve on the Nuclear Waste Technical Review Board (NWTRB). However, they represented themselves at the working group session as individual professionals from their respective universities, rather than as members of the NWTRB.

The focus on uncertainty and realism relates to the issue of risk-informing the performance assessment. The Committee has long held the view that to comply with regulations that are designed to be risk-informed, a license applicant must provide analyses that include an answer to the question, “what is the risk?” Of course the answer is expected to include the applicant’s best estimate of what is the *real risk*, not some other assessment such as an extreme over- or under-estimate of the risk. Our point has always been that it is best to estimate the real risk, including its uncertainty, as a baseline against which to determine how much safety margin actually exists and to better aid the decisionmaking process as to what seems to be a “reasonable” safety margin.

The Committee was very pleased with the depth and breadth of the technical discussions and the opportunity to hear the different views and exchanges of the participants. We anticipate that the record and insights provided will enhance our ability to effectively offer advice to the Commission as the Yucca Mountain project moves into the licensing phase. While there was sharp and in-depth discussion of several technical issues, the Committee heard no issues and received no information that would establish a basis for major changes in the positions we have taken in reports to the Commission on past performance assessment work.

The technical discussions centered on the (1) chemical and temperature environment of the drip shield and waste package and their effects on degradation mechanisms, (2) uncertainties and realism of the performance assessment models, and (3) NRC staff readiness to perform a comprehensive review of the performance assessment that will be submitted as a part of the DOE license application. The discussions also included the following highlights:

- The State of Nevada has a concern that severe corrosive environments might be possible in the vicinity of the drip shield and waste package. This concern arises from their opinion that the performance assessments have failed to properly represent the appropriate water chemistries. They believe that water composition is important and that vadose zone water ought to be the basis for the water chemistry, rather than well water as presently assumed. The state representatives presented no evidence concerning the effect of different water chemistries on the overall performance of the repository.

- Two members of the expert panel shared their views about temperature effects on the performance of the repository. They pointed out that exceeding certain temperature thresholds can lead to the activation of specific corrosion processes in the presence of some environments. They have concerns that those conditions exist in the temperature regime of the current design and such temperature data have not been adequately employed in the assessments. For example, DOE’s calculations of high- and low-temperature repository designs showed essentially no difference between the two in terms of the dose calculations. Using the TPA, the NRC staff should be able to conduct an independent analysis of different repository temperature profiles to verify the effect on the dose calculations.

- Another participant posed a question, “Do the models simulate all the processes that are major sources of uncertainty?” The large margins of safety in the current dose calculations accommodate considerable uncertainty, but only if the uncertainties are properly represented. Primary sources of uncertainty associated with the near-field are

the specific chemical environment of the corrosion models and key parameters and assumptions in the source term calculation. Examples of important parameters and assumptions are temperature, chemical form and phase, humidity, and solubilities, including in-package chemistry effects on those solubilities. Work is in progress by both DOE and the NRC staff to quantify the important uncertainties, and it appears that they are making considerable progress.

- Other participants challenged the realism of some of the source term modeling. Each successive performance assessment has made progress toward making the models more realistic with respect to both conservative and nonconservative assumptions. Areas of improvement have included the climate process model, treatment of coupled effects (thermal, hydrological, and chemical), use of more realistic solubilities for important radionuclides, treatment of thermal effects, and chemical environment of the drip shield and waste package. A specific example of addressing nonconservatism has been a more realistic representation of the amount of water accessing the near-field. As a result, the infiltration rates in the current models are considerably higher than in the early models. An example of increased conservatism is the radionuclide release model of the DOE TSPA with respect to the assumption of a fully water-saturated environment inside the waste package in the absence of dripping water. Recognizing these inconsistent assumptions and basing the calculations more on the supporting evidence has resulted in the performance assessments moving in the direction of greatly improved realism.

- The WGS provided the opportunity to challenge the NRC staff on their progress toward a capability to perform a comprehensive review of the complex TSPA expected in DOE's license application. The staff did an outstanding job of demonstrating that they are well-positioned for that effort. They recognize that their role is to review the TSPA, rather than simply performing independent analyses, and they manifest that recognition in the way in which they have specialized their performance assessment code. The staff's ongoing investigations of important contributors to the performance of the proposed Yucca Mountain repository are creative and insightful. The Committee strongly recommends that they continue this work.

A more detailed discussion of the WGS follows.

Principal Technical Issues

The principal technical issues discussed during the WGS included the chemical environments for initiating and sustaining corrosion, the temperature at which those environments occur, and the uncertainties and realism associated with the corrosion and radionuclide mobilization and transport models in the near-field. The representatives from the State of Nevada focused primarily on the chemical environment, while two members of the five-member panel emphasized the temperature issue and several participants, including the Committee, contributed to the discussion concerning model uncertainties.

Chemical Environment

Some WGS participants, primarily the representatives from the State of Nevada, were skeptical that sufficient data exist to exclude extreme corrosive environments for the drip shield and waste package. They believe that there is a need for additional data on water chemistries before they can be convinced that extreme environments cannot exist. They consider water

composition to be a major chemical environmental factor and expressed concern at the project's use of well water, rather than vadose (unsaturated) zone water. The Committee has not seen evidence that such changes in water chemistry will lead to changes in the dose calculations of sufficient magnitude to represent a significant compliance issue, but we will follow this issue as the performance assessments evolve.

Temperature Effects

Temperature is an environmental parameter, but it is often discussed as a specific issue because of its high profile in the performance assessment debate. The Nuclear Waste Technical Review Board (NWTRB) has raised this issue for some time and panel members from that Board (participating as individuals, not as representatives of the Board) introduced the topic into the WGS. Their specific concern is that exceeding certain temperature thresholds can lead to the activation of specific corrosion processes in some environments. In particular, they do not believe that the corrosion models are based on realistic temperature data. DOE has analyzed so-called hot and cold temperature profiles in supplemental performance assessment work, but the results did not show any significant difference in the safety performance of the repository. If the phenomena are properly captured, however, differences may arise in both the results and their uncertainties; this will require careful review. The ACNW has not reviewed the details of these differences to form an opinion concerning the effect they may have on the dose calculations. The safety margins of the calculations that DOE has performed are such that it would be surprising if these differences threatened compliance with the dose standard. We are confident that the NRC staff has the capability to determine the sensitivity of the dose calculations to different temperature profiles.

Uncertainties in the Analyses

Uncertainties in the source term parameters were extensively discussed during the WGS. The uncertainties include water composition, because of how it affects the mineral phases inside the waste package, the solubility limits for some of the radionuclides involved, and the details of the corrosion process. The primary parameter and phenomena uncertainties are temperature, chemical form and phase, humidity, and solubilities, including in-package chemistry effects on those solubilities. How much water exists in thin films for diffusive transport or in droplets by advective flow continues to be an issue in the respective DOE/NRC performance assessment models.

DOE's TSPA model treats the release of radionuclides from the engineered barrier system (the source term) by both diffusion and advection from "cracks" associated with stress-corrosion cracking and general corrosion "patches." The NRC's TPA model treats releases from the waste package as being primarily driven by advection, rather than by diffusion. While the models differ, some of the WGS panel members expressed the opinion that the DOE and NRC models have identified most of the relevant processes.

The issues are the rationale for the differences in the details of the corrosion and release mechanisms more than the results obtained. How important are source term uncertainties? The importance of these uncertainties is diminished if (1) they are adequately quantified and (2) in the presence of the uncertainties, there is still a reasonable safety margin in terms of meeting the radiation dose standard. DOE and the NRC staff are currently involved in work to quantify the important uncertainties.

For calculated doses within the first 10,000 years following closure of the repository, uncertainties continue to exist with regard to the assumptions made in the performance assessments about early failures of waste packages as a result of manufacturing flaws. The flaws of greatest interest are improper heat treatment of waste package lid welds. Assumptions about such flaws and the uncertainties therein account for the appearance of a calculated dose in the most recent versions of the TSPA model for the first 10,000 years. The calculated doses are extremely small. The issue discussed at the WGS was the lack of supporting evidence for the calculations of manufacturing flaws and the fact that such flaws could be the most significant cause of early failures of the waste packages.

NRC Staff Readiness

One of the clear benefits of the WGS was that it gave all those in attendance, including the Committee, a chance to see how the NRC staff is progressing in their capability to review a very complex performance assessment. In general, the Committee was very impressed with the staff's progress. We are confident that the necessary technical tools and staff will be in place to perform a competent review when DOE submits its license application (LA). Other factors that contribute to our confidence are (1) the NRC staff's experience base (~25 years) in developing and performing performance assessments (2) specialization of the tools, especially the TPA code, to assess the LA performance assessment, and (3) a capability to map the results of the DOE performance assessment into the NRC's key technical issues.

The centerpiece of the staff's analytical tools is the TPA code. The Committee has followed the TPA work since its inception and has urged the staff to risk inform the code as much as practicable, including the ability to quantify uncertainties. We have especially encouraged the staff to develop the ability to rank the importance of contributors to repository performance, including the contribution of individual barriers. While much of the importance-ranking capability is not yet automated, the offline use of the code to make such assessments is impressive. One advantage of the TPA code is that its development and application involve very few individuals and organizational entities. By comparison, DOE does not have such a simple computational management structure, and must rely on many different contributions from several different contractors with their ability to make the proper linkages. The TPA code should be a powerful tool for challenging the completeness of the TSPA in terms of its scope and the degree to which it is fully integrated.

Realism of the Performance Assessment Models

DOE and the NRC staff are making progress toward more realistic performance assessment models. The three scenarios to consider in the TSPA are (1) nominal performance, (2) disruptive events, and (3) a stylized human intrusion scenario that is specified by regulation. Examples of improvements in the realism of the TSPA models include the climate process model, treatment of coupled effects (thermal, hydrological, chemical), use of more realistic solubilities for important radionuclides, accounting for retardation of selected radionuclides, treatment of igneous events, and the uncertainty analysis of selected contributors to risk.

The progress in the TPA code is illustrated by its ability to account for uncertainties including variability of system attributes, the treatment of thermal effects for calculating temperatures at critical locations such as the drift wall and the waste package surface, and improvements in the ability to model groundwater flow and the near-field chemical environment. To assist in reviewing DOE's TSPA, the next version of the TPA code will incorporate a diffusion model—a

release mechanism that figures prominently in DOE's TSPA model. The staff is also considering evaluating cladding protection of the fuel in the next version of the TPA code.

The Committee continues to question the realism of the release model in DOE's TSPA. Much of the skepticism centers on the assumptions about the in-package environment and the supporting data. For example, the TSPA assumes that the waste package is fully saturated, even in the absence of any dripping water, and the analysis includes calculating the cladding and waste reaction rates and chemical concentrations for these conditions. The conditions may be bounding in terms of the source term, but the evidence does not support the need for such an extreme model for mobilizing the waste. We continue to question the extent to which diffusive transport is the basis for radionuclides to exit the waste package. We also need to better understand the effect of different mineral phases on the mobilization of the waste. This issue was discussed at length during the WGS. Again, it is not so much a concern that the dose standard cannot be met, as it is a matter of having a realistic baseline for the level of risk involved.

As previously noted, there are other barriers to complete realism in the models such as the somewhat prescriptive human intrusion model and the biosphere dose model. The result is the possible masking of either conservative or nonconservative contributors to risk. The degree of this masking is difficult to assess at this time, but it is a possibility the Committee will follow.

Of the various activities concerning realism, the Committee strongly supports backtracking from the final results of the performance assessment, where few radionuclides dominate the performance, into the internals of the model. As discussed in previous letters to the Commission, the Committee believes this approach will enable the staff to ferret out the contributing factors and the basis for their respective contributions. The NRC staff is doing just that with their own TPA model and the insights are extremely valuable in exposing what is really important. In fact, they have taken the concept further by seeking answers regarding why other radionuclides do not contribute to the risk. Some of the important insights are the effect of different engineered and natural barriers, the impact of modeling assumptions, and the importance ranking of contributors to performance. As we have in other reports to the Commission, we strongly recommend that this work continue.

Other Points of Discussion

In addition to the key points regarding technical issues, staff readiness, and realism, two other important observations arose from the WGS. One involved the debate over whether Yucca Mountain is a research project or an engineering project. This debate centered on the meaning of "reasonable expectation." Some participants expressed the opinion that given that it is a first-of-a-kind project, it requires a far greater depth of scientific activity than other large-scale projects. Other participants argued that the evidence does not support that view, noting that the analyses performed so far, which many WGS participants consider very conservative, have indicated a trivial safety issue in comparison to other risk issues facing our society. This debate turned out to be an excellent illustration of the value of uncertainty analysis in determining the "adequate" amount of scientific investigation. The Committee has always advocated that the best way to know how much additional scientific work is needed is to quantify the uncertainties of the important contributors to risk. If the contributors, with all of their uncertainties, make little difference to the bottom-line risk measure, there is evidence that further work is not necessary. This is a primary benefit of risk-informing the analyses.

Finally, in terms of model structure, the participants expressed strong support for staging performance assessment models along the lines of modules that represent "pinch points," that is, structuring the model according to inputs and outputs of specific stages that facilitate the transparency of the total system. Such a structure permits a detailed examination of the initial conditions of the model, and also identifies the boundary conditions for the different stages. Such discretization better portrays the dynamics of the repository. Also, a staged structure allows clear exposition of the assumptions made on critical parameters as material moves through the repository region. Both DOE and the NRC have incorporated relevant modules in their models, but the interfaces between the modules lack definition in terms of specific inputs and outputs in a pinch point sense.

Summary

This outstanding WGS met the goals to (1) better understand the principal issues of performance assessment that might affect the licensing process, (2) review the readiness of the NRC staff to evaluate a total system performance assessment, and (3) assess the level of realism in the modeling of the repository. The WGS provided an excellent forum in which to exchange views on the technical issues associated with the performance assessment process and the particular issues surrounding the definition of the source term for the proposed Yucca Mountain repository.

Sincerely,

/RA/

George M. Hornberger
Chairman