

Questions from Congressman Ed Markey:

1. *In addition to the Nuclear Waste Technical Review Board (NWTRB), the International Atomic Energy Agency/Nuclear Energy Agency has reviewed the scientific and technical work of the DOE. They state in their review that “In general, the level of understanding of the hydro-geology of the site. . .is low, unclear and insufficient to support an assessment of the realistic performance.” They continue “Until these questions are answered, it is not possible to develop a realistic conceptual model of the site, or to build a probabilistic saturated zone local model.” Do you agree with their assessment? Is the DOE’s model unrealistic because of lack of data and basic understanding of physical process?*

Answer: We agree generally with the concerns expressed by the International Atomic Energy Agency/Nuclear Energy Agency Peer Review Panel (International Panel) but would like to make several observations to put their comments in perspective. The International Panel comment cited above includes three elements: (1) an assessment of the realistic performance, (2) a realistic conceptual model of the site, and (3) a saturated zone local model. (In the context of this question, *realism* may be viewed as the set of models and assumptions that most nearly describes the natural and engineered repository system and produces neither overly pessimistic nor overly optimistic predictions of waste isolation.) The three elements are interlinked: A realistic performance assessment requires a realistic saturated zone site-scale model, and that requires a realistic conceptual model. Although the general concepts of the Yucca Mountain hydrogeologic system are understood, important details remain unresolved. Consequently, the performance estimates for the saturated zone in the Total System Performance Assessment for Site Recommendation (TSPA-SR) may not be realistic. The TSPA-SR was the sole focus of the International Panel. Since that time, results released by the DOE in subsequent documents indicate that some progress has been made in addressing questions raised by the International Panel and in developing a credible conceptual model of the site. Those results have not been incorporated in performance assessments, however, and substantial work remains to be done to develop a realistic saturated zone site-scale model on which a realistic assessment of performance attributable to site hydrogeology could be based.

In answer to your question on the DOE’s model, the Board stated in its January 24, 2002, letter report to Congress and the Secretary of Energy that it has limited confidence in current DOE performance estimates because of uncertainties created by gaps in data and basic understanding of the proposed repository system (including the saturated zone). The Board has recommended that, if policy-makers decide to approve the Yucca Mountain site, the

DOE should continue a vigorous, well-integrated scientific investigation to increase its fundamental understanding of the potential behavior of the repository system. Increasing understanding could show that components of the repository system, including the saturated and unsaturated zones, perform better than or not as well as the DOE's performance assessment model now projects. In either case, making performance projections more realistic and characterizing the full range of uncertainty could improve the DOE's performance estimates.

- 2. The DOE is relying heavily on the ability of the canisters to withstand corrosion and contain the radioactive waste for long periods of time. The NWTRB report states that essentially no corrosion data exists for conditions above 275 degrees (120° C), despite the fact the repository could reach temperatures as high as 350 degrees (165° C). In your opinion, can the DOE make any real assessment of the engineered barriers above 275 degrees? What are some of the effects that elevated temperatures could have on the canisters?*

Answer: To answer your second, more general, question first: The severity of corrosion tends to increase with increasing temperatures. In fact, some forms of corrosion are not even observed unless the temperature exceeds a certain threshold value. This applies to essentially all alloys and metals used as construction materials, including Alloy 22, the material that the DOE has chosen to provide corrosion resistance for its waste package. In addition, and perhaps more important, predicting the chemistry (composition and strength) of salt solutions contacting the waste packages becomes more difficult and more uncertain with increasing temperature. The type and severity of corrosion depend on the makeup of those solutions.

Regarding your first question, data on the chemistry of salt solutions that may contact the waste package as well as data on corrosion of Alloy 22 exposed to such waste package environments are both essentially nonexistent for temperatures above 120° C. These key data needed to assess the likelihood that corrosion could penetrate waste packages during the 10,000-year regulatory period. This absence of information weakens the technical basis of the DOE's performance estimates for its high-temperature, base-case repository design. Uncertainty about waste package performance decreases, however, with lower repository temperatures because more corrosion data and more data on the chemistry of salt solutions that may contact waste package surfaces are available. Uncertainty also is reduced with low temperatures because corrosion severity generally decreases as temperatures decrease. The Board believes, therefore, that confidence in waste package and repository performance potentially could increase if the DOE adopts a low-temperature repository design. However, a full and objective comparison of high- and low-temperature repository designs should be completed before the DOE selects a final repository design concept.

3. *The DOE only has 2 years of corrosion data for alloy 22 based canisters, yet they are extrapolating this data to 10,000 years. Is this acceptable? Is there currently any way to adequately determine the integrity of these canisters 10,000 years in the future?*

Answer: Alloy 22 relies on the formation of an ultrathin passive (i.e., nonreactive) film for its corrosion resistance. The DOE's models predict that corrosion will not penetrate Alloy 22 waste packages for at least 10,000 years, perhaps for longer than a million years. However, experience with Alloy 22 and comparable alloys spans only several decades, and experience with alloys that rely on passive films for corrosion resistance spans only about a century. Although a few natural or man-made materials have been identified that might provide insights into the long-term passivity of metals, none has been confirmed yet as a suitable analogue. Thus, this type of corrosion resistance over many thousands of years can be extrapolated only by using theories and assumptions. At this point, on the basis of the information developed by the DOE and others, Board members believe that claims of minimum waste package durability of a few thousand years to a few tens of thousands of years are not out of the question. Underlying this belief are the following suppositions: that temperatures and chemical conditions on the waste-package surface will be no more severe or uncertain than those in the DOE's preliminary analysis of the low-temperature operating mode; that supporting research will be continued to fill in data gaps and to rule out unexpected modes of failure; that research, development, and demonstration of waste-package welding, fabrication, and inspection are completed successfully; and that no major "surprises" are found.

4. *The Chlorine-36 "fingerprints" of above ground nuclear testing have been found in the interior of Yucca Mountain, suggesting that water from the surface can migrate 1000 feet to the repository level of the mountain within 50 years. What are the implications of this data for contamination of the ground water below the repository? What are the implications for corrosion of the canisters?*

Answer: The discovery of elevated amounts of chlorine-36 (a product of nuclear testing in the 1950's) at the depth of the proposed repository at Yucca Mountain would provide direct evidence of the existence of "fast paths" through which rainwater could travel from the surface of Yucca Mountain to the repository horizon within about 50 years. However, questions have been raised about the validity of the results of the original chlorine-36 study that showed evidence of such fast paths. In 1999, the DOE sought to validate the original tests. Scientists using different testing procedures have shown differing estimates of the amount of chlorine-36 present in the underground rocks. The validation study is still under way, and the DOE has not reached any conclusions. The DOE's current models of repository performance are based on the general assumption that some fast-flow paths *do* exist in Yucca Mountain.

To answer the question on the effects of possible fast paths on groundwater contamination, it would be necessary to verify that they exist and to estimate the volume of water being transported along the pathways under current and future climate conditions. The chlorine-36 validation study may resolve the question of the presence or absence of fast pathways for water flow. Estimation of the volumetric flux associated with fast pathways requires additional investigations, some of which are ongoing and some of which are planned.

In terms of the effects of fast paths on waste package corrosion rates, if the assumption is (as the DOE's is) that corrosion proceeds as rapidly under high-humidity conditions as under dripping conditions (a reasonable assumption), whether fast paths are present or absent has essentially no effect on waste package corrosion rates. However, larger fluxes of water generally result in shorter times of radioactive waste isolation. Current models, based on multiple lines of evidence, do not allow for large volumes of water to flow through these fast pathways. If the current thinking is found to be incorrect, then radionuclide transport predictions may need to be revised.

5. *Secretary Abraham said in his testimony that Yucca Mountain will meet the EPA radiological exposure standard. But the NWTRB report notes that DOE has not published updated calculations of radiological doses based on the recent travel time estimates. Is the Secretary's statement premature? Can DOE be confident that Yucca Mountain will meet the EPA's standard without having completed these calculations?*

Answer: The DOE's performance calculations should be updated to take into account new information on travel-time estimates. However, because many things, in addition to groundwater travel times, affect the DOE's projections of compliance, the effect of revised travel-time estimates on judging compliance with the EPA standard may not be large. For example, current DOE models show that the waste package will last longer than the 10,000-year compliance period.

The Board believes that the technical basis for the DOE's current repository performance estimates is weak to moderate. The question of whether the Secretary's statement is premature depends on how much uncertainty one finds acceptable at this decision point. That is a policy question, which is outside the Board's technical and scientific mandate.

6. *Spent fuel – uranium dioxide – will be the majority of the stored waste in Yucca Mountain. What will happen to the fuel rods as they sit in the repository? Will they rust? Has the DOE considered the effect of rusting in their assessment of Yucca Mountain and containment of the radioactive waste?*

Answer: The spent-fuel rods consist of uranium dioxide pellets enclosed in metallic cladding. The cladding for the vast majority of the rods is zircaloy, a very corrosion-resistant alloy of zirconium. Once the cladding is exposed to aqueous or high-humidity environments (e.g., after penetration of the waste package), the cladding will begin to corrode. Eventually, corrosion will cause the cladding to fail after thousands of years. The DOE has considered cladding corrosion in its performance assessment models. However, the Board believes that the DOE's current level of understanding of cladding performance is incomplete and should be improved.

Questions from Congressman George Radanovich:

1. *Would you agree with the statement “Geologic isolation cannot and will not play any significant role at the Yucca Mountain repository?”*

Answer: No, the statement is too strong. Although the DOE’s current estimates of repository performance rely heavily on components of the engineered barrier system, the natural barriers do play a role. Further analysis and the reduction of uncertainties will permit a more realistic assessment of the relative significance of the contribution of the engineered and natural barriers in the proposed repository system.

2. *What is the NWTRB opinion of the ability of the man-made containers to meet the NRC and EPA standards for radioactive release into the environment?*

Answer: At this point, on the basis of the information developed by the project (and others), Board members believe that claims of minimum waste package durability of a few thousand years to a few tens of thousands of years are not out of the question under relatively mild and less uncertain (lower temperature) in-drift conditions. Underlying this belief are the following suppositions: that temperatures and chemical conditions on the waste-package surface will be no more severe or uncertain than those in the DOE’s preliminary analysis of the low-temperature operating mode; that supporting research will be continued to fill in data gaps and to rule out unexpected modes of failure; that research, development, and demonstration of waste-package welding, fabrication, and inspection are completed successfully; and that no major “surprises” are found.