Department of Energy

Washington, DC 20585

September 10, 1999

Dr. Jared L. Cohon
Chairman
U.S. Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

Dear Dr. Cohon:

We appreciate the Nuclear Waste Technical Review Board's comments on our evaluation of alternative repository designs. We also appreciate your recognition that the comprehensive and resource intensive effort conducted by our Management and Operating (M&O) Contractor has resulted in a much better understanding of the relative importance of the many factors involved in a repository design. The evaluation performed by the M&O Contractor used the information gathered during site characterization and the understanding of repository system behavior gained from a series of performance assessments to guide the evolutionary process of design development. We have used the results from this evaluation, and the results from subsequent analyses performed by the M&O, to select the next generation design concept that will be developed for use in evaluating the site and preparing the license application if the site is suitable. A summary of our evaluation process, criteria, and results may be found in the enclosure.

We agree that the repository design concept and, in particular, the temperature regime associated with that concept may have a profound effect on the cumulative uncertainty in estimates of long-term repository performance. We also recognize that this uncertainty may affect confidence in decisions regarding the suitability of the Yucca Mountain site. We have sought to select a design and to specify conditions on its implementation that are responsive to the Board's concerns while balancing all significant factors, including long term public safety, inter- and intra-generational equity, worker safety, and cost. We have also emphasized the need for flexibility to ensure that scientific and engineering data gathered throughout site characterization, construction, operation and monitoring, and any evolution in national policy can be accommodated through reasonable changes in the repository design or operational concept.

After considering the technical information provided by our M&O Contractor, as well as the issues raised by external oversight groups, including the Board, we have selected a design concept to be used as the basis for the next phase of project activities. The selected design concept features much lower thermal impacts than the Viability Assessment design as well as significant enhancements in the engineered barrier system. We are in the process of incorporating this design basis in our programmatic and requirements documents. The concept we selected is based on the design alternative recommended by our M&O contractor, but includes the following, flexibility-enhancing conditions on its implementation:

1. The design will permit the repository to be kept open, with only routine maintenance, for approximately 125 years from initiation of waste emplacement, which is approximately the time necessary for the ventilation system to remove sufficient heat to keep the drift walls below boiling (96°C at the elevation of the potential repository) following closure.

2. The design will permit the repository to be closed during the period from 50 years to approximately 125 years from the start of waste emplacement. The design will not preclude keeping the repository open, with appropriate maintenance and monitoring, for 300 years after initiation of waste emplacement. A decision on when it is appropriate to close the repository will be made considering the results from performance confirmation testing and analyses, taking into account the need to dispose of the waste in a way that minimizes the transfer of the burden to future generations. This is consistent with current Program policy that future generations will make the ultimate decision on whether it is appropriate to continue to maintain the repository in an open monitored condition, or to close and seal it.

3. The sensitivity of the postclosure performance of the repository system to uncertainties associated with coupled, thermally driven processes will be examined for preclosure durations of 50 and 125 years.

4. The models that are the basis for the evaluation of thermal conditions will be refined to reduce conservatism. Design options that can increase the efficiency of heat removal will also be evaluated.

The selected design concept provides the flexibility to adjust emplacement conditions, and ventilation design and duration, to keep the rock temperatures below 96°C and as cool as is reasonably achievable given technical, institutional, and cost considerations. It also provides the flexibility to increase the rock temperatures, should new scientific and engineering data show that such an alternative is beneficial. The emphasis on flexibility in the evolutionary process of design development is consistent with the position taken by the Advisory Committee on Nuclear Waste (ACNW) in a recent letter to the Nuclear Regulatory Commission. The ACNW expressed the view that although a cooler repository design may simplify modeling of water redistribution, the potential for a higher temperature design to reduce the quantity of water reaching the emplacement drifts should not be abandoned without further assessment.

The design concept we selected also preserves the flexibility for future generations to determine whether to close the repository early or to keep it open for as long as 300 years with appropriate maintenance and monitoring, based on their own judgements regarding the significance of uncertainties. The early closure assumption of 50 years is consistent with the retrievability period required by the Nuclear Regulatory Commission and should provide adequate time to complete the performance confirmation program required before a Commission decision on closure can be sought.

We value the Board's feedback and recognize the contribution its has made to the quality of our products. We look forward to further input as we work toward completing the technical documentation necessary to provide a basis for a site recommendation decision. If you have any questions, please contact me at (202) 586-6842.

Sincerely,

Lake H. Barrett, Acting Director
Office of Civilian Radioactive
Waste Management

Enclosure

ENCLOSURE

BASIS FOR DEPARTMENT OF ENERGY (DOE) DESIGN SELECTION

General Principles

DOE has selected the repository design to be used as the basis for development of the Site Recommendation (SR), as the next step in the evolutionary process of design development. The decision is based on general policy considerations of fairness and equity within and between generations, together with technical considerations involving five principal factors:

- *Public safety as measured by postclosure performance*
- *Demonstrability of postclosure performance in licensing*
- *Preclosure worker safety*
- *Flexibility to accommodate design changes and improvements in understanding*
- *Cost*

Policy Considerations of Fairness and Equity

The Nuclear Waste Policy Act includes among its findings that the national problem created by the accumulation of spent nuclear fuel and high-level waste requires that "*appropriate precautions must be taken to ensure that such waste and spent fuel do not adversely affect the public health and safety and the environment for this or future generations.*" A stated purpose of the Act is "*to establish the Federal responsibility...for the disposal of such waste and spent fuel.*"

In its 1990 report "*Rethinking High-Level Radioactive Waste Disposal,*" the National Research Council Board on Radioactive Waste Management considered what we owe to future generations and cited the Environmental Protection Agency (EPA) regulations requiring that radioactive releases be limited for 10,000 years as an illustration of concern for the distant future.

If a site for a repository is approved and the repository is licensed for emplacement of the Nation's high-level waste, any decision to close and seal the repository following an extended period of waste emplacement and monitoring will be made by some future generation. The design selected as the basis for site recommendation must provide the flexibility for future generations to make this decision based on their own criteria and to minimize the transfer of the burden from this generation to our descendents.

International organizations have developed position statements, representing the collective opinion of the parties involved, on the technical and ethical basis for geologic disposal. There is general agreement that the ethical basis for geologic disposal of long-lived radioactive waste involves considerations of fairness and equity within and between generations.

The International Atomic Energy Agency (IAEA), in its Report on Radioactive Waste Disposal (IAEA, 1993), states that a basic objective of safe waste disposal is "*to dispose of the waste in such a way that the transfer of responsibility to future generations is minimized.*" With regard to the responsibility of today's waste producers to future generations, the IAEA proposes as a safety principle that "*the burden to future generations shall be minimized by safely disposing of high level radioactive wastes at an appropriate time, technical, social and economic factors being taken into account.*"

The members of the Nuclear Energy Agency (NEA) Radioactive Waste Management Committee, in their report on The Environmental and Ethical Basis of Geological Disposal (NEA, 1995):

- *consider that from an ethical standpoint, including long-term safety considerations, our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores* [storage facilities] *which require surveillance, bequeath long-term responsibilities of care, and may in due course be neglected by future societies whose structural stability should not be presumed;*

- *believe that the strategy of geological disposal of long-lived radioactive wastes:*

  - *takes intergenerational equity issues into account, notably by applying the same standards of risk in the far future as it does to the present, and by limiting the liabilities bequeathed to future generations; and*

  - *takes intragenerational equity issues into account, notably by proposing implementation through an incremental process over several decades, considering the results of scientific progress;*

- *conclude that stepwise implementation of plans for geological disposal leaves open the possibility of adaptation, in the light of scientific progress and social acceptability, over several decades, and does not exclude the possibility that other options could be developed at a later stage.*

Consideration of these issues prompted DOE to adopt a policy that meets the obligation to provide for disposal of high-level waste at an appropriate time, while leaving flexibility to adapt and change in the future based on scientific progress or other considerations. Specifically, the repository design should permit future generations to close the repository as early as they might choose, allowing sufficient time to complete the performance confirmation program required for a Nuclear Regulatory Commission decision on an application for closure. The 50-year retrievability period from the initiation of waste emplacement, required by the Nuclear Regulatory Commission in both 10 CFR Part 60 and the proposed 10 CFR Part 63, was established as a reasonable estimate of the time that might be needed to complete the performance confirmation program required to support a Commission decision on repository closure. At the same time, the design should permit future generations to keep the repository open for a longer period, with appropriate maintenance and monitoring, based on their own evaluation of the technical, social, and economic factors involved.

Technical Evaluation Factors and Basis of Evaluation

Five technical factors were identified and considered by DOE in its evaluation of design alternatives and selection of the design that will be developed to support site recommendation.

- *Public safety as measured by postclosure performance*
- *Demonstrability of postclosure performance in licensing*
- *Preclosure worker safety*
- *Flexibility to accommodate design changes and improvements in understanding*
- *Cost*

The order of discussion reflects DOE's view of the relative importance of each of these factors to the decision that is the outcome of the design selection process. The DOE's evaluation for each of the factors, based on the technical information and analyses presented in the License Application Design Selection (LADS) Report, is summarized below.

Public safety as measured by postclosure performance

All five enhanced design alternatives (EDAs) evaluated provide an adequate margin of safety as measured by a comparison of their calculated postclosure performance against the 25 millirem/year screening criterion imposed. All EDAs were estimated to provide at least a three-order-of-magnitude margin on the screening criterion at 10,000 years following closure. On this basis, safety, as measured by performance against the screening criterion, is not a discriminator. The same conclusion holds when the performance of the EDAs is compared to the individual protection standard of 15 millirem/year recently proposed by the EPA in 40 CFR Part 197.

The only potential basis for discrimination among the EDAs in terms of postclosure safety is found in the results of the long-term (>10,000 years) performance evaluation. All EDAs, other than EDA IV, have comparable performance in terms of the time required for the screening criterion to be exceeded (approximately 300,000 years) and the order of magnitude of the calculated peak dose rate (roughly 100 millirem/year). EDA IV, on the other hand, is estimated to exceed the screening criterion earlier (at about 100,000 years) and to have a peak dose rate that is an order of magnitude higher than the other EDAs. Although EDA IV appears to have better performance over the 10,000-year period, it was considered to be the least favorable design alternative on the basis of estimated long-term postclosure performance characteristics.

Demonstrability of postclosure performance in licensing

Although all EDAs provide an adequate margin of safety as measured by performance for the period following closure, there are uncertainties associated with understanding and modeling the processes that have the potential to significantly affect conclusions about performance. Such uncertainties may complicate the licensing process by making it more difficult to demonstrate with reasonable assurance that the postclosure performance objectives established by the NRC will be met. One means of dealing with these uncertainties is to enhance the defense-in-depth provided by the combination of barriers that comprise the repository system. The addition of a drip shield to the engineered barrier system for all EDAs and the use of highly corrosion-resistant alloy-22 as the outer barrier of the waste package in EDAs I, II, III, and V, are examples of this approach. Both of these enhancements are expected to compensate for uncertainties in modeling the processes that affect performance and to improve the calculated performance of the repository system over that for the VA design.

The complexity and uncertainty that may be associated with modeling of thermally-driven coupled processes may be reduced through a corresponding reduction in the magnitude of the driving force for these processes and, therefore, the spatial and temporal extent of their potential influence. This can be achieved by design choices, which include emplacing the waste so that the overall temperature in the repository is lowered, emplacing the waste so that the spatial and temporal characteristics of the thermal field are controlled, and using ventilation to remove waste-generated heat prior to repository closure to reduce the overall heat load and temperatures following closure. All five EDAs employ preclosure ventilation for 50 years following the start of emplacement to remove heat (and water vapor). Only two EDAs attempt to lower the intrinsic thermal driving force for coupled processes. EDA I employs smaller, more widely spaced waste packages with lower thermal outputs to reduce temperatures across the repository and keep the drift walls below 96°C. EDA II employs a line-loading concept with widely spaced emplacement drifts to tailor the thermal field such that the bulk of the rock between the emplacement drifts stays below 96°C, reducing the complexities associated with thermal coupling between drifts. Both of these alternatives are likely to significantly reduce the complexity and uncertainty associated with modeling of coupled processes, although in different ways.

None of the alternatives are intended to keep the waste package surface temperature below a specified value in an attempt to reduce the driving force for corrosion processes. Such a design would require a significant change from the alternatives considered in the LADS Report and would likely increase the risk to worker safety as well as increasing construction and operating costs for the same reason that EDA I affects these considerations. The incorporation of a drip shield in all five designs is intended to delay the onset of waste package corrosion and to greatly extend waste package lifetime, due to the lower corrosion rates expected after temperatures return to near-ambient values. In addition, preliminary analyses indicate that the waste packages in EDA I and EDA II do not enter the temperature-humidity-water chemistry susceptibility window for crevice corrosion of alloy 22.

Preclosure worker safety

All of the EDAs, except EDA I, are comparable in terms of operational issues that may affect worker safety since they each require a similar number of waste packages and length of emplacement drift. EDA I, on the other hand, requires roughly fifty percent more waste packages and construction of more than double the total length of emplacement drift, because it relies on smaller, more widely spaced waste packages to achieve its thermal goals. As a result, the operational burden and the risk to worker safety are increased.

Flexibility to accommodate design changes and improvements in understanding

DOE must proceed with development of the technical basis for a decision on SR based on a defined design concept. DOE intends to proceed with development of a design concept that provides the flexibility to accommodate changes in national policy (increased repository capacity, for example); changes in technical understanding of the processes that affect repository performance; or changes in emplacement conditions, ventilation design, and duration of the period prior to closure.

EDAs III, IV, and V are predicated on emplacement at an areal heat loading that is equal to or higher than that for the VA design. All occupy an area comparable to or less than that for the VA design. All three result in temperatures that exceed 96°C across most or all of the repository and all produce a thermal field that will keep emplacement drifts dry for a prolonged period. Although the areal heat loading for these EDAs could be reduced, subject to construction of additional emplacement drifts, this can not be done without changing the essential basis for the designs.

EDAs I and II are based on areal heat loadings that are lower than for the VA design and consequently occupy larger areas. The heat loading can be increased or decreased for both alternatives, subject to certain constraints that are more restrictive for EDA I than EDA II. In both cases, decreasing the heat load would require expansion of the repository emplacement area and construction of additional emplacement drifts. The heat load for EDA I could be increased up to the point where the waste packages are emplaced in a line-load configuration in all of the drifts. This configuration results in temperatures in the rock between emplacement drifts that exceed 96°C. Modifying EDA I to approximate EDA II by emplacing waste packages as a line load in every other drift, while retaining the smaller waste package capacity of EDA I, would increase the repository area by about 20 percent and would raise only a small portion of the rock in the drift wall above 96°C. To increase the rock temperature further would require a change in the basic waste package design for EDA I.

EDA II employs a waste package comparable in capacity to EDAs III, IV, and V, but lower in thermal output than EDAs III and IV. EDA II offers significant flexibility to increase the heat loading, subject to construction of more closely spaced emplacement drifts. The heat loading for EDA II could be decreased by constructing additional emplacement drifts and spreading the waste packages over a larger area, but the ability to reduce local temperatures at the drift wall is limited by the capacity and thermal output of the individual packages, all other factors being held constant. Although the waste package capacity could be reduced, this is not necessary in order to achieve lower postclosure temperatures.

The design concept embodied in EDA I is determined by the thermal goal of keeping the drift wall temperature below 96°C following closure. EDA II, however, offers the flexibility to achieve a range of postclosure temperatures, including drift wall temperatures below 96°C, by adjusting the duration of the preclosure ventilation period, without changing the basic design concept. The ventilation rate might also be increased or other features included to improve the overall effectiveness of heat removal and possibly shorten the preclosure ventilation period. Current estimates are that a preclosure ventilation period of approximately 125 years at a ventilation rate of 10 cubic meters per second would be adequate to keep the drift wall temperature below 96°C. This estimate may be reduced as the models used in evaluating the thermal response to EDA II are refined.

In a August 9, 1999, letter to the Nuclear Regulatory Commission, the Advisory Committee on Nuclear Waste (ACNW) stated its view that further analyses must be done before a determination can be made on a choice between a repository where the postclosure temperature is kept below 96°C everywhere, and one in which the temperature is allowed to exceed 96°C over some portion of the repository volume. The ACNW expressed the view that although a cooler repository design may simplify modeling of water redistribution, the potential for a higher temperature repository design to reduce the quantity of water reaching the emplacement drifts should not be abandoned without further assessment.

Based on the considerations discussed above, DOE believes that EDA II offers the greatest range of flexibility, without the need for significant alteration of the basic design concept. EDA II, because it employs a line-loading concept with widely spaced emplacement drifts, provides the flexibility to raise the drift wall temperatures above 96°C after closure while the bulk of the rock between the emplacement drifts remains below 96°C, reducing the complexities associated with thermal coupling between drifts. EDA II also offers the flexibility to keep postclosure drift wall temperatures below 96°C, by adjusting the duration and rate of preclosure ventilation without changing the basic design concept.

Cost

All of the EDAs, except EDA I, are comparable in terms of construction and operating costs since they each require a similar number of waste packages and length of emplacement drift. EDA I, as noted above, requires roughly fifty percent more waste packages and more than twice the length of emplacement drift. As a result, the operational burden is increased and the cost is estimated to be 20-25 percent higher than the other four EDAs. The relative difference in cost between EDA I and the other four EDAs provides a basis for discrimination among the alternatives. This factor was considered but did not unduly constrain the DOE's design selection process.

Design Selection and Conditions

On the basis of the evaluations outlined above for each of the factors considered, DOE has approved a change to incorporate EDA II as the basis for project design activities for SR. The implementation of EDA II is subject to the following conditions:

1. The design will permit the repository to be kept open, with only routine maintenance, for approximately 125 years from initiation of waste emplacement, which is approximately the time necessary for the ventilation system envisioned as part of EDA II to remove sufficient heat to keep the drift walls below 96°C following closure.

2. The design will permit the repository to be closed during the period from 50 years to approximately 125 years from the start of waste emplacement. The design will not preclude keeping the repository open, with appropriate maintenance and monitoring, for 300 years after initiation of waste emplacement. A decision on when it is appropriate to close the repository will be made considering the results from performance confirmation testing and analyses, taking into account the need to dispose of the waste in a way that minimizes the transfer of the burden to future generations. This is consistent with current Program policy and requirements, which specify that future generations will make the ultimate decision on whether it is appropriate to continue to maintain the repository in an open condition, or to close it.

3. The postclosure performance of the repository system will be evaluated for potential preclosure periods of 50 years and approximately 125 years so that the sensitivity of system performance to uncertainties that may be associated with coupled, thermally driven processes may be examined as a function of preclosure duration.

4. The models that are the basis for the evaluation of thermal conditions will be refined to reduce conservatism that can increase the estimate of the preclosure period required to achieve a particular temperature at the drift wall. Design options that can increase the efficiency of heat removal will also be evaluated.

Conclusion

Selection of EDA II with the conditions specified provides DOE the flexibility to adjust emplacement conditions, and ventilation design and duration, to keep the rock temperatures below 96°C and as cool as is reasonably achievable given technical and cost considerations. It also preserves the flexibility for future generations to decide to close the repository as early as 50 years after the start of emplacement, thereby minimizing the transfer of responsibility to later generations, should that prove to be the appropriate option based on performance confirmation results and institutional considerations at the time. The 50-year period for early closure is consistent with the retrievability period required by the Nuclear Regulatory Commission in both 10 CFR Part 60 and the proposed 10 CFR Part 63. A preclosure period of 50 years should also provide sufficient time to complete the performance confirmation program required to support a Commission decision on repository closure, should such a decision be sought. The design selected would also permit future generations to keep the repository open for as long as 300 years with appropriate maintenance and monitoring, should they choose to do so.