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

June 7, 1996

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

Dear Chairman Jackson:

SUBJECT: TIME SPAN FOR COMPLIANCE OF THE PROPOSED HIGH-LEVEL WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

The purpose of this letter is to communicate the Advisory Committee on Nuclear Waste's (ACNW) observations and suggestions on the general principles for establishing the time span for compliance of nuclear waste facilities and our recommendations for specifying the regulatory time frame of compliance for the proposed geologic high-level waste (HLW) repository site at Yucca Mountain, Nevada. This letter follows up a letter from the ACNW dated February 9, 1996, on "Issues and [U.S. Nuclear Regulatory Commission] NRC Activities Associated with the National Research Council's Report, *Technical Bases for Yucca Mountain Standards*."

The time period for compliance of geologic HLW repositories is established at 10,000 years in the Environmental Protection Agency (EPA) standard 40 CFR Part 191 and the NRC regulation 10 CFR Part 60. Elements of the HLW standards and regulations were scrutinized by a National Research Council/National Academy of Sciences (NAS) Committee, which was prescribed by the Energy Policy Act of 1992. The findings of the NAS Committee are published in the *Technical Bases for Yucca Mountain Standards* (National Research Council, 1995). The NAS Committee concluded that there was no scientific justification or basis for specifying a truncation of the analyses at 10,000 years or at any other period of time. Instead, it recommended that the compliance evaluation be conducted to peak risk within the limits of the basic geologic stability of the Yucca Mountain region, which it suggested was on the order of a million years. In contrast to this recommendation, the ACNW has supported the 10,000-year time frame (e.g., letters to the Chairman of the NRC of June 27, 1991, and February 9, 1996). Nonetheless, in our most recent letter on this topic, the ACNW stated that further deliberations on the subject were appropriate. This letter reports on the results of our additional study. The ACNW will report to you in the near future on our recommendations on the time span for compliance of low-level nuclear waste facilities, building upon the

principles identified and discussed in this letter. In addition, the ACNW plans to review the reference biosphere and critical group issues.

Our recommendations are derived from a working group meeting on "Regulatory Time of Compliance for Radioactive Waste Disposal" held during the 82nd meeting of the ACNW on March 27, 1996, and subsequent deliberations by the Committee. Three main topics were discussed at the working group meeting: (1) background and regulatory context for the existing HLW standard that specifies 10,000 years as a time frame for regulatory compliance, (2) insights on time of compliance from performance assessments for both high- and low-level nuclear waste, and (3) scientific/technical issues and concerns. During the working group meeting, presentations were made by personnel from the EPA; the Division of Waste Management, Office of Nuclear Materials Safety and Safeguards, NRC; the U.S. Department of Energy; the National Research Council staff; the Electric Power Research Institute; the Oak Ridge National Laboratory; as well as by individuals from private industry and academia. The latter individuals provided both national and international viewpoints on the problem of compliance time in regulations.

Background of the Problem

A necessary element of a standard or regulation that ensures the health and safety of the public is the compliance period -- the time that the risk of adverse consequences is below a specified level. This compliance period requires the integrity of the facility over the stipulated time interval. In the case of an HLW repository, the assessment of risk involves evaluation of the repository source term, including inventory and waste form; the performance of waste containers and engineered barriers; and the geological, hydrological, and climatological attributes of the site. If the risk of health effects is to be determined, this assessment also involves the specification of the biosphere and the critical population group in proximity to the repository.

In the existing generic standard for geologic HLW repositories, 40 CFR Part 191, EPA established a 10,000-year time of compliance at a distance of no more than 5 km from the boundary of the repository -- a time value that also was used in the NRC regulation. This time period has no scientific or technical justification but was based on an arbitrary compromise between conflicting desirable characteristics. Long time periods have attendant large uncertainties in the behavior of the geosphere and the biosphere, while short time periods have lower uncertainties but do not adequately address the time spans of some of the critical processes that cause release of radionuclides to the biosphere. This compromise was perhaps a justifiable approach for comparative evaluation of the

multiple sites being considered when 40 CFR Part 191 was promulgated. Although not considered a compelling technical basis, this time period was roughly consistent with the period of glacial cycling and the potential profound impact of continental glaciation upon the geosphere and the biosphere. In providing a rationale for the 10,000-year time limit, the EPA stated, "This is not to say that times beyond 10,000 years are not important, but the Agency feels that a disposal system capable of meeting the proposed Containment Requirements for 10,000 years would continue to protect people and the environment well beyond 10,000 years." Although the standards of other nations differ in detail, the international community largely accepts the 10,000-year time frame, but also recognizes the need to evaluate site performance beyond the 10,000-year period, which constitutes a two-part approach.

In its appraisal of the technical bases for site-specific Yucca Mountain standards, the NAS Committee rejected the 10,000-year compliance period although it accepted that a transition to a glacial climate with its cooler, wetter seasons is probable during the next 10,000 years. Rather, the NAS Committee decided that long-lived radioisotopes derived from the repository might not reach the biosphere for more than 10,000 years, and thus it is important to evaluate the repository for a longer time interval. The NAS Committee chose to set this period of time at the predicted time of peak risk to the population as a result of leakage from the repository. It viewed this decision as requiring a period of time possibly extending into hundreds of thousands of years. In so doing, it did not accept the view espoused in the EPA and NRC standards and regulations that the uncertainties in predicting the repository performance at these periods are so large that the results are of questionable utility. The basis of the argument is that the subsurface environment at the repository horizon of Yucca Mountain is sufficiently stable that repository performance can be assessed with an acceptable uncertainty over a period of roughly one million years. The NAS Committee believes that inherent spatial uncertainties in interpolation of site characteristics, which are time independent, are a major contributor to assessment uncertainty.

The dilemma faced in developing the time span of compliance is that the period of time must be sufficiently long to include the evaluation of potential processes leading to the loss of the integrity of the repository and transport of radionuclides to the biosphere. Yet the time span should not be so long that the uncertainties in the process and events, and in the biosphere and critical population group, lead to meaningless results. In the case of a specific site, sufficient information should be available so that reasonable assumptions can be made in order that a defensible solution can be reached regarding the problem of a regulatory period of compliance. This approach is based on general

principles and knowledge of the engineering and scientific aspects of the repository and its site.

Considerations in Defining a Time of Regulatory Compliance

After reviewing the basis for establishing a time of regulatory compliance, the ACNW has concluded that a series of premises and assumptions are a necessary foundation for the decision making process. These include general policy decisions that are generic and a range of scientific and technical considerations that are largely specific to the site and problem:

- The HLW repository system -- waste, containers, engineered barriers, and site geology -- must be capable of preventing leakage of radionuclides to the biosphere for a minimum period of time measured in several thousands of years.

- Risk evaluation is based on characterization of the repository site and investigations of the waste and its container and engineered barriers using performance assessment (PA). However, in the development of the regulations, the marked limitations in using PA as a predictive tool needs to be recognized. PA is primarily an investigative tool that can be used to distinguish between positive and negative attributes of the elements of the repository and, in the best of conditions, the relative range of risk under various assumed scenarios.

- The standard for a nuclear waste repository should be based on limiting risk to a critical group without the constraint of a prescribed time period of compliance. A time period should be defined in the regulations that implement the standard and should be prepared in concert with the characteristics of the waste, engineered barriers, and the nature and vagaries of the geosphere and the biosphere of a specific facility and site.

- The reference biosphere and the critical group that are used in assessing compliance should be defined in the regulations. These definitions are necessarily based on site characteristics and on the impact of climate and predicted climate modifications. They are related to predictions of the nature of society through time. Because of the great uncertainties in the latter, the ACNW recommends that the current societal state be used as the base scenario in predictions of the future states of society.

- Uncertainties in assessing future risks associated with the geologic/geographic setting and the repository design and related engineered features will increase with time. Factors that influence this increasing uncertainty include the

following: geologic conditions and events that may disrupt the repository; climatic changes that could drastically increase the flux of water through the disposal system or change the regional hydrologic flow regime; degradation of the waste containers or repository materials; and synergistic effects of changing site conditions on the degradation of repository features. Design features can be implemented to preclude extreme variations in releases (e.g., waste forms, containers, and near-field barriers may be engineered to minimize transport out of the immediate repository facility and thus minimize uncertainties in transport for several thousand years).

Regulatory Principles for Establishing the Time Span for Compliance

On the basis of the preceding considerations, the ACNW recommends that a two-part approach to definition of the compliance period be established for nuclear waste facilities. The first part involves the following three elements:

(1) The time period for compliance should be based on the estimated time for release and transport of the radionuclide contaminants to reach the critical group. This time estimate should be based on geologic, geochemical, and hydrologic characterization of the site and its environs, as well as regional study of geologic processes and their potential effects on the site, and total systems performance assessment. This estimate must confirm the ability of the repository system to retain radionuclides for a minimum of several thousand years. The selection of the time of compliance must be evaluated along with the specification of the reference biosphere and critical group.

(2) The reference biosphere and the lifestyles of the critical group should be defined on the premise that no major changes will occur in society that will significantly affect their lifestyles as they relate to risk from the repository and that the climate can be reasonably bounded. The minimum distance from the boundary of the repository to the critical group will be a major decision.

(3) The compliance time should be sufficiently short such that extrapolations of significant processes and their rates can be made robustly with reasonably modest uncertainties.

The second part of the compliance period regulations should be based on assessments extending from the specific compliance period to the calculated time of the peak risk to the critical group. There is no definitive measure of compliance in the sense of a numeric match between a standard and the calculated peak risk, and

this second part should not be allowed to become a de facto regulation. A comparison between the standard used in the first part and the calculated peak risk should lead to identification of important performance factors that define risk to the critical group. Depending upon the extent to which the peak risk exceeds the standard, ameliorating actions to reduce this difference should be initiated, such as increasing the integrity of the engineered barriers, improving site characterization to more closely bound uncertainties, or, in the extreme, abandoning the candidate site.

Scientific and Technical Insights Into the Time Span for Compliance of the Proposed Yucca Mountain Repository

Critical steps in the regulatory principles for establishing time of compliance as specified above in element (1) are the characterization of the proposed repository site and the relevant processes acting upon it and assessing the total system. Although site characterization is still in progress at Yucca Mountain, extensive data have been acquired and information has been derived from these data. The following scientific and technical insights that have been gained at the site over the past decade bear upon the definition of the compliance time in the forthcoming regulations designed specifically for Yucca Mountain.

- The current climate in the Yucca Mountain region is arid, with annual precipitation of roughly 15 cm. In the future, the climate will change, depending upon the relative importance of advancing cooler (glaciation) conditions and possible greenhouse effects that may counteract the cooling effect. Although the timing and precise amplitude of the climate change cannot be predicted, the range of conditions can be bounded in terms of timing and effect. Paleoclimatological studies in the region of Yucca Mountain suggest that during the last glacial period (14 to 20 thousand years ago) the precipitation may have been four times the present and the average annual temperature 10 °C cooler (Forester and Smith, 1995). Climatic conditions are anticipated to change, but the region is likely to be at least semiarid and will lie south of the glaciated area. Thus, it is unlikely that climate change will have a marked effect on the reference biosphere or the lifestyle of the critical group. Infiltration is likely to significantly increase as a result of the increased precipitation and cooler temperatures, but the total flux through the repository will still be limited. The maximum climatic change is not predictable with our present science, but all evidence from extrapolations indicates that the principal effect will occur prior to ca. 20,000 years.

- Results of recent site characterization activities at Yucca Mountain indicate that matrix, fracture, and fault infiltra-

tion are present in the unsaturated zone. Matrix flow results in long travel times, but fracture and fault flow that may lead to relatively rapid travel times also occurs. Ground water travel times within the saturated zone between Yucca Mountain and the location of the critical group, which is likely to reside in the Amargosa Valley several tens of kilometers south of the proposed repository, are poorly documented at this time. However, the low hydraulic gradient indicates that travel times are likely to be long. Further, the sorptive capacities of formations through which the water will traverse are not presently known and the degree of dilution of contaminants within the saturated zone has not been ascertained. In view of the likely long travel time of water in the saturated zone from the proposed Yucca Mountain repository to the critical group, the movement of contaminants may well take in excess of 10,000 years to reach the accessible environment, despite the potential for relatively short travel time through the fractures and faults of the unsaturated zone.

- The relative uncertainties in predicting the time dependent and spatial variations in the Yucca Mountain geosphere and related geologic processes have come to the forefront as a result of the NAS Committee's report and their statements on the confidence that can be placed on performance assessment at distant future times. The NAS Committee concluded that although ". . . the level of confidence for some predictions might decrease with time . . . [m]any of the uncertainties in parameters describing the geologic system are due not to temporal extrapolation, but rather to difficulties in spatial interpolation of site characteristics." The ACNW acknowledges that the spatial variations in the Yucca Mountain geosphere contribute to uncertainty. Nonetheless, we believe that with the completion of an adequate characterization of the site and with consideration of the integration over the heterogeneities for the operational scale of the pertinent processes, the time-dependent uncertainties in events and processes, such as climate change, will be more prominent than those derived from spatial variations. Yucca Mountain lies within a region of potentially high gradient tectonic and climatic processes. As a result, the ACNW anticipates that uncertainties will increase with time, although we agree with the National Research Council/NAS report that it should be possible to bound these uncertainties over a time span on the order of one million years.

Recommendations for a Yucca Mountain Repository Compliance Period

On the basis of the previous discussion of both generic principles and Yucca Mountain specific insights, the ACNW recommends the

following two-part approach to establishing the time period for compliance for the proposed HLW repository site at Yucca Mountain, Nevada:

The first part involves the following:

(A) The time period of compliance should not be specified in the risk-based standard for Yucca Mountain being prepared by the EPA. Rather, it should be defined in the regulations being developed by the NRC to implement the EPA standard and should use existing knowledge of the engineering and scientific aspects of this proposed repository and its environment.

(B) The time period should be defined in concert with specifying the reference biosphere and the critical group. The definition of the biosphere and the critical group should take advantage of known site characteristics and any other long-term effects that can be technically supported.

(C) The time span for the compliance period should be no shorter than an estimate of the anticipated time it takes for potential radionuclide contaminants to reach the nearest critical group and no longer than a time period over which scientific extrapolations can be convincingly made. Because of the need to come to closure on this subject, the ACNW suggests that the NMSS staff review the scientific and technical components needed to make these decisions, identify critical missing elements, and provide the necessary information in a timely manner. On the basis of currently available information, the ACNW anticipates that the appropriate compliance period will be somewhat greater than the present standard of 10,000 years. The increased distance from the proposed site to the nearest probable location of the critical group, the nature of the site and the likely characteristics of the waste, the containers, the engineered barriers, and the design of the repository, together with consideration of the stability of the site, suggest a time frame on the order of a few tens of thousands of years, but specifying a precise value must await more comprehensive assessments.

The second part of the compliance regulation should require assessment extending from the specified compliance period to the time of the calculated peak risk to the critical group. The regulation for compliance during this intervening period should be significantly less stringent than is used in the previous period, considering the increasing scientific, technical, and critical group uncertainties. Depending upon the extent to which the peak risk exceeds the standard for the first part, steps should be considered to ameliorate the potential risk. This second part of

the compliance regulations should not be allowed to become the de facto regulation.

Summary

The regulatory time period for compliance is an important element in regulations for nuclear waste facilities and remains a problem in developing site-specific requirements for protecting the health and safety of the Nation, as well as its environment. The ACNW suggests a solution to this problem from a generic standpoint, which employs two parts. Using scientific and technical insights into the environment of the repository proposed for Yucca Mountain, we recommend an approach that establishes the time of compliance of the facility at this site, which differs from the current regulation and the proposal on this topic made by the National Research Council/NAS Committee in its report, *Technical Bases for Yucca Mountain Standards*. We believe that our recommendations will lead to a simple, robust, and defensible regulation that can be readily implemented.

Sincerely,

Paul W. Pomeroy
Chairman

References:

1. Report dated February 9, 1996, from Paul W. Pomeroy, Chairman, ACNW, to Shirley Ann Jackson, Chairman, NRC, Subject: Issues and NRC Activities Associated with the National Research Council's Report, "Technical Bases for Yucca Mountain Standards"

2. Report dated June 27, 1991, from Dade W. Moeller, Chairman, ACNW, to Kenneth M. Carr, Chairman, NRC, Subject: "Response to questions Accompanying Working Draft #3 of the EPA Standards"

3. R. M. Forester and A. J. Smith, "Late Glacial Climate Estimates for Southern Nevada: The Ostracode Fossil Record," in High-Level Radioactive Waste Management, Vol. 4, pp. 2553-2561, 1994