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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 15, 1993

MEMORANDUM FOR: The Chairman
Commissioner Rogers
Commissioner Remick
Commissioner de Planque

FROM: James M. Taylor
Executive Director
for Operations

SUBJECT: SECOND MEETING OF THE NATIONAL ACADEMY OF SCIENCES' COMMITTEE ON TECHNICAL BASES FOR YUCCA MOUNTAIN STANDARDS, AUGUST 26-27, 1993, LAS VEGAS, NEVADA

On August 26-27, 1993, the National Academy of Sciences (NAS) Committee on Technical Bases for Yucca Mountain Standard held its second meeting in Las Vegas, Nevada. The NRC was represented at this meeting by the NRC liaison to the Committee, other staff of the Division of High-Level Waste Management, and a member of Commissioner Remick's staff. The full 15 member Committee was in attendance. The meeting was held in Las Vegas to facilitate public involvement.

This meeting served as the first of three that will review the state of scientific understanding of various aspects of the questions before the Committee. The August meeting was devoted to a review of the scientific and technical support for health-based standards. The meeting was organized in a speaker/discussant format with extended presentations and shorter responses on each topic. Expert presenters from national laboratories and universities spoke on topics including: characterization of radionuclide releases of importance in the accessible environment over time, biospheric transport from release to dose, environmental transport of gaseous releases of radionuclides, dose-response relationships, technology vs. health-based standards, and alternative forms of health-based standards. The meeting agenda and a summary of the presentations and the questions raised by the Committee are provided as enclosures. The Committee expressed interest in a number of issues including the validity of applying the linear, no-threshold hypothesis to very low doses, assumptions underlying dose modeling generally, the potential benefit of longer waste package lifetimes, specification of an acceptable reference biosphere, and the appropriateness of dose truncation in collective dose calculations.

Two additional meetings organized in a similar fashion are scheduled for November 9-10, 1993, in Las Vegas and December 16-17, 1993, in Washington, D.C. The November meeting will focus on performance of a repository considering disruption by human intrusion or natural events. In addition, the effectiveness of active and passive institutional controls will be considered. The December meeting will focus on the performance of an undisturbed repository and models for assessing that performance. Robert Bernero, Director of Nuclear Material Safety and Safeguards, has been invited to make a presentation to the Committee at the December meeting. Additional meetings

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have been scheduled for February and April 1994 in Las Vegas as well as a closed writing session in June. The Committee expects to issue its formal, peer-reviewed recommendations by December 1994. The NRC staff will continue to provide, as requested by the Committee, information consistent with the Commission's previous positions on these issues and will raise to the Commission's attention any new matters of policy.

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Enclosures:
1. Preliminary Meeting Agenda
2. Presentation Summary

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NATIONAL RESEARCH COUNCIL
COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES
2101 Constitution Avenue Washington, D.C. 20418

BOARD ON
RADIOACTIVE WASTE MANAGEMENT
(202) 334-3066 Fax: 334-3077

Office Location:
Milton Harris Building
Room 456
2001 Wisconsin Avenue, N.W. 20007

PRELIMINARY AGENDA

COMMITTEE ON TECHNICAL BASES FOR YUCCA MOUNTAIN STANDARDS

Alexis Park Hotel
375 East Harmon Avenue
Las Vegas, NV

SECOND MEETING
August 26-27, 1993

All sessions are open to the public except as noted.

Thursday, August 26
Marketplace Room

8:30 am Introductions and Opening Remarks
Bob Fri, Committee Chairman

- Purpose of meeting
- Approval of agenda
- Format for discussions

8:45 am Characterization of radionuclide releases of importance in the accessible environment over time ..... *TAB H*

speaker: Ralston Barnard (Sandia National Laboratory)

speaker: Paul Eslinger (Battelle Pacific Northwest Laboratory)

discussant: Robin McGuire (Risk Engineering, Inc)

11:15 am Biospheric transport from release to dose ..... *TAB I*

speaker: Bruce Napier (Battelle Pacific Northwest Laboratory)

discussant: Don Shettel (Geosciences Management Institute, Inc)

12:30 pm Lunch

1:30 pm Environmental transport of gaseous releases of radionuclides ..... *TAB J*

speaker: Richard Van Konynenburg (Lawrence Livermore National Laboratory)

discussant: Ben Ross (Disposal Safety, Inc)

Committee on Technical Bases for Yucca Mountain Standards

Second Meeting

Thursday, August 26 (continued)

3:00 pm Dose-response relationships ..... *TAB K*

speaker: Niel Wald (Univ. of Pittsburgh)

4:00 pm Break

EXECUTIVE SESSION

4:15 pm Complete bias discussion

Friday, August 27 **OPEN SESSION**
Marketplace Room

8:30 am Technology-based standard v. health-based standard ..... *TAB L*

speaker: Dade Moeller (Harvard University, Professor Emeritus)

discussant: Dave Kocher (Oak Ridge National Laboratory)

EPA's generic standard

10:30 am Alternative forms of health-based standards ..... *TAB M*

speaker: Dade Moeller

discussant: Tom Cotton (J.K. Research Assoc.)

discussant: Bob Wilems (Del Mar Consultants)

discussant: Dave Kocher

12:30 pm Additional comments from the public ..... *TAB N*

1:00 pm Committee discussion of future plans

- tasks and assignments
- schedule ..... *TAB C*
- agenda for meetings on November 9-10 and December 16-17

1:30 pm Adjourn

SECOND MEETING OF THE COMMITTEE ON TECHNICAL BASES FOR
YUCCA MOUNTAIN STANDARDS
August 26 & 27, 1993

PRESENTATION SUMMARY

SESSION 1. CHARACTERIZATION OF RADIONUCLIDE RELEASES TO THE ACCESSIBLE ENVIRONMENT OVER TIME

This first tutorial session was a general overview identifying those nuclides expected to be released from a repository and, of those, which are most likely to contribute to offsite dose estimates.

Richard Barnard (Sandia National Laboratory) characterized repository releases using examples from the DOE Total System Performance Assessment (TSPA). Fractional releases by nuclide were presented for individual scenarios over the first 10,000 years after closure and from the results of DOE's first iteration or TSPA-1991. Mention was made of the limitations of the scenarios and processes modeled in TSPA-1991 and the extent to which improvements are being incorporated in the next iteration (TSPA-2) now in progress. [Note that the NRC staff has prepared detailed comments on the TSPA-1991 which, once forwarded to DOE, will also be made available to the NAS Committee.]

These limitations notwithstanding, the speaker discussed how the nuclides of greatest significance vary depending on the key modeling assumptions and scenarios selected. For example, for gradual aqueous releases over the repository's undisturbed lifetime, the dominant nuclides of concern are Tc-99 and I-129, their release being largely a function of the low retardation of the surrounding media for these nuclides. Human intrusion scenarios, however, usually result in a more straightforward mechanical transport of repository contents to the accessible environment and, not surprisingly, the nuclides of interest (plutonium, americium and cesium) are more characteristic of the average repository inventory over 10,000 years.

Assumptions with regard to the mechanism of geohydrologic flow are critical to the timing of releases. When it is assumed that flow through fractures is fully coupled to groundwater flow in the surrounding rock matrix (what DOE calls "composite porosity model"), no aqueous releases were seen before 10,000 years. If flow is modeled as progressing directly (and more rapidly) along fractures (DOE's "weeps" model) releases are predicted to occur as early as 1,000 years.

The Committee was quite concerned with the presentation of the data showing the relative importance of specific nuclides under various scenarios because neither the relative probabilities of the respective scenarios or the relative magnitudes of any of the releases were indicated. The speaker committed to provide the Committee with additional material to depict these considerations.

Paul Eslinger (Battelle Pacific Northwest Laboratory) focused on those radionuclides released from a repository which contribute most to doses received. Differences in the modeling required for individual dose and population dose calculations were discussed using PNL Performance Assessment results as illustrations. Evaluating compliance with a standard that limits

maximum individual dose requires modeling that predicts peak releases and peak exposures, whenever they may occur. When evaluating compliance with a standard limiting population dose, however, either to the world population or some smaller, target population, it may be more appropriate to limit or define the appropriate time horizon. According to Eslinger, the important contributors to population doses from gaseous release at an unsaturated site are carbon-14 and radon. There were no important radionuclides for the gaseous releases from a saturated site (individual or population) or for individual doses at an unsaturated site. Because nuclide release and transport are so strongly influenced by the relative solubility of individual nuclides and the relative sorption affinity of the surrounding matrix for those specific nuclides, the most important contributors to offsite dose are generally not the dominant contributors to repository inventory.

The discussant, Robin McGuire (Risk Engineering, Inc.), made the point that probability models are the most useful way to assess repository performance because it is possible to estimate distributions of release based on probabilities of states of nature and future conditions. Performance assessment is not, he argued, a predictive tool, but should be viewed as a decision tool. He provided an example of a model to convert releases to doses. From this example he provided suggested recommendations including the use of a reference population (such as the average individual in a critical group).

The Committee expressed keen interest in the assumptions underlying the modeling of all presenters. Specifically, they were interested in whether the assumptions were driven by the current regulatory basis or were developed from technical and scientific bases. It was noted that when TSPA-1991 was initiated, the 1985 EPA standard and NRC's Part 60 subsystem performance criteria were "the only game in town." Committee members repeatedly emphasized the importance of making explicit assumptions and describing the sensitivity of the analyses to those assumptions. Serious interest was expressed in demonstrations of the potential benefit of long-lived waste packages relative to the modeled period as well as in the critical time period for releases. The importance of peer review of the assumptions supporting the various modeling efforts was also discussed.

SESSION 2. BIOSPHERIC TRANSPORT FROM RELEASE TO DOSE

Bruce Napier (Battelle Pacific Northwest Laboratory) provided the tutorial on the biospheric transport of radionuclides from release to dose considering a range of exposure scenarios. The tutorial began with an overview of radionuclide transport mechanisms and intake-to-dose conversions. Individual doses are usually used for "snapshot in time" calculations encompassing a short time period. Collective doses are performed over longer time periods, but are performed using simplifying assumptions.

He observed that it is awkward to combine limits on specific pathways, such as drinking water, with an overall limit on all pathways, and that control of a single pathway frequently renders more conservative dose limits. A comparison of the generic EPA models used as the basis of the 1985 standard to those used in the DITTY dose code[1] indicated that the models provided similar results when asked the same questions. The conclusion was offered that the models which formed the basis of EPA's 1985 standards are not inherently bad, but have been inappropriately applied such that the release limits for Yucca Mountain are somewhat arbitrary.

Dose modeling using the DITTY dose code produced results with uncertainties that span well over an order of magnitude. Individual dose calculations generally have large levels of variability and are more sensitive to parameter extremes. Population or cumulative doses, however, tend to dampen the effects of parameter extremes. For arid locations, the individual dose criterion is frequently limiting because the small amount of groundwater greatly restricts the potential for dilution. It was suggested that all dose calculations should be stochastic to allow for future uncertainties in parameters.

Napier had several suggestions for the Committee on how to proceed using dose limits. In particular, he repeatedly emphasized the importance of using highly stylized calculations for dose estimation with parameters and assumptions about the reference biosphere explicitly defined within the regulations. The speaker reminded the Committee that without such specification, any dose limit could be exceeded by combinations of sufficiently conservative assumptions.

The Committee questioned the assumptions and the impact of the 10,000 year time period, inquired as to how a meaningful reference population might be defined, and also questioned how reasonable stylized calculations might be developed. Concern over public acceptance of such stylized calculations was expressed by Jean Barr. Charles McCombie mentioned that the use of reference conditions, based upon today's environment, has met some measure of success in European programs when presenting the potential impacts of a repository to the European public.

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[1]The DITTY (Dose Integrated for Ten Thousand Years) dose code was originally developed for the Hanford site by the Battelle Pacific Northwest Laboratories. The code accounts for both air and liquid pathways and calculates both individual and collective doses.

The discussant, Don Shettel (Geosciences Management Institute, Inc., representing Nye County, Nevada), expressed concern that the predictions in performance assessment were attempting to cover 10^4 - 10^6 years, while relying on limited data that spans only several years. It was asserted that performance assessment models currently ignore vitrified waste forms[2]. Shettel also cautioned that predictive models need to account for the evolution of the site over time (e.g., changes in porosity and permeability). In conclusion, the speaker opined that the uncertainties in release modeling are significant enough that adding the further complexities of dose calculations may not be warranted.

SESSION 3. ENVIRONMENTAL TRANSPORT OF GASEOUS RELEASES OF RADIONUCLIDES

Richard Van Konynenburg (Lawrence Livermore National Laboratory) presented a tutorial that addressed gaseous releases predicted for a Yucca Mountain repository. Initial screening criteria limit potential gaseous releases to ^{14}C (certain release) and ^{129}I (unlikely release). The natural concentrations and historical anthropogenic releases of ^{14}C were presented and compared to potential levels of release from a repository located at Yucca Mountain. Transport and exposure mechanisms were discussed and doses projected for a global population, a regional population, and a maximally exposed individual. Conclusions included: (1) that ^{14}C appears to be the only nuclide of concern for gaseous release from a potential repository at Yucca Mountain, (2) that ingestion is normally the only significant mode of exposure, (3) that average global exposure depends upon the release rate, and (4) that regulation of Carbon-14 is not uniform for reactor effluents and waste disposal.

Ben Ross (Disposal Safety, Inc.), as the discussant, argued that it is an easier engineering problem to prevent gaseous releases as a single pulse than it is to restrict releases consistent with the release rate criterion contained in 10 CFR Part 60. He also made the point that all risks are not valued equally raising the question of the significance of extremely low doses to large numbers of people.

The Committee expressed interest in the inventory of ^{14}C in the spent fuel, the release rates of ^{14}C from reactors, and the impact of certain modeling assumptions. Chris Whipple questioned whether having only an individual dose would provide adequate protection from the 33 million person-rem which could potentially result from release of the entire repository inventory.

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[2]Jeremy Boak of DOE's Yucca Mountain Project Office later refuted this assertion during the public comment session.

SESSION 4. DOSE-RESPONSE RELATIONSHIPS

Dr. Niel Wald (University of Pittsburgh) provided a comprehensive review of the medical evidence regarding dose-response relationships, with emphasis on the findings of the BEIR IV and BEIR V reports. He discussed the various end points of primary concern (cell killing, mutagenesis, carcinogenesis, and teratogenesis) as well as the differences between the nature and time of appearance of deterministic and stochastic radiological effects. The speaker noted that the current threshold for biologically-detectable, deterministic effects (i.e., chromosomal transformations) is about 5 rad. The currently accepted hypothesis holds that no threshold exists for stochastic effects.

The existing data base that supports the generally-accepted models and hypotheses concerning dose-response relationships was reviewed. The current views regarding hormesis were discussed. In particular, some investigators have hypothesized that very low doses of radiation may, in fact, contribute to the stimulation of adaptive or repair mechanisms. Wald was questioned about the true impact of minuscule individual doses which, when summed, yield large collective dose estimates attributable to potential ^{14}C releases from a repository over 10,000 years. Wald indicated that, in his opinion, the actual occurrence of the large numbers of cancers predicted by a strict application of the linear hypothesis was unlikely. The effects of the approximately 30 million person rem would not be detectible given the vastly larger numbers of cancers associated with background radiation. The Committee sought an opinion on what dose cut-off should be used in calculating collective dose. Wald declined to offer an opinion on any specific number, but indicated that no differences have been measured in cancer rates for populations living in areas with substantially elevated levels of background radiation.

SESSION 5. TECHNOLOGY-BASED VS. HEALTH-BASED STANDARDS

Dade Moeller (Harvard University, Professor Emeritus) spoke to the Committee about technology-based standards and health-based standards. These standards might be "basic" or "derived." "Basic" limits would be those expressed in dose or risk levels, while "derived" standards could be expressed in terms of concentrations or intake limits. He cautioned that derived standards should be no more stringent than the basic standard. The advantages of each class of standard and their implementation were discussed. The concept of collective dose assumes a strict extrapolation of the linear, no-threshold hypothesis and it applies only to stochastic processes. Limiting collective doses can provide a measure of societal impact. Dr. Moeller discussed the important components of a critical population group. He also compared dose and risk limits and expressed his view of the benefits of risk limits. Although he recognized the importance of defense in depth, Moeller also expressed concern with regard to excessive apportionment of generally-applicable, environmental standards (e.g., regulatory limits on specific pathways such as drinking water). The speaker noted that EPA standards are characterized as being technology-based, despite the fact that EPA could not assess adequately what technology could and could not achieve in a repository environment over the long periods of concern. Moeller concluded by expressing his view that a much stronger health-basis would be appropriate and that the excessive

apportionment in the current standards should be eschewed. He also recommended that human intrusion be addressed separately.

David Kocher (Oak Ridge National Laboratory) was the discussant on this issue. He argued that there is no clear distinction between the two types of standards in practice and that, while technology-based standards might be those standards that are primarily based on achievable results, they are not devoid of judgements on acceptable levels of health effects. It was indicated that most radiation protection standards are technology based. It was noted, however, that NRC's 10 CFR Part 20 and EPA's NESHAP[3] standards are health based. The speaker also highlighted the merit of a technology-based approach to standard setting as it's use is a clear application of ALARA. In summary, Kocher sought to convince the Committee that there is nothing inherently wrong with technology-based standards if they are "reasonably achievable" and if they "give acceptable health risks to the public."

A vigorous discussion ensued over those regulatory decisions that were clearly not founded on a health basis when EPA developed the original 1985 standards. In this regard, mention was made of the EPA Science Advisory Board's urging of EPA to increase the release limits (from the average lifetime risk of 10^{-7} for the U.S. population) to correspond more closely to reasonable limits on acceptable risk and of the fact that the definition of "accessible environment" does not directly relate to the biosphere.

Sol Burstein inquired about the meaning of "reasonable assurance" and whether the level of detail required could be specified in advance. Questions about the size of the critical group, the impact of accepting a negligible individual risk level (NIRL), and the utility of an unsaturated site were also raised. Moeller opined that appropriate critical groups would be of the order of 1-2 dozen individuals and would be determined on a site specific basis as part of a stylized calculation. Moeller also indicated that the NCRP addresses the 1 mrem as a NIRL by associating that level of risk to that which the public considers negligible and takes no steps to avoid. Charles McCombie stressed that a health-based standard is much easier to understand and that there are no grounds for accepting a technology-based standard if it cannot be demonstrated to be sufficient to satisfy specific health objectives. Thomas Pigford asked how it was decided that 1000 deaths in 10,000 years represents an acceptable level of safety. Kocher indicated that the 1000 health effects value was derived from evaluating the expected performance of a range of hypothetical repositories. In response to questions, Richard Van Konynenburg indicated that, historically, ^{14}C was not controlled as a release from commercial reprocessing based on a cost/benefit determination.

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[3]William Gunter of EPA joined the discussion from the audience to explain that EPA initially set out to establish its NESHAPs on a technology basis but was later required by the court (in the vinyl chloride decision) to establish the standards on the basis of acceptable risk and was proscribed from considering cost, achievability, or technology in this judgement. Only if EPA wished to consider additional steps beyond those necessary to achieve the acceptable risk objectives, to ensure an ample margin of safety, could it take costs and technology into account.

SESSION 6. ALTERNATIVE FORMS OF HEALTH-BASED STANDARDS

Dade Moeller also spoke to the Committee on alternative forms that health-based standards could assume. He indicated that standards that incorporate ALARA and best available technology (BAT) are frequently more stringent and could be used to drive technology or to effect additional controls. A distinction was drawn between dose limits which can be applied to design or operation and secondary standards, such as release limits or collective dose, which are useful primarily for design. Moeller indicated that it is preferable to set limits only upon the total system performance and those subsystem performance measures which amount to apportionment and prescriptiveness should be avoided. Also discussed were standards that have spatial or temporal graduations or cut-offs, standards based on a comparison to other levels of health effects, and compensatory standards where health effects could be traded for health effects prevented in other areas.

Tom Cotton (J.K. Research Associates) indicated that the Nuclear Waste Policy Act and the nation's commitment to deep geologic disposal (which, by definition, will concentrate the waste rather than disperse it) amount to an implicit acceptance of some potentially large individual doses in the vicinity of a geologic repository and that the standards should reflect this judgement. This would require a definition of a "reasonable" treatment of potential water use. This water use scenario could be either deterministic, considering a single critical group, or could be probabilistic. The scenario(s) would be defined through regulatory rulemaking or through the DOE license application. He indicated that in developing the 1985 standards EPA had considered, and rejected, sole reliance on an individual dose.

Bob Wilems (Del Mar Consultants) indicated that regulations to protect the public health and safety should reflect the same criteria used in site selection (i.e., isolation, containment, and dilution). He then outlined a framework for a health-based standard that uses a distribution of risk or dose to average individuals. The modeling to support such a standard would produce an estimate of an average individual risk to a member of a critical group. Wilems' proposal relies on the ability to use a probabilistic approach to modeling the biosphere similar to that used currently to model the long-term performance of the geosphere. He indicated that multiple time periods might be used, each with different performance measures. According to Wilems, a set of parameters for the biosphere, and their distributions, would have to be defined on a site-specific basis. The biosphere assumptions should be established by rulemaking and would rely heavily on the use of expert judgement. The Committee questioned the feasibility of developing such a probabilistic biosphere model and whether such an approach would result in additional protection.

David Kocher indicated that the enthusiasm for individual dose limits arises from familiarity and experience with operating facilities. As a reasonable alternative for a geologic repository, he repeated his earlier support for prescriptive, deterministic criteria, along the lines of those present in NRC's 10 CFR 60.122 siting criteria, that consider the geologic structure, mineralogy of the host rock, etc.

PUBLIC COMMENTS

At the conclusion of the scheduled presentations, the Committee provided the opportunity for members of the public and representatives of other groups to speak and present their views. David Okrent (UCLA) drew attention to those areas that the Committee is specifically not addressing. He argued that the decisions that the Committee will make are not only technical decisions, but are also political decisions; that the philosophy of waste disposal standards needs to be discussed and examined; that a comparison of long-lived chemical waste and radioactive waste must be made; and that intergenerational equity must be considered.

Harry Mortenson (Cygnus Scientific) provided a rebuttal of Richard Van Konynenburg's presentation on ^{14}C. He questioned the underlying assumptions of Van Konynenburg's model and pointed to deficiencies within the computer modeling. It was also argued that the ^{14}C effects calculated for the EPA Science Advisory Board underestimated the associated health effects.

Ed Fuller (American Nuclear Society (ANS)) presented responses to specific questions raised at the first meeting about the initial ANS statement. Positions clarified by the ANS include those on the linear theory, partitioning of safety goals, post-closure oversight, individual dose standards, and the prediction of human intrusion.

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