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The Honorable J. Bennett Johnston
Chairman, Committee on Energy
and Natural Resources
United States Senate

The Honorable James A. McClure
Ranking Minority Member
Committee on Energy and Natural Resources
United States Senate

On March 26, 1984, you requested that we provide quarterly status reports on the implementation of the Nuclear Waste Policy Act of 1982 (NWPA). The act required the Office of Civilian Radioactive Waste Management within the Department of Energy (DOE) to implement a federal program for the safe and permanent disposal of high-level nuclear waste in one or more geologic repositories. It also assigned responsibility for licensing and regulating repositories to the Nuclear Regulatory Commission (NRC) and development of environmental standards for disposal of these wastes to the Environmental Protection Agency (EPA). An NRC decision to license a repository must be based on a determination that the proposed repository complies with both EPA's standards and NRC's regulations.

In November 1989 NRC staff questioned whether it is possible to satisfactorily implement, in a repository licensing proceeding, an EPA standard on long-term containment of radioactive wastes. This report addresses that issue and its implications for DOE's program to determine if a candidate site at Yucca Mountain, Nevada, is suitable for a nuclear waste repository.

Results in Brief

NRC and others are concerned that EPA's repository containment standard may be written in such a way that it may be difficult, if not impossible, for DOE to satisfactorily demonstrate compliance with the standard in an NRC licensing proceeding. The standard establishes limits on the cumulative releases of radioactive materials to the environment over a 10,000-year period and requires that DOE demonstrate that the probability of exceeding these limits is acceptably small. The specific concern is that limitations and uncertainties in the methods and data for making the necessary numerical calculations—such as predicting the occurrence of uncertain events like earthquakes over the long period of

time—could lead to lengthy licensing delays unless EPA and/or NRC pr vide sufficient guidance on acceptable methods for addressing these li itations and uncertainties.

NRC's staff has taken initial steps in what it expects to be a collaborati process with EPA to develop additional guidance on how DOE is to dem strate whether or not the Yucca Mountain site complies with the containment standard. Of particular concern to the staff is that emphasis maintained on the quality of the scientific work that supports the numerical results of DOE's compliance analyses. Furthermore, both NR and EPA expect that DOE's experience over the next several years in de onstrating that its new repository for certain defense wastes—DOE's Waste Isolation Pilot Plant (WIPP)—complies with EPA's standards sho provide valuable insights into the problems that can be expected in de onstrating compliance with the containment standard for an NRC-licensed repository.

Background

NWPA, as amended, requires DOE to characterize (investigate) the Yucc Mountain site and, if it is found suitable, to apply to NRC for a reposit license. DOE must satisfactorily demonstrate to NRC that the combinati of the site and the repository design complies with EPA's standards an NRC's regulations. DOE would demonstrate compliance by collecting an analyzing data; developing, validating, and using predictive models; a assessing the potential repository's expected performance. Until DOE applies for a license, NRC's role in the program is limited to providing regulatory guidance and oversight of DOE's program.

EPA's containment standard relies on the novel approach of using num ical probabilities to establish requirements for containing radioactivit within the repository. Specifically, cumulative releases of radioactivit from a repository to the environment for 10,000 years must have a lil lihood of less than 1 chance in 10 of exceeding limits established in th standard and a likelihood of less than 1 chance in 1,000 of exceeding times the limits. EPA does not require absolute proof that the standard can be met; rather, it established a test of "reasonable expectation" o compliance based on "practically obtainable" information and analysi EPA added this qualifying language to its standard in 1985 after NRC h objected to the unqualified standard proposed by EPA in 1982.

NWPA required NRC to establish licensing regulations that are not incon sistent with EPA's standards. NRC issued its regulations in 1981 and 19

Although NRC has had substantial experience in licensing nuclear reactors and related facilities, licensing a geologic repository for nuclear waste will be a new experience. Moreover, NRC has had only limited regulatory experience with standards that are based on numerical probabilities. For example, NRC's nuclear power regulations are generally qualitative in that determining compliance with the regulations ultimately rests on engineering judgments.

EPA's Containment Standard Could Affect Waste Program Success

Of special concern to NRC's staff is whether EPA's probabilistically-based containment standard can be implemented without paralyzing a repository licensing proceeding with litigation over numerous details of DOE's analysis supporting compliance with the standard. Specifically, the staff believes that the standard can be implemented successfully in a licensing proceeding only if the inherent uncertainties involved in making long-term projections of repository performance can be satisfactorily taken into account.

The contrasting approaches taken by EPA and NRC in developing the containment standard and nuclear power plant safety goals, respectively, illustrate the NRC staff's concern. In 1986, NRC established two safety goals that broadly define acceptable levels of risk from operation of nuclear power plants. The goals are stated in qualitative terms; specifically, there should be no "significant" additional risk to either individuals or to society from normal nuclear plant operations and accidents. To help implement the goals, NRC established two safety objectives in which risks are to be calculated numerically and expressed as a percentage of other, non-nuclear, risks to individuals and society.[1] Because of the sizeable uncertainties in the analytical methods and gaps in the data used to calculate risks, however, NRC decided that (1) the safety objectives must be subordinate to the qualitative safety goals and (2) analyses of compliance with the safety goals may not be used as the sole basis for licensing decisions.

EPA took the opposite approach in developing its containment standard in that it established, as the centerpiece of the standard, specific probabilities that cumulative releases of radioactive materials will not exceed established limits. EPA then qualified this numerical standard to recognize the inherent uncertainty and limitations in the required analysis with its test of reasonable expectation.

[1]NRC defines risk as a mathematical expression of the probability that an event will occur multiplied by the estimated consequences (effects) of that event.

NRC's staff believes that additional clarification and guidance from the NRC Commissioners and EPA are needed to decide how qualitative techi cal judgments are to be used by DOE in demonstrating compliance with EPA's containment standard. The staff plans to identify and resolve potential implementation problems with the standard and encourage I to clarify the standard. This would be accomplished through NRC and I staff interaction and possible amendments to EPA's regulations. Also, N would amend its existing regulations, conforming them with EPA's stai dards, and may issue new rules aimed at reducing technical licensing impediments.

An advisory committee to NRC, the Advisory Committee on Nuclear Waste, did not agree that the NRC staff's proposed course of action is sufficient to resolve implementation issues with EPA's containment an other standards.[2] In a December 21, 1989, letter to the Chairman NRC, the advisory committee said that it had continuing doubts about whether compliance with the EPA standards could be effectively demo strated for a specific repository site, even with the present qualificati of "reasonable expectation" of compliance. According to officials of tl committee, the Commission subsequently asked the committee to provide it with additional information on the committee's basis for this objection and to recommend a possible solution to the standards-imple mentation issue.

Challenges DOE Faces in Complying With EPA Containment Standard

DOE has a formidable task in demonstrating if a repository at Yucca Mountain can safely isolate waste from the environment over 10,000 years. In fact, DOE recently extended by 7 years its repository develop ment schedule because, in part, of the scientific challenge of adequate investigating the site. According to DOE's December 1988 site characte zation plan, it will demonstrate compliance with the containment stan ard by conducting performance assessments of the natural features ai man-made components of the repository.[3] These assessments are to be based on various computerized, conceptual models describing the chai acteristics of the Yucca Mountain site and knowledge of the processes and events that could occur at the site.

[2]The Advisory Committee on Nuclear Waste, established in 1988, is the principal advisor to the N Commissioners in nuclear waste matters.

[3]DOE defines performance assessment as any analysis that predicts the behavior of a system or c ponent of a system under a given set of constant or transient conditions.

NRC and others, including a group representing utilities who operate nuclear power plants, have commented on DOE's site characterization plan. According to NRC's staff, current information on the Yucca Mountain site is inadequate to determine whether meaningful probability estimates can be developed for that site; therefore, this major issue should be resolved as early as practicable during site characterization. For example, in its comments on DOE's plan, NRC staff said that DOE should assign high priority to investigating whether the site is subject to unacceptably high chances of disruption due to occurrences of volcanic activity, faulting, or seismic movements.

The utility group believes that DOE's site characterization plan does not reflect a full appreciation of, and concern for, difficulties that will be encountered in reducing uncertainties about the site. According to the group, difficulties with modeling are likely because heavy reliance must be placed on the judgments of experts to interpret site data and to predict site conditions for 10,000 years, and there is likely to be disagreement on these interpretations. Also, challenges to expert judgments can be difficult to resolve.

NRC's advisory committee raised related concerns about DOE's site characterization program. In a July 1989 letter to the Chairman, NRC, the advisory committee stated that DOE was not giving sufficient emphasis to limitations in its data collection techniques regarding preliminary site characterization activities at Yucca Mountain. The committee said that uncertainties and limitations in the data used to justify conclusions will be the center of most repository contentions and that planning for management of the uncertainties and limitations by DOE is essential.

EPA and NRC believe that DOE's future assessment of the performance of its WIPP facility, located near Carlsbad, New Mexico, may provide valuable insights into how readily EPA's containment standard can be implemented in a repository licensing proceeding. The WIPP project was initiated in 1981 when DOE decided to develop a mined geologic repository to store transuranic waste generated in its defense-nuclear activities.[4] The WIPP facility must adhere to EPA's disposal standards; however, DOE, and not NRC, is responsible for deciding whether or not the facility meets EPA's standards.

[4]Transuranic waste is trash that typically contains small amounts of long-lived and hazardous radioactive elements, such as plutonium.

Both EPA and NRC are concerned that if DOE's experience with WIPP ind cates that EPA's standards are unworkable, the standards should be cl ified or modified to allow NRC to make a reasoned licensing decision o DOE application to construct a repository at Yucca Mountain or elsewhere. EPA, in commenting on a DOE draft supplemental environmenta impact statement for WIPP, urged DOE to publish its performance asses ment for WIPP so that the public can review and comment on it. Also, NRC's staff has noted that a demonstration that a real repository can achieve compliance with EPA's containment standard could help devel performance assessment capabilities at Yucca Mountain.

Recent Related Events

On March 22, 1990, the Nuclear Waste Technical Review Board, creat by the Nuclear Waste Policy Amendments Act of 1987, submitted its first report to the Congress on DOE's nuclear waste disposal program. Among many topics addressed in its report, the Board noted that the federal government is simultaneously embarking on two ventures: (1) effort to characterize the Yucca Mountain site and determine its suita ity and (2) an evolving process of developing regulations that will impact on site characterization activities and a repository's design, co struction, and operation.

Concerning the first initiative, the Board recommended that DOE proc as rapidly as possible to develop the needed methodology for perform ance assessment and to begin making preliminary performance calcul tions with available scientific information and data. The Board believ that an early application of performance assessment techniques may help DOE identify critical problem areas in a timely manner and might demonstrate the suitability—or unsuitability—of the site at an earlie date.

Concerning the second initiative, the Board listed seven areas of conc based on its review of the initial working draft of EPA's revised dispos standards. For example, the Board noted that it is not apparent how geologic uncertainties and limitations are to be characterized in deter mining probabilistic computations and what burden of evidence is needed to meet the standards' requirements.

Observations

Although DOE has primary responsibility for achieving the nuclear wa disposal objectives of NWPA, the roles assigned to EPA and NRC, and the potential effects that actions by these agencies could have on achievi NWPA's objectives, are critical to the program's success. DOE must desi

and conduct its site characterization program at Yucca Mountain to demonstrate to NRC that the site and repository design comply with EPA' standards and NRC's regulatory requirements.

Unless EPA and NRC can resolve the latter's concerns about EPA's containment standard, demonstrating that a proposed repository complies with the standard might not be possible and could result in a lengthy and potentially unsuccessful NRC licensing proceeding. The potential impact of NRC's concern is highlighted by the contrast between its reactor safet; goals and EPA's containment standard. NRC does not permit quantitative objectives underlying its safety goals to be used as the sole basis for regulatory decisions because of inherent uncertainty in the calculations of risks. Compliance with EPA's standard, on the other hand, requires numerical calculations of the probabilities of exceeding specified releas limits.

EPA's approach to the containment standard raises questions about whether NRC could license a repository that meets, with a high degree o assurance, all EPA and NRC criteria except for the containment standard. In such a case, would the proposed repository be disqualified? Also, if DOE's analysis shows that the proposed repository only marginally complies with EPA's standard, could uncertainty in the analysis disqualify the repository?

Because of DOE's new extended repository development schedule, there is time to address the containment standard issue before DOE characterizes the Yucca Mountain site and applies to NRC for a construction license. However, NRC's and EPA's progress in resolving concerns about the standard bears watching by interested parties because the resolutio may also affect DOE's site characterization program.

One potentially important contributor to resolution of the containment standard issue is DOE's future assessment of WIPP's performance. Although much about this facility differs from a potential repository at Yucca Mountain, DOE must demonstrate in the same general way—data collection and analysis; development, validation, and use of models; and an overall assessment of the facility's expected performance—that WIPI complies with EPA's standards. Therefore, it is important that NRC and EPA have complete and timely access to all DOE data and analyses that are used in preparing the WIPP performance assessment. This would permit the agencies to take advantage of whatever lessons can be learned from DOE's experience in applying EPA's standards to an actual repository.

Methodology

To assess the issue of whether EPA's containment standard can be impl mented satisfactorily in a repository licensing proceeding conducted b NRC, we reviewed the NRC staff's October 17, 1989, paper addressing th issue. We also attended the November 21, 1989, briefing of NRC's Commissioners by their staff on this issue and obtained and reviewed a tra script of the meeting. We also reviewed EPA's final standards for dispo of nuclear waste in repositories issued in September 1985, a January 3 1990, working draft of EPA's proposed revised standards, NRC's regulations on high-level nuclear waste repositories, and its safety goals poli statement for nuclear power plant operations. Finally, we reviewed pe tinent parts of DOE's site characterization plan for Yucca Mountain and comments on the plan by NRC, its Advisory Committee on Nuclear Was and a group representing utilities that operate nuclear power plants.

We discussed the facts presented here with cognizant officials of DOE and NRC, and we incorporated their comments where appropriate. Our work was performed between November 1989 and February 1990.

Appendix I discusses the development of EPA's environmental standar for nuclear waste disposal and NRC's actions concerning the containme standard. Appendix II discusses DOE's plans to implement EPA's standards at Yucca Mountain and at WIPP.

We are sending copies of this report to the Chairmen of the Senate Co mittee on Governmental Affairs, the House Committee on Government Operations, and the House Committee on Energy and Commerce; the Secretary of Energy; the Chairman, Nuclear Regulatory Commission; t Administrator of EPA; and other interested parties. If you have any qu tions, please contact me at (202) 275-1441.

Major contributors to this report are listed in appendix III.

Victor S. Rezendes
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Abbreviations

ACNW	Advisory Committee on Nuclear Waste
ACRS	Advisory Committee on Reactor Safeguards
C.F.R.	Code of Federal Regulations
DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
RCED	Resources, Community, and Economic Development Division
WIPP	Waste Isolation Pilot Plant

Issues Concerning Development of Environmental Standards for Nuclear Waste Disposal

NRC and others have continuing concerns that one of the EPA's standar for nuclear waste disposal might paralyze or even block NRC's licensin process for nuclear waste repositories. The standard requires numeric projections of the probability that harmful radiation will escape from underground nuclear waste repository into the environment over a 10,000-year period. At issue is whether EPA's long-term containment standard that requires predictions be made of highly uncertain events such as earthquakes, flooding, and fires, can be used effectively in a repository licensing proceeding. NRC anticipates that the DOE may have difficulty in demonstrating compliance with the standard before a licensing proceeding because the standard may emphasize the bottom-line numerical results of DOE's analysis, rather than the quality of the scientific work supporting the analysis.

EPA's use of a probabilistic standard contrasts sharply with the regulatory approach NRC took in developing safety goals for nuclear power plants. Because of the limitations and uncertainties in calculating the risks to individuals and to society from nuclear power plant operation NRC subordinated such calculations to qualitative statements of its safety goals. In contrast, EPA's containment standard sets out a quantit tive standard and then qualifies the standard to recognize the inheren limitations and uncertainties in establishing compliance with the standard.

Background

NWPA established a federal program and policy for management of highly radioactive nuclear waste administered by DOE. The act mandat that the agency develop, site, construct, and operate one nuclear wast repository and select a site for a second repository. Subsequently, in December 1987 the Congress amended the act by, among other things, directing DOE to characterize (investigate) only one site—Yucca Mountain, Nevada—and deferring activities on a second repository until th twenty-first century.

NWPA also assigned key responsibilities to EPA and NRC. EPA was directe to issue standards for protection of the general environment from releases of radioactive material in nuclear waste repositories. NRC was directed to issue technical requirements and criteria for use in approving or disapproving any DOE applications for authorization to construc and operate nuclear waste repositories. NRC's technical requirements a criteria must not be inconsistent with EPA's standards.

Following site characterization, if DOE determines that Yucca Mountain is suitable for a nuclear waste repository, it will recommend selection of the site to the President. If the site is eventually selected, DOE will use the information acquired during site characterization to prepare a license application to NRC. To obtain a repository license from NRC, DOE must demonstrate that the site and proposed repository comply with EPA's standards and NRC's regulatory requirements.

EPA's Standards

EPA's environmental standards for management and disposal of nuclear waste in geologic repositories are in two sections.[1] The management part of the standards—Subpart A—addresses waste storage operations. The disposal part—Subpart B—establishes four standards for disposal of nuclear waste as follows:

- Containment requirements: cumulative releases of radioactive materials from a repository to the environment for 10,000 years after disposal shall have a likelihood of less than 1 chance in 10 of exceeding limits established in the standard, and a likelihood of less than 1 chance in 1,000 of exceeding 10 times the limits.[2]
- Individual protection requirements: exposures of radiation to individual members of the public for 1,000 years must not exceed specified limits.
- Groundwater protection requirements: limits are placed on the concentration of radioactivity for 1,000 years after disposal from the repository to a nearby source of groundwater that (1) currently supplies drinking water for thousands of persons and (2) is irreplaceable (i.e., no reasonable alternative source of drinking water is available to that population).
- Qualitative assurance requirements: these are prescribed technical or institutional procedures or steps providing confidence that the containment requirements are likely to be met.[3]

In developing its disposal standards, EPA made a clear distinction between the containment requirements and the individual and groundwater protection requirements. The latter two standards primarily

[1] Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes. Final Rule (40 C.F.R. part 191).

[2] Although EPA recognized that radioactivity could be hazardous beyond 10,000 years, it said that a disposal system capable of meeting requirements for 10,000 years after disposal would continue to protect the environment well beyond this period.

[3] These requirements apply only to DOE repositories, such as WIPP, that are not licensed and regulated by NRC.

require DOE to make informed technical judgments of compliance base on traditional engineering and analytical techniques. DOE's judgments may also take into account such factors as systematic predictions of tl probability that certain events would occur and measurements of thei associated risks. These two standards also require that DOE make dete minations of compliance with the limits imposed by the standards bas upon the predicted "undisturbed performance" of the repository. Und this criterion, DOE is not obliged to take into account relatively unlikel processes and events that may disrupt the repository from performin as intended, such as human intrusion (for example, inadvertent drillin into the repository) or natural events (earthquakes, flooding, and fire

In contrast, EPA linked compliance with its containment requirements t quantitative (numerical) projections of how much radiation is likely tc be released to the accessible environment for 10,000 years after disposal. In the scientific community, EPA's containment standard is referred to as a "probabilistic" standard because compliance with the standard hinges on calculating the probabilities that potentially impor tant events will occur and multiplying the probabilities by predictions the consequences (such as in terms of releases of radioactive material to the environment) of those events. Similar to the individual and groundwater protection standards, EPA's containment standard assign limits to the total amount of specific radioactive materials that can be released into the accessible environment.[4] Unlike the other two standards, however, the containment standard also states that compliance with the standard requires a demonstration that the probability of exceeding the limits is less than 1 chance in 10, and that the probabilit of exceeding 10 times the limits is less than 1 chance in 1,000. Projections of the total releases must include releases resulting from process and events that are normally expected to occur and those that occur from disruptions to the repository site by both natural phenomena an human-induced events which have at least 1 chance in 10,000 of occu ring over 10,000 years.

In July 1987, the U.S. Court of Appeals (First Circuit) withdrew and remanded the disposal standards to EPA to reconcile provisions related groundwater contamination with its safe drinking water standards promulgated under authority of the Safe Drinking Water Act. The Cou also found no basis for the 1,000-year period of the individual protection standard and inadequate notice and comment opportunity of the

[4]The release limits of quantities of radioactive materials are found in appendix A to the EPA standards.

groundwater protection standard. The Court did not find defective EPA's containment standard. EPA plans to propose new disposal standards in late 1990 and anticipates a final rule in mid-1992. A January 31, 1990, working draft of EPA's proposed new standards indicates that the containment standard is not likely to change significantly.

NRC Technical Requirements and Criteria

NRC's regulations set forth procedural and technical requirements applicable to DOE, in submitting an application for a repository license, and to NRC, in considering DOE's application.[5] Through these regulations, NRC will implement and enforce EPA's disposal standards. In addition, NRC's regulations also require that DOE meet a number of performance objectives and design criteria, including

- NRC standards for radiation protection,
- design criteria for the surface and underground facilities of a repository and the waste packages,
- a minimum life (300 to 1,000 years) of the waste package to be emplaced in the repository,
- a limit on the release rate of radiation from the engineered barriers of the repository, and
- a minimum groundwater travel time of 1,000 years from the repository to the accessible environment, determined without consideration of the effects of the waste.

Until DOE applies for a repository license, NRC's role in the repository program is limited to providing regulatory guidance and oversight of DOE's program.

Can EPA's Containment Standard Be Effectively Implemented?

On November 21, 1989, the NRC staff briefed the NRC Commissioners on plans to continue their evaluation of EPA's standards and on a proposed strategy for implementing the standards through NRC's repository licensing regulations. The major issue of concern to the NRC staff is whether NRC can implement EPA's containment standard in a repository licensing proceeding without unduly delaying or paralyzing its licensing regulatory process. The staff noted that NRC had accepted EPA's standards in October 1985, but had some continuing reservations at that time about how it would implement the standards. NRC's staff intends to draw on its

[5]NWPA permitted NRC to issue its repository regulations (10 C.F.R. part 60) in advance of EPA's standards but required NRC to amend its regulations, if necessary, to ensure that the regulations are "not inconsistent" with EPA's standards.

experience with probabilistic methods of assessing risk related to nuclear power plants, such as application of NRC's safety goals to nuclear plants, to determine if the staff retains confidence that the standard can be implemented.

NRC Is Reconsidering EPA's Containment Standard

The NRC staff's concern is that demonstrating compliance with EPA's standard may rest too heavily on the numerical calculations and analyses that DOE must make in projecting the long-term performance of a repository—a process that involves, among other things, predicting the occurrence of highly uncertain events over a 10,000-year period. Furthermore, the staff believes that the standard does not sufficiently clarify how expert technical judgments and other qualitative factors that have traditionally played an important role in NRC's regulatory decision are to be weighed in licensing a nuclear waste repository.

NRC believes that a strict interpretation of EPA's containment standard could paralyze its repository licensing process. The NRC staff recognizes that EPA does not intend that repository licensing decisions be based solely on numerical estimates of the probability of occurrence of infrequent events. For example, EPA recognizes that DOE and NRC may have to make qualitative judgments when necessary to evaluate a proposed repository. In an October 17, 1989, paper prepared for the Commission the NRC staff noted, however, that (1) the probabilistic standard is still the governing standard, (2) an acceptable approach to implementing the containment standard has not been clearly established, and (3) a question still remains as to whether probability estimates for very unlikely events can be derived in any meaningful way. The NRC staff summarizes its concerns in the paper as follows:

"Differing views on implementation of the [EPA] standards ultimately derive from different perceptions of the statistical rigor required for estimates of the probabilities of potentially disruptive events such as fault movement, volcanic activity, and climate change. A rigorous application of EPA's numerical standards would require estimates of the probabilities of potentially disruptive events that are derived from a statistical data base of previous occurrences of those events at the repository site. Some of the events of interest may be relatively rare compared to the length of the geologic record for the repository site . . . Moreover, some potential events may not even be evidenced in the geological record (e.g., human-initiated events). Therefore, a rigorous application of the EPA standards would lead to the conclusion that the standards cannot be implemented in a licensing review." (Underscoring added.)

An NRC official who spoke at the November 1989 Commission meeting stated that the best alternative standard to the present containment

standard that NRC staff could identify was a purely qualitative standard. According to the official, an advantage of a qualitative standard is flexibility of implementation, but there is also a loss of precision in such a standard.

NRC Approaches to Resolving the Containment Standard Issue

NRC's staff is exploring options on how it can best implement EPA's nuclear waste standards. Specifically, the staff believes that additional clarification and guidance from the Commission and EPA are needed to decide how qualitative technical judgments are to be used by DOE in demonstrating a "reasonable expectation" of compliance with EPA's containment standard.

In its October 1989 paper, the NRC staff said that NRC could (1) reaffirm its original acceptance of the containment standard if EPA clarified areas of concern to NRC or (2) petition EPA to reissue the standard in an altered or non-probabilistic form if NRC decides that the standard cannot be implemented. NRC's staff believes that either of these two actions may also have to be combined with appropriate amendments to NRC's regulations. Therefore, the NRC staff identified four alternative courses of action:

Alternative 1: Maintain the probabilistic format of the EPA standard in conjunction with NRC's current licensing regulations, with minimal changes to resolve implementation problems and ensure consistency between the regulations.

Alternative 2: Make the EPA standard more qualitative, and implement it through NRC's current licensing regulations.

Alternative 3: Maintain a probabilistic format for the EPA standard, but have EPA expand its interpretation of the standard and NRC appropriately amend its regulations.

Alternative 4: Assume that revised EPA standards will not be in place before a repository licensing proceeding. NRC would use a qualitative criterion of "no unreasonable risk to public health and safety" from its existing regulations.

In evaluating the four alternatives, the NRC staff recommended that alternative 3 be adopted, and in fact, had already begun pursuing this approach. Under this alternative, the staff would attempt to identify and resolve potential implementation problems with EPA's containment

standard and encourage EPA to clarify the standard. This would occur through NRC interaction with EPA's staff, preferably before EPA issues revised standards to comply with the 1987 court decision.

NRC staff also would amend its licensing regulations to resolve, where practicable, any outstanding disagreements between EPA and NRC. The NRC staff believes that it may have to develop and issue two or three rules to accomplish this. One proposed rule would conform NRC's repository licensing regulations with EPA's revised disposal standards. In a sec ond proposed rule, NRC staff would identify a basis for DOE to make site-specific determinations of "potentially disruptive" processes and event: in calculating projected radiation releases. NRC is also considering the possibility of developing a third rule that will provide DOE guidance on acceptable means to implement the standards, such as specification of methods to validate DOE models and computer codes used to support compliance with the standard. According to NRC staff, these actions should help resolve certain controversial issues before a repository licensing proceeding and reduce impediments that may otherwise delay or prevent a licensing decision.

NRC staff does not favor alternative 1 because it might complicate the licensing process by leaving many issues unresolved until that process begins. For example, the NRC staff said, unless NRC identifies and clarifies acceptable methods for DOE to estimate the likelihood of potentially disruptive events, it could be virtually impossible to resolve related issues within the 3-year repository licensing period permitted by NWPA. The staff believes that alternative 2 might allow more flexibility for implementation of EPA's containment standard by substituting qualitative terms (such as likely, unlikely, etc.) for the numerical expressions of probabilities now contained in the standard. However, the staff did not recommend this approach because the lack of a clearly acceptable standard might introduce significant uncertainties in interpreting the standard during the licensing process.

The NRC staff is not in favor of alternative 4 because it presumes that EPA's revised standards will be available when they are needed. NRC plans to keep abreast of EPA's plans to reissue the standards as directed by the court, and if necessary, to reevaluate the desirability of explorin this alternative.

An advisory committee reporting to NRC on high-level nuclear waste pol icy and nuclear reactor safety matters, the Advisory Committee on Nuclear Waste (ACNW), did not agree that the NRC staff's proposed

approach was adequate to resolve implementation issues with EPA's containment and other disposal standards. In a December 21, 1989, letter to the Chairman, NRC, ACNW noted that it had continuing concerns about whether compliance with the EPA standards could be effectively demonstrated for a specific repository site, even though EPA had added the qualification of a "reasonable expectation" of compliance to the standards. It also stated that one alternative that NRC should consider was to object to the EPA's proposed revisions to the standards because the standards (1) may be unrealistic, (2) are overly stringent and inconsistent compared to those for other health and safety risks, and (3) according to strong evidence, will be wasteful of resources and provide little commensurate benefit. It recommended that the NRC staff be more aggressive in dealing with EPA to ensure that the EPA standards are scientifically sound, consistent, and readily subject to implementation and interpretation. According to ACNW officials, the NRC Commissioners asked ACNW to provide them with additional information on ACNW's basis for objection and to recommend a possible solution to the standards-implementation issue.

NRC Objected to EPA's Original Proposed Containment Standard

EPA published draft standards for nuclear waste repositories in December 1982, and NRC commented on the standards in May 1983. NRC objected to the probabilistic nature of the proposed containment standard. NRC contended that demonstrating compliance with this standard would require a degree of precision in evaluating a real waste disposal system that is not likely to be achievable. It would, NRC said, presumably require the use of numerical risk analysis techniques to identify potential sequences of events or processes leading to releases of radioactive materials, followed by preparation of a numerical probability estimate for each of these sequences. NRC considered the latter step both unworkable and unnecessary for determining the acceptability of a proposed repository.

At that time, NRC did not completely rule out EPA's probabilistic approach to the containment standard. Rather, NRC recognized that the approach may be useful to the extent that meaningful data are available, as one of the bases for establishing disposal system performance. NRC suggested that EPA substitute qualitative terms to the proposed containment requirements, emphasizing that expert technical judgment is needed in determining compliance with them. Moreover, NRC stated that there should be a test of "reasonable assurance" rather than of absolute certainty that the containment standard could be met.

EPA incorporated some of the modifications that NRC had suggested into its final containment standard. For example, EPA emphasized that it did not expect unequivocal proof of compliance with the standard because of the substantial uncertainties inherent in making long-term projection of repository performance. Instead, EPA established a test of "reasonable expectation" of compliance based upon practically obtainable information and analysis.

Based on EPA's changes to its proposed containment standard, NRC withdrew its objections. In an October 1985 paper, the staff informed the Commission that, although implementing EPA's probabilistic standard would pose a significant challenge to NRC, the final standard nevertheless could be implemented. The NRC staff also stated that it planned to conduct technical analyses to determine whether any changes were necessary to the repository performance objectives in NRC's regulations to ensure consistency of its regulations with EPA's standards. The NRC Commissioners accepted the staff's recommendations.

The Advisory Committee on Reactor Safeguards (ACRS), the predecessor NRC advisory group to the ACNW, did not agree with NRC's staff. The ACRS was highly critical of EPA's final standards and, in particular, the containment standard. For example, in an October 1985 letter to the NRC Chairman, ACRS described the probabilistic containment standard as "unreasonably restrictive" and containing "serious deficiencies." ACRS also stated that the overly restrictive nature of the probabilistic standard would introduce unnecessary licensing obstacles with only minimal benefit to the public health and safety. Finally, ACRS stated that because of the combination of the low level of allowable risk and the probabilistic nature of the containment standard, it had no confidence that NRC would succeed in making a formal determination that a proposed DOE repository complies with the standard.

The NRC Commissioners reaffirmed their support of EPA's standards, but concluded that NRC should accelerate its efforts to develop analytical methods to determine whether a proposed repository would comply with EPA's standards. Moreover, it said that ACRS' concerns should be addressed by (1) clarifying ambiguities in the application of the probabilistic standard and (2) conforming NRC's repository performance objectives to EPA's standards. In June 1986, NRC subsequently published a proposed rule to conform its regulations to the EPA standards. However, before NRC could complete the rulemaking, the 1987 court decision to withdraw and remand the standards to EPA for further work was issued and NRC curtailed its initiatives to conform its rules to EPA's standards.

Contrast Between EPA's Containment Standard and NRC's Safety Goals

As discussed above, one concern of the NRC staff is that, although EPA's containment standard only requires "reasonable expectation" of compliance, the numerical standard is the governing standard. This approach is in sharp contrast to NRC's safety goals for nuclear power plants. Those goals are stated in qualitative terms and supported by probabilistic objectives. Furthermore, in adopting the safety goals, NRC made it clear that, because of the limitations of risk assessment technology and related data, the probabilistic objectives were not to be substituted for existing safety regulations.

In response to recommendations of the President's Commission on the Accident at Three Mile Island, between 1981 and 1986 NRC developed a policy statement on safety goals for the operations of nuclear power plants. The objective of the policy statement was to establish goals that broadly define an acceptable level of radiological risk to the public as a result of the operation of nuclear power plants during both normal operations and accidents. In the policy statement, NRC adopted two qualitative safety goals as follows:

- Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear no significant additional risk to life and health.
- Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks.

In addition, NRC established two quantitative (probabilistic) objectives that were to be used in determining achievement of the safety goals. The objectives are as follows:

- The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of 1 percent of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.
- The risk to the population, in the area near a nuclear power plant, of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of 1 percent of the sum of cancer fatality risks resulting from all other causes.

According to NRC's policy statement, progress in developing the techniques for quantitatively estimating risks made it feasible to begin to

use quantitative safety objectives for limited purposes. However, because of the sizable uncertainties present in the methods and the gap in the data base—essential elements needed to gauge whether the objectives have been met—the quantitative objectives should be viewed as aiming points or numerical benchmarks of performance. In particular, because of the present limitations in the state of the art of quantitatively estimating risks, the quantitative objectives are not a substitute for existing regulations.

Finally, NRC specified in the policy statement that the safety goals were not meant to be used as a sole basis for licensing decisions but could be considered as one factor in a licensing decision. This position was consistent with our conclusion in a June 1985 report on NRC's use of probabilistic risk assessment technology in regulating commercial nuclear activities.[6] In that report, we cautioned that NRC should not use probabilistic risk assessments as the sole or primary basis for regulatory decisions; rather, NRC should use this technology to supplement its more traditional analytical and engineering methods.

Thus, in developing safety goals for nuclear power plant operations, NRC made quantitative estimates of risks to both individuals and society subordinate to qualitative statements of its safety goals. In contrast, EPA's containment standard sets out a quantitative standard and then qualifies the standard to recognize the inherent limitations and uncertainties in establishing compliance with the standard.

[6]Probabilistic Risk Assessment: An Emerging Aid To Nuclear Power Plant Safety Regulation (GAO/RCED-85-11, June 19, 1985).

Challenges DOE Faces in Complying With EPA's Containment Standard

DOE has a formidable task in successfully determining if a repository at Yucca Mountain can safely isolate waste from the environment for at least 10,000 years. Its site characterization plan lays out an approach that recognizes the considerable uncertainties in achieving this objective. Also, DOE recently extended its repository schedule 7 years because, in part, of the scientific challenge of adequately investigating the site. DOE now expects to begin investigating the site in about 1 year. If the results are favorable and the site is selected, DOE plans to apply for an NRC license to construct a repository in about 2001. With a 3-year licensing period followed by repository construction, DOE projects that it could begin waste disposal operations by 2010.

NRC, its advisory group on nuclear waste, and utility representatives are concerned that uncertainties associated with data to be collected and the analysis of the data using computer models simulating site conditions may be great enough to prevent DOE from convincingly demonstrating compliance with the containment standard. Accordingly, they are concerned that compliance with the standard could be an issue subject to protracted litigation in a future licensing proceeding. In this regard, EPA and NRC believe that DOE's pending assessment of the WIPP facility's compliance with EPA's disposal standards may provide valuable information for implementing the standards at Yucca Mountain.

DOE's Plans to Comply With EPA's Containment Standard

In 1985, after EPA had modified its draft containment standard to recognize qualitative considerations, DOE concluded that EPA's standards were flexible enough to be implemented in its repository program. The agency's December 1988 site characterization plan describes its approach for implementing the standards in investigating the Yucca Mountain site and in developing a repository design.[1] DOE will address the EPA standards, particularly the probabilistic containment standard, by conducting performance assessments of the natural features and man-made components of the repository.[2]

According to DOE's plan, performance assessments are to be based on various conceptual models used to describe the characteristics of the site and on knowledge of the processes and events that could occur at the

[1]DOE recognized in its site characterization plan that the EPA standards were vacated by the 1987 court decision. However, until such time as changes to the EPA standards are implemented, DOE plans to collect data on the Yucca Mountain site and repository based on EPA's 1985 standards.

[2]DOE defines performance assessment as any analysis that predicts the behavior of a system or component of a system under a given set of constant or transient conditions.

site acquired through site investigations. The latter includes infrequently occurring events such as volcanic activity, earthquakes, flooding, and climate changes. Using these inputs, DOE will develop computational models of site and repository performance.

DOE plans to conduct its performance assessment of Yucca Mountain in the following sequence:

- Identify all significant anticipated and unanticipated processes and events that may affect the geologic repository.
- Group related processes and events into various classes or scenarios for the release of radiation.
- Screen the scenario classes in terms of their probability of occurrence and the potential releases of radioactivity associated with them.
- Develop appropriate computational models for evaluation of the scenario classes.
- Evaluate the effect of the related processes and events on the release of radiation into the accessible environment.
- Calculate an overall probability distribution for the cumulative release of radiation to the accessible environment, taking into account the uncertainties in the parameters of the computational models and the probability of occurrence for each scenario class.

DOE acknowledges that to demonstrate overall waste system (site, repository, and waste package) performance, it will place heavy reliance on the conceptual models of the repository site, physical systems, and the hypotheses on which they are based. If the models can be confirmed by tests conducted during site characterization, then its testing strategy should be sufficient, according to DOE, to resolve repository performance and design issues. However, DOE recognizes that some of the conceptual models and its associated testing strategies may need to be modified as site characterization progresses.

Uncertainties Related to Yucca Mountain

DOE recognizes that each conceptual model of one or more repository systems has some degree of uncertainty associated with it, and this uncertainty is reflected in the fact that DOE must also consider alternative conceptual models. In other words, more than one set of hypotheses may be consistent with the data that DOE collects. According to DOE officials, it is evaluating many alternative conceptual models as part of its site characterization program. DOE's challenge is to identify those alternative models that are potentially descriptive of the site and to ensure

that these models are given appropriate consideration in its performance assessments. Moreover, DOE has noted that expert judgment will also play an important part in developing performance assessments and in selecting scenarios and scenario classes necessary to calculate the overall probabilities of projected cumulative radiation releases.

During site characterization, DOE intends to evaluate and reduce the uncertainty in its estimates of repository performance that are supported through predictive models. DOE's goal is to ensure that its modeling efforts result in a level of uncertainty that is acceptable to NRC and that regulatory requirements will be satisfied with a reasonable degree of assurance.

In addition, DOE plans to validate its performance assessment models and the underlying conceptual models on which they are based. The validation process will demonstrate that mathematical representations of repository performance adequately replicate the repository's actual performance. DOE also plans to validate the quality and appropriateness of its data, including the assumptions it uses to build predictive models. Overall, DOE believes that outside peer reviews may be necessary to assess the competence of its scientific investigations and to judge the uses made of results.

Utility Group's Comments on Uncertainties

The Edison Electric Institute and the Utility Nuclear Waste and Transportation Program jointly commented on DOE's site characterization plan.[3] The group is concerned that DOE's final plans do not reflect a full appreciation of the difficulty in reducing site-related uncertainties. In addition, the group believes that DOE's processes of gathering, analyzing interpreting, and summarizing its data on Yucca Mountain involve considerable judgments which may be challenged during a licensing proceeding.

According to the utility group, difficulties with modeling are likely because heavy reliance must be placed on the judgments of experts to interpret site data and predict site conditions over the next 10,000 years, and there is likely to be disagreement on these interpretations. Also, challenges to expert judgments can be difficult to resolve during licensing. The group said DOE should anticipate and acknowledge the

[3]The Edison Electric Institute is the association of the nation's investor-owned electrical companies. The Utility Nuclear Waste and Transportation Program is an association of electric utilities that monitors the implementation of federal statutes and regulations concerning nuclear waste management.

problems associated with making and defending modeling-related judgments that are critical to site evaluation and repository licensing.

The group also noted that although the site characterization program is extensive, DOE will, quite appropriately, sample only a small fraction of the site's volume. The resulting database will be used primarily by experts in making judgments, such as predictions about future volcanic activity. Moreover, because of the site's complexity, expert predictions will have wide ranges of uncertainty. According to the group, when uncertainties are combined in models assessing the performance of the site and repository, the assessment results will also be uncertain. Because the group believes that resolving issues related to the site's suit ability and performance will be more difficult than implied in DOE's plar it urged DOE to develop and describe strategic plans for coping with these issues.

NRC Comments on Uncertainty and EPA's Containment Standard

NRC has been actively monitoring the progress of DOE's site characterization program, including its efforts to address EPA's nuclear waste standards. Comments by NRC's staff in its October 1989 staff paper indicate that DOE's plans for site characterization appear to correspond well witl the staff's interpretation of what the standards require. However, the staff is particularly concerned that DOE emphasize the scientific work needed to support the required probabilistic analyses rather than the comparison of the analyses' results with the release limits specified in EPA's containment standard.

NRC's staff believes that meaningful, though not statistically rigorous, probability estimates can be developed and reasonably defended for repository sites that are not complex or unusually geologically active. Ir fact, the staff believes that the required probability estimates will help determine how well a site is understood and, therefore, how much confi dence can be placed in its future performance as part of a repository. However, the staff added that it is too early to tell whether meaningful probability estimates can be developed for Yucca Mountain. According to the NRC staff's October 1989 paper, this issue is to be resolved as early as practicable during site characterization. For example, in review ing and commenting on DOE's site characterization plan, NRC staff noted that DOE should assign high priority to conducting investigations to determine whether the site is subject to unacceptably high chances of disruption due to occurrences of volcanic activity, faulting, or seismic movements.

For several years, advisory groups to NRC have raised concerns about DOE's site characterization program and compliance with the EPA standards. For example, in July 1989 ACNW advised the NRC Chairman that DOE was not giving sufficient emphasis to the limitations and uncertainties in its databases concerning preliminary site characterization activities at Yucca Mountain. The Committee said that uncertainties and limitations in DOE's data will be the center of most repository contentions and that planning for the management of these uncertainties and limitations by DOE is essential. Finally, the committee stated that DOE may have considerable difficulty in calculating an overall probability distribution necessary for demonstrating compliance with EPA's containment standard. According to ACNW, this problem could represent a disqualifying feature for the proposed repository.

WIPP May Provide Valuable Insights to Implementing Containment Standard

NRC and EPA are seeking ways in which they can resolve present and future implementation issues associated with the latter agency's nuclear waste standards. The specific issue is whether there is adequate confidence that the standards—particularly the probabilistic containment requirements—can be implemented in an NRC licensing proceeding for a repository at Yucca Mountain or elsewhere. One approach that both agencies have suggested to address this issue is to look at the experience being gained through other programs for radioactive waste storage in a geologic environment. In particular, the agencies identified DOE'S WIPP repository near Carlsbad, New Mexico, as a possible precedent for determining how much confidence can be placed in the present or revised EPA standards.

The WIPP facility is the culmination of many years of effort to find a site for permanent disposal of transuranic wastes generated as a by-product of the federal government's defense-nuclear activities. The WIPP project was initiated in 1981 when DOE decided to proceed with the development of a mined geologic repository to store such wastes. To date, DOE has spent about $800 million to complete WIPP site characterization, construction, and preoperational activities.

Unlike the principal source of nuclear waste to be emplaced in Yucca Mountain—spent (used) nuclear reactor fuel—transuranic waste forms typically contain smaller amounts of radioactivity. Yet, because this waste contains long-lived and hazardous radioactive elements, such as plutonium, it warrants isolation from the environment. Accordingly, WIPP, like a potential repository at Yucca Mountain, must comply with EPA's disposal standards. An important distinction for the WIPP facility,

however, is that it is exempt from NRC regulation. DOE itself makes the determination of whether or not the facility meets EPA's standards.

DOE will conduct a computer-simulated performance assessment of WIPP similar to that of Yucca Mountain, to determine if the facility complies with EPA's standards. Specifically, using assumptions on the total inven tory of various elements to be disposed of in WIPP and computerized models, DOE will identify, categorize, and analyze significant processes and events that could affect the repository's performance; will estimat the cumulative releases of radiation to the accessible environment and potential doses to individuals; and will compare the predicted release rates and doses to release rates and doses contained in the standards.[4]

DOE designated the first 5 years of WIPP operation as a research and development phase for the purpose of demonstrating the safe disposal of transuranic waste. According to the agency's latest estimate, this phase is expected to begin as early as July 1990, and the performance assessment is expected to be completed within 4 years. Our recent report on WIPP provides additional details on the status of the facility, DOE's plans for the testing phase, and potential problems that DOE must deal with in demonstrating compliance with EPA's standards.[5]

EPA and NRC believe that DOE's preparation of the WIPP performance assessment may provide valuable insights on how readily EPA's standards can be implemented in a licensing proceeding. Both agencies shar a concern that if DOE's experience indicates that EPA's standards appear unworkable, the standards should be clarified or modified to allow NRC to make a reasoned licensing decision on a DOE application to construct repository.

EPA has stated its intention to reexamine its disposal standards and issu alternative standards if necessary. Moreover, EPA has recognized that WIPP may prove to be useful in assessing the feasibility of implementing the current environmental standards. In its comments on a draft supple mental environmental impact statement for WIPP, EPA urged that DOE publish WIPP performance assessments as an additional supplement to the environmental impact statement, or a similar document, for public

[4]According to DOE, it will establish WIPP's compliance with EPA's groundwater protection standar by demonstrating that there is no special source of groundwater, as defined in EPA's disposal standards, in the vicinity of the facility.

[5]Nuclear Waste: Storage Issues at DOE's Waste Isolation Pilot Plant in New Mexico (GAO/RCED-90-1, Dec. 8, 1989).

review and comment. According to EPA, this should be done after the 5-year test phase at WIPP but before DOE begins waste disposal operations at the facility.

In its October 1989 staff paper, NRC's staff also recognized that DOE's application of EPA's standards to WIPP could help answer questions abou implementing the standards. NRC noted that a demonstration that a real repository can achieve the risk levels of EPA's containment standard ha not been made. NRC's staff believes that it should review the performance assessments for WIPP as they are released for public comment because the assessments could provide significant insights into the development of performance assessment capabilities at Yucca Mountai

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