REVIEW COMMENTS ON INITIAL SUMMARY REPORT FOR REPOSITORY/WASTE PACKAGE ADVANCED CONCEPTUAL DESIGN, VOLUMES I & II, AUGUST 29, 1994

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ABSTRACT

A technical review was conducted of the Initial Summary Report for Repository/Waste Package (WP) Advanced Conceptual Design (ACD), volumes I & II, August 29, 1994. This Initial Summary Report, the first in a series of three summary reports on ACD work to be issued by the U.S. Department of Energy, was designed to be a compendium of information available to date on the ACD of the proposed repository and candidate WP. The review reported herein has the objective of qualitatively assessing the ability of the conceptual design to meet the ultimate goal of satisfying the design and performance objective requirements of 10 CFR Part 60. Selected major concerns raised in this review include:

- Information and data related to hydrology, geochemistry, and climatology and meteorology were not considered in the development of the ACD

- Technical uncertainties other than the potential impacts of thermal and seismic loads that may impact on the long-term repository performance were not considered in the development of the ACD

- Potential surface movement, such as that due to the long-term deformation and deterioration of the pillars in the area of emplacement drifts, was overlooked

- Not all parameters affecting the retrieval were considered, such as rock instability due to thermal loading and associated thermal, hydrological, mechanical, and chemical effects

- Description of waste package design changes were not discussed

Other areas in which questions and concerns are raised include inadequacy and inconsistency of the presented information related to:

- Options for waste retrieval and drift backfilling

- Specific criteria and justification for the proposed repository location

- The complexity of the actual fault characteristics in the Primary Area

- Joint characteristics around the drift excavation boundary

- Required design to support the separation of two independent ventilation systems

- Fault characteristics in the primary area

CONTENTS

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1 INTRODUCTION

The Initial Summary Report for Repository/Waste Package (WP) Advanced Conceptual Design (ACD) (U.S. Department of Energy, 1994) reviewed herein is the first in a series of three summary reports on the ACD to be issued by the U.S. Department of Energy (DOE). An Interim Summary Report and a Final Summary Report will be issued by the DOE in FY95 and FY96, respectively. This Initial Summary Report is a compendium of information available to date on the ACD for the repository and the WP.

The objective of this review is to qualitatively assess the ability of the conceptual design to satisfy the ultimate goal of compliance with performance objective requirements of 10 CFR Part 60 (Nuclear Regulatory Commission, 1991). The scope includes a review of: (i) Chapter 5—Site Description, (ii) Chapter 7—Surface Repository Design Description, (iii) Chapter 8—Subsurface Repository Design Description, (iv) Chapter 9—Closure and Decommissioning, and (v) Chapter 12—Uncertainties, Issues, and Recommendations. However, only an overview review has been conducted for Chapter 6—Waste Package/Engineered Barrier Development.

This report has two major components: (i) general concerns,and (ii) specific concerns. Both general and specific concerns have been presented in a standard format consistent with previous Nuclear Regulatory Commission (NRC) submittal of concerns provided to the DOE (e.g.,Nuclear Regulatory Commission, 1989). This standard format includes objections, comments, and questions. Related references are provided for each comment or concern individually, following the recommendation sections. The definitions of objections, comments, and questions are given in Section 2 of this report.

References:

Nuclear Regulatory Commission. 1989. *NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada*. NUREG-1347. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1991. *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Title 10, Energy, Part 60 (10 CFR Part 60). Washington, DC: U.S. Government Printing Office.

U.S. Department of Energy. 1994. *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design, Volumes I & II, August 29, 1994*. B00000000-01717-5705-00015. Las Vegas, NV: TRW Environmental Safety Systems Inc.

2 CATEGORIZATION OF CONCERNS

In this chapter, the major categories of concerns used for the review of the ACD report are summarized. These major categories consist of objections, comments, and questions and are defined and used consistent with other submittals of concerns from the NRC to DOE in the high-level nuclear waste (HLW) program.

2.1 OBJECTIONS

An "objection" is a concern with the DOE program related to either:

(i) Potentially adverse effects on repository performance

(ii) Potentially significant and irreversible/unmitigable effects on characterization that would physically preclude obtaining information necessary for licensing

(iii) Potentially significant disruption to characterization schedules or sequencing of studies that would substantially reduce the ability of the DOE to obtain information necessary for licensing

(iv) Inadequacies in the Quality Assurance (QA) program that must be resolved before work begins

Objections are reserved primarily for concerns with activities, tests, and analyses which, if started, could cause significant and irreparable adverse effects on the site, design, construction, and operations. Due to the irreparable nature of activities associated with objections, the NRC would recommend that the DOE not start work until the objections are satisfactorily resolved.

2.2 COMMENTS

A comment is a concern with the DOE program that would result in a significant adverse effect on licensing if not resolved, but would not cause irreparable damage if activities started before resolution. The DOE program could be modified in the future, with some risk to not having the necessary information for licensing; the adverse effects would be primarily related to the program schedule. Therefore, for these concerns, the DOE would start work at its own risk before resolving such concerns with the NRC. The NRC would recommend timely resolution of comments. If resolution is not achieved in a timely manner, comments could be elevated to the higher category of objections described above (i.e., potential significant disruption of schedules that would reduce the ability to obtain information necessary for licensing).

2.3 QUESTIONS

A question is a concern with the presentation of the DOE program such as missing information, level of detail, contradictions, and ambiguities that preclude understanding part of the DOE program, thereby preventing the staff from being able to comment. The NRC would recommend a timely response by the DOE to such questions. If a question is related to a potential objection, satisfactory resolution should be accomplished before work begins. If the question is not related to an objection, then the DOE could choose to proceed with work at its own risk, and resolve the question in future reports.

3 GENERAL CONCERNS

3.1 OBJECTION

There are no objections based on the review of this initial summary version of the ACD.

3.2 COMMENTS

COMMENT 1

The title implies that ACD for the WP and the repository are the topics of this report, but there is almost no technical description of the revised WP form, the multi purpose canister (MPC).

Basis:

The purpose of the report and the status of the MPC advanced concept design are not adequately stated. Essentially the only information provided is that the MPCs will be large and parked in the main tunnels on rail cars or on fixed supports. No rationale justifies the change of the previous waste package concept to the MPC concept.

The report appears to be a statement of repository design status, which is to be modified by the elimination of vertical or horizontal emplacement holes required for the former WP design. Does "Advanced Conceptual Design" simply mean that the design is now advancing beyond some prior level or is it intended to mean that new and novel designs are being proposed?

Recommendations:

Describe why the WP design was changed to the MPC. Describe the proposed MPC design in more detail. Define the meaning of ACD. All these topics should be addressed early in the discussion.

COMMENT 2

Although there is discussion of equipment replacement and repair over the proposed 100-yr period of retrievability, the topics of tunnel opening stability and potential influence of seismicity for this time period are not addressed.

Basis:

A number of topics of concern during the period of retrievability are discussed, but the primary concern of tunnel opening stability is not. This lack of discussion suggests an incomplete consideration of primary issues. Opening stability is a common concern in mining and is the subject of considerable literature.

Recommendation:

Address all the related issues that affect tunnel opening stability in the repository environment, such as thermal load, seismic load, and aging and corrosion of ground-control systems. Also, include examples of case studies of old tunnels in similar conditions, relevant literature, and any DOE work planned or performed to date.

COMMENT 3

Insufficient information is presented in Sections 5.3—Hydrology, and 5.5—Climatology and Meteorology. These data are not specifically considered for the ACD.

Basis:

Insufficient description is provided of the hydrology, climatology, and meteorology of the proposed repository site (Sections 5.3 and 5.5). It is not clear whether site-specific characteristics are used in supporting the development of the ACD. A description of the hydrology is cited to the previous section. However, the discussions are concentrated only on the groundwater characteristics, and the annual rainfall and infiltration are not discussed.

Recommendations:

It is recognized that the repository block (extent, location, and depth) has been selected primarily based on the geology and geoengineering characteristics of the site. However, the ACD should describe the significance and impact of the hydrology, climatology, and meteorology of the site on the design. Justification should be given if these data are not used as part of the design considerations.

COMMENT 4

Removal of heat and moisture from the system by ventilation needs to be addressed in the repository design and in supporting thermohydrologic calculations.

Basis:

Many researchers have recognized that ventilation can remove significant amounts of heat and moisture from the repository. For over 10 yr (Roseboom, 1983), it has been recognized that there is "the possibility of removing most of the heat by ventilation during the operational phase of the repository." In the Climax study (Patrick et al., 1986), it was observed that "about 20 tonnes of water were removed from the facility each year in the ventilation airstream," although ventilation effects were purposefully minimized. Similarly, a significant amount of heat was reported to be removed by ventilation. Recently, Danko (1991), and Danko and Mousset-Jones (1992, 1993), have analyzed heat and moisture removal. In a FY93 thermal loading study (Saterlie and Thomson, 1994) numerous references are given to the need to account for the effects of ventilation. Given that the DOE is considering a prolonged time period for repository operations (up to 150 yr), and in-drift emplacement, ventilation is important as a thermal management tool which may remove significant amounts of heat and moisture from the repository and have an effect on long-term performance.

To date, many thermohydrologic calculations have neglected to account for ventilation (e.g., Pruess et al., 1990; Pruess and Tsang, 1993; Buscheck and Nitao, 1993). It appears that ventilation is an important thermal management tool, in addition to the age of the waste, size (payload) of waste packages, and the density of waste package spacing.

Recommendation:

The DOE should investigate the use of ventilation as a thermal management option, and evaluate ventilation effects on long-term performance of the repository.

References:

Buscheck, T.A., and J.J. Nitao. 1993. Repository-heat-driven hydrothermal flow at Yucca Mountain, part I: Modeling and analysis. *Nuclear Technology* 104: 418–448.

Danko, G. 1991. Emplacement rift temperature reduction by cooling enhancement and ventilation. *Proceedings of the Second International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 1,585–1,593.

Danko, G., and P. Mousset-Jones. 1992. Coupled heat and moisture transport model for underground climate prediction. *Proceedings of the Third International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 790–798.

Danko, G., and P. Mousset-Jones. 1993. Modeling of the ventilation for emplacement drift re-entry and rock drying. *Proceedings of the Fourth International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 590–599.

Patrick, W.C. et al. 1986. *Spent Fuel Test—Climax: An Evaluation of the Technical Feasibility of Geologic Storage of Spent Nuclear Fuel in Granite*. UCRL-53702. Livermore, CA: Lawrence National Laboratory.

Pruess, K., and Y. Tsang. 1993. Modeling of strongly heat-driven flow processes at a potential high-level nuclear waste repository at Yucca Mountain, Nevada. *Proceedings of the Fourth International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 568–575.

Pruess, K., J.S.Y Wang, and Y.W. Tsang. 1990. On thermohydrologic conditions near high-level nuclear wastes emplaced in partially saturated fractured tuff 1. Simulation studies with explicit consideration of fracture effects. *Water Resources Research* 26(6): 1,235–1,248.

Roseboom, E.H. 1983. *Disposal of High-Level Nuclear Waste Above the Water Table in Arid Regions*. Geological Survey Circular 903. Alexandria, VA: U.S. Geological Survey.

Saterlie, S.F., and B.H. Thomson. 1994. *FY 93 Thermal Loading Systems Study Final Report*. B00000000-01717-5705-00013. Las Vegas, NV: TRW Environmental Safety Systems Inc.

COMMENT 5

The report section on "Retrieval Considerations" does not provide any discussion of a contingency for potential backfilling of emplacement drifts or backfilling around the waste package within an emplacement drift.

Basis:

The performance objective dealing with retrievability makes it evident that backfilling of portions of the underground facility may be allowed in advance of permanent closure. Discussions in NUREG-0804 (Nuclear Regulatory Commission, 1983) indicate that allowing partial backfilling around waste packages prior to permanent closure is a "substantive" point.

Recommendation:

If the use of backfill in emplacement drifts or around waste packages within emplacement drifts has been ruled out by the DOE, this fact should be so stated in the "Retrieval Considerations" section of the report. Alternatively, the "Retrieval Considerations" section of the report could refer to another report section where all the related safety considerations, with or without immediate backfill option, would be discussed.

Reference:

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories*. NUREG-0804. Washington, DC: Nuclear Regulatory Commission.

COMMENT 6

On page 8-169, paragraph 1, the statement of "the two basic reasons that retrieval is necessary" does not accurately portray environmental protection as one of the reasons for retrieval as identified by the Nuclear Waste Policy Act of 1982. While the DOE may choose to retrieve HLW for resource value, the reason for retrieval specified by the NRC is due to lack of reasonable assurance that the overall performance objective would be met. This lack of reasonable assurance does not necessarily mean that the site or any of the repository designs, at the time of retrieval, are causing a possible risk to public health. However, such risk may be anticipated at some future time in the repository performance life.

Basis:

The Nuclear Waste Policy Act of 1982 requires repository design to permit retrieval "...for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel," Section 122.

From NUREG-0804 (Nuclear Regulatory Commission, 1983), "In the Commission's view, it is clear that retrieval could be required at any time after emplacement and prior to permanent closure if the Commission no longer had reasonable assurance that the overall system performance objective would be met. This situation could exist for a variety of reasons and the Commission believes that it should retain the flexibility to take into account all relevant factors and that it would be imprudent to limit the Commission's discretion by specifying in advance the particular circumstances that would make it necessary to retrieve wastes." This statement has been paraphrased loosely in the text of the ACD report as "failure in the site, or the WP is causing a possible risk to public health..."

Under the Nuclear Waste Policy Act of 1982, the Commission's technical criteria "shall include such restrictions on the retrievability of the solidified high-level radioactive waste and spent fuel in the repository as the Commission deems appropriate," Section 121(b)(1)(B). The criteria set forth in this rule represent the criteria which, for purposes of this provision, the Commission deems appropriate.

Recommendation:

The discussion on reasons for retrieval should be modified to more accurately reflect environmental protection in accordance with the Nuclear Waste Policy Act of 1982 and the Commission's intent that retrieval could be required if the Commission no longer had reasonable assurance that the overall system performance objective would be met.

Reference:

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories*. NUREG-0804. Washington, DC: Nuclear Regulatory Commission.

Nuclear Waste Policy Act of 1982. 1983. Public Law 97-425, Section 121(b)(1)(B). Washington, DC: U.S. Government Printing Office.

COMMENT 7

The ACD has addressed many difficulties and problems related to placing reliable backfill in the emplacement drifts, but has not addressed the impact of backfill on the long-term performance of the WP.

Basis:

It is recognized that backfilling of the emplacement drifts is not required by the regulation. The choice of whether to place the backfill remains an option, and Section 9 of the ACD is an initial summary (incomplete draft). The impact of backfill (if used) on the long-term performance of the waste package should be addressed at least as part of a future plan if the option remains open. Such impact may include, for example, characteristics of backfill loading on the waste package, and how backfill changes the thermal conditions of the emplacement drifts.

Recommendation:

The ACD should recognize and address the long-term impact of backfill (if used) on the performance of this WP.

COMMENT 8

The use of expert opinion and its aggregation to quantify bounds of uncertainty is not discussed.

Basis:

There is a discussion of uncertainties, but no discussion of DOE/Electric Power Research Institute (EPRI) work to quantify uncertainty by using expert opinion. Several reports have resulted from such efforts in development of seismic and fault offset design criteria.

Recommendation:

Briefly discuss the DOE efforts in the use of expert opinion to quantify uncertainty, for example, cite and review the April 29, 1994, TRW report on seismic design input for Exploratory Studues Facility (ESF) at Yucca Mountain (Quittmeyer et al. 1994).

References:

Electric Power Research Institute. 1993. *Earthquakes and Tectonics Expert Judgment Elicitation Project.* EPRI TR-102000. Palo Alto, CA: Electric Power Research Institute.

Quittmeyer, R., T. Grant, C. Menges, R. Nolting, S. Pezzopane, R. Richter, W.J. Silva, D.B. Slemmons, P. Somerville, C.T. Statton, and I.G. Wong. 1994. *Seismic Design Inputs for the Exploratory Studies Facility at Yucca Mountain.* Technical Report BAB000000-0717-5705-00001 REV00. Las Vegas, NV: U.S. Department of Energy, Yucca Mountain Site Characterization Office.

COMMENT 9

The ACD has not addressed control and monitoring systems for construction and operation bases.

Basis:

It is proven by mining experience that early detection of potential problems is the best way to prevent events of greater magnitude and consequence.

Recommendations:

The ACD should identify major hazards and other operational parameters which should be monitored. Control and monitoring systems should be designed as appropriate.

3.3 QUESTIONS

QUESTION 1

The reasons for the choice of repository design Option I over Option II are not described. (See pages xxiii, xxiv, Section 8.6)

Basis:

The text includes too little information regarding the two options and no basis to support the decision that Option I is preferred.

Recommendation:

Describe the two options with additional detail. Delineate the bases for comparison. Describe why one option was chosen over the other in the context of these bases.

QUESTION 2

Cracking implications for the MPC when blast cooling is employed are not discussed.

Basis:

A general observation of nuclear power plant owners/designers is that the thick-walled piping required to resist seismic motions is or may be prone to cracking caused by thermal stresses induced at shutdown. The MPC is reputed to have a thick outer shell, which might be considered analogous to the thick-walled piping and which might also be prone to cracking on sudden cooling.

Recommendation:

Discuss the thermal cracking potential of MPC outer shells subject to blast-cooling, or refer to planned studies in which this determination is to be made.

QUESTION 3

The ACD overlooks that crushed tuff (if selected as backfill material), a byproduct of Tunnel Boring Machine (TBM) operation, may be subject to chemical alteration and weathering due to the long-term storage on the ground surface.

Basis:

After several decades of surface storage, crushed tuff or other byproducts of the TBM proposed as an alternative backfill material, may be subject to chemical alteration and weathering. Such weathering may degrade the expected performance of the backfill (e.g., reduction of the particle density and strength, increase of particle permeability, and increase of the potential settlement, etc.). Amendments used to stabilize the spoil piles or control dust may also alter its properties.

Recommendations:

The ACD should address the effects of long-term surface storage of crushed tuff or byproduct of TBM, if it is to be used as part of the backfill material.

QUESTION 4

The choice of 50 °C (122 °F) as representative of acceptable working conditions during the potential retrieval process is marginal for even sedentary human activity. Expected humidity level should also be discussed, since humidity plays an important role in acceptable working conditions.

Basis:

Woodson defines the "upper limit for continued occupancy over any reasonable period of time" as 90 °F (32 °C) (Woodson, 1981). At 50 °C, the upper limit of tolerable humidity with conventional clothing, also from Woodson, is given as 28 percent. A curve reproduced by Woodson from the National Institute for Occupational Safety and Health Indicates that lightly dressed males can tolerate 50 °C for less than 5 hours resting or about 2.5 hours working.

Recommendation:

If any human occupants would be confined to controlled-temperature environments, or if operations do not require human activity in the 50 °C environment, this fact should be stated. If not, DOE should consider reevaluation of the choice of 50 °C as an upper limit and should also consider humidity effects for acceptable working conditions during the potential retrieval process. Experience with deep mining (e.g., Sunshine Mine) and other experimental programs (e.g., Waste Isolation Pilot Plant) can be useful to determine practical temperature limits for human activity. Amendments used to stabilize the spoil piles and/or control dust may also alter its properties.

Reference:

Woodson, W.E. 1981. *Human Factors Design Handbook.* New York, NY: McGraw-Hill.

National Institute for Occupational Safety and Health. 1972. *Criteria for a Recommended Standard-Occupational Exposure to Hot Environments* HSM72-10269. Washington, DC: U.S. Government Printing Office.

QUESTION 5

No mention is made in the report section on "Retrieval Considerations" of plans for compliance with the waste package (WP) design requirement in 10 CFR 60.135(b)(3) to design the waste package for containment during retrieval.

Basis:

The regulatory requirement in 10 CFR 60.135(b)(3) requires that the WP be designed for containment of radionuclides during retrieval.

Recommendation:

The report section on "Retrieval Considerations" should describe the plans for compliance with the WP design requirement in 10 CFR 60.135(b)(3) to design the WP for containment during retrieval (Nuclear Regulatory Commission, 1991). Alternatively, the report section on "Retrieval Considerations" could refer to a description of plans for compliance with this WP design criterion where it appears elsewhere in the report.

Reference:

Nuclear Regulatory Commission. 1991. *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Title 10, Energy, Part 60 (10 CFR Part 60). Washington, DC: U.S. Government Printing Office.

QUESTION 6

The time periods required for cooling to 50 °C (122 °F) given in the text (page 8-176, paragraph 3, and page 8-178, paragraph 1) cannot be deduced from Figure 8.12.5-1 as asserted.

Basis:

Figure 8.12.5-1 is based on 100 m^3/sec airflow rate, while the discussion of time periods necessary to cool to 50 °C is based on 150 m^3/sec air flowrate.

Recommendation:

Figure 8.12.5-1 should be replaced with a similar figure that displays results for 150 m^3/sec airflow rate, so that the information in the figure and that in the text can be correlated by the reader.

Reference:

Figure 8.12.5-1 on page 8-177.

4 SPECIFIC CONCERNS

4.1 OBJECTIONS

There are no objections based on the review of this initial summary version of ACD.

4.2 COMMENTS

Section 5.1.1 Topography and Section 5.1.5 Faults

COMMENT 1

The quote (page 5-1) that the Primary Area contains "Relatively few faults with only minor offset and rare Breccia" and the map shown in Figure 5.1.5-5 do not reflect knowledge recently gained regarding the Ghost Dance Fault Zone and the Sun Dance Fault Zone. The faulting in the Primary Area at an elevation of 1,067 m could be more complex than shown on Figure 5.1.5-2.

Basis:

Recent detailed surface geologic mapping (Spengler et al., 1993) has shown that the Ghost Dance Fault is a zone nearly 366 m wide. A zone 274 m wide of near-vertical N30°–40°W trending faults was recently mapped (Spengler et al., 1994). This recent detailed mapping suggests that the primary area may be more structurally complex than suggested in the ACD.

Recommendation:

The role of small but numerous faults and downward projection of these fault zones into the repository horizon should be considered in the ACD. A standoff of 120 m is probably not conservative, given the width of these zones at the surface. However, the NRC recognizes that, until the zone has been penetrated by the ESF tunnel, most predictions of subsurface fault distribution are estimations.

References:

Spengler, R.W., C.A. Braun, L.G. Martin, and C.W. Weisenberg. 1994. The Sundance Fault: A newly recognized shear zone at Yucca Mountain, Nevada. *Proceedings of the Fifth Annual International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 2,359–2,366.

Spengler, R.W., C.A. Braun, R.M. Linden, L.G. Martin, D.M. Ross-Brown, and R.L. Blackburn. 1993. Structural character of the Ghost Dance Fault, Yucca Mountain, NV. *Proceedings of the Fourth Annual International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society: 653–659.

Section 5.1.2.2 Zeolitic Tuffs

COMMENT 2

Section 5.1.2.2 on zeolitic tuffs is not adequate as a description of the distribution and potential role of zeolites in repository performance at Yucca Mountain.

Basis:

Zeolites at Yucca Mountain have been widely cited as a potentially favorable characteristic of the Yucca Mountain site because of their sorptive capacity. Extensive research has been conducted on the distribution, stability, and sorption characteristics of these zeolites. If zeolites are anticipated in the ACD to provide an important "barrier" to radionuclide transport, then the design for the location of wastes in the repository should take account of current understanding of their distribution and chemistry. Section 5.1.2.2, however, recognizes no literature dated after 1986.

Recommendation:

If zeolitic tuffs and their role in retardation of radionuclide transport are to be a significant element of the ACD, it is recommended that references provided below and related information be reviewed for incorporation into an ACD.

References:

Bish, D.L. 1990. Long-term thermal stability of clinoptilolite: The development of a "B" phase. *European Journal of Mineralogy* 2: 771–777.

Bish, D.L., and J.L. Aronson. 1993. Paleogeothermal and paleohydrologic conditions in silicic tuff from Yucca Mountain, Nevada. *Clays and Clay Minerals* 41: 148–161.

Bish, D.L., and S.J. Chipera. 1989. *Revised Mineralogic Summary of Yucca Mountain, Nevada.* LA-11497-MS. Los Alamos, NM: Los Alamos National Laboratory 68.

Broxton, D.E. 1992. Chemical changes associated with zeolitization of the tuffaceous beds of Calico Hills, Yucca Mountain, Nevada, USA. *Water-Rock Interaction.* Y.K Kharaka and A.S. Maest, eds. Rotterdam, The Netherlands: A.A. Balkema.

Broxton, D.E., D.L. Bish, and R.G. Warren. 1987. Distribution and chemistry of diagenetic minerals at Yucca Mountain, Nye County, Nevada. *Clays and Clay Minerals* 35: 89–110.

Levy, S.L. 1991. Mineralogic alteration history and paleohydrology at Yucca Mountain, Nevada. *Proceedings of the Second Annual International High-Level Radioactive Waste Management Conference.* La Grange Park, IL: American Nuclear Society: 477–485.

Levy, S.L., and J.R. O'Neil. 1989. Moderate-temperature zeolitic alteration in a cooling pyroclastic deposit. *Chemical Geology* 76: 321–326.

Murphy, W.M., and R.T. Pabalan. 1994. *Geochemical Investigations Related to the Yucca Mountain Environment and Potential Nuclear Waste Repository*. NUREG/CR-6288. Washington, DC: Nuclear Regulatory Commission.

Pabalan, R.T. 1994. Thermodynamics of ion-exchange between clinoptilolite and aqueous solutions of Na^+/K^+ and Na^+/Ca^{2+}. *Geochimica et Cosmochimica Act* 58: 4,573–4,590.

Section 5.4 Geochemistry

COMMENT 3

It is questionable that an adequate ACD can be developed when "Data related specifically to soil, groundwater, or rock geochemistry have not been specifically considered for ACD" as stated in Section 5.4.

Basis:

Groundwater, gas, and mineral chemistry have fundamental impacts on containment because they control the waste package degradation process. Geochemistry has a fundamental impact on the radionuclide source term because it controls processes of waste form alteration and radioelement solubilities. Geochemistry has a fundamental impact on radionuclide transport because it affects hydraulic properties by changes in porosity, permeability, saturation, and tortuosity; because it controls aqueous radionuclide speciation; and because it controls the distribution of radionuclides among phases and surfaces, which, in turn, controls retardation of radionuclide transport. Designs for waste forms, waste containers, and engineered structures should account for the manner in which they will interact with the chemical environment because of the important relations of these interactions to repository performance. In the absence of consideration of these effects, a conceptual design may well have fundamental flaws such as basic incompatibilities between engineered materials and the environment.

Recommendations:

Develop a detailed description of site geochemistry and evaluate relations between geochemistry and other aspects of the conceptual design and repository performance. Basic references are given in the following section.

References:

Apps, J.A., C.L. Carnahan, P.C. Lichtner, M.C. Michel, D. Perry, R.J. Silva, O. Weres, and A.F. White. 1982. *Status of Geochemical Problems Relating to the Burial of High-Level Radioactive Waste*. NUREG/CR-3062. Washington, DC: Nuclear Regulatory Commission.

Krauskopf, K.B. 1988. *Radioactive Waste Disposal and Geology*. New York, NY: Chapman and Hall.

Science Applications International. 1992. *Report of Early Site Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada*. SAIC-91/8000. Las Vegas, NV: Science Applications International.

U.S. Department of Energy. 1988. *Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada*. DOE/RW-0199. Washington, DC: U.S. Department of Energy.

Section 8.2.1.3 Preferred Orientation of Drifts

COMMENT 4

Selection of the most favorable drift orientation requires more justification. The rationale for deciding the orientation without considering the sidewall stability and the justification for 30° standoff were not provided.

Basis:

The most favorable drift orientation was based on SAND84-2641 (page 6-33) (Sandia National Laboratories, 1987) with the assumption of two joint sets. However, Table 5.1.6-1 and Section 8.2.1.4 of the present document identify four joint sets in the Topopah Spring member as measured in USW GU-3 and USWG-3 boreholes. Each joint set shows considerable variation around the mean value [Figures 3-2(b) and 3-3(b) of Lin et al., 1993]. Moreover, SAND84-2641 considered only the stability of the roof; no consideration was given to the sidewall stability of the drifts. Stability of the sidewalls of an opening in a fractured rock mass is one of the primary factors governing the roof stability. Strictly speaking, the immediate rock mass above the roof cannot be stabilized unless the sidewalls are effectively stable. Because of the above deficiencies, the estimated most favorable drift orientation may not be correct.

Recommendation:

DOE should conduct the analysis taking into consideration the site-specific information about the rock joint sets. The analysis should consider both the roof and sidewall stability and the ground control measures necessary (Hoek and Brown, 1980), taking into account the observed variation of dip and direction within each joint set.

References:

Hoek, E., and E.T. Brown. 1980. *Underground Excavations in Rock*. Institution of Mining and Metallurgy: London, U.K.

Lin, M., M.P. Hardy, and S.J. Bauer. 1993. *Fracture Analysis and Rock Quality Designation Estimation for the Yucca Mountain Site Characterization Project*. SAND92-0449. Albuquerque, NM: Sandia National Laboratories.

Sandia National Laboratories. 1987. *Nevada Nuclear Waste Storage Investigations Project, Site Characterization Plan Conceptual Design Report*. SAND84-2641. Albuquerque, NM: Sandia National Laboratories.

Section 8.3.2 Repository Thermal Loading

COMMENT 5

In Table 8.3.1-1, the sixth thermal goal is not a goal.

Basis:

In Table 8.3.1-1, 16 thermal goals are listed. Most items have a clear statement of the process of interest, performance measure, and thermal goal. The sixth goal, however, is stated to have the performance measure of "thermal loading." Thermal loading is not a performance measure but is a controllable design feature that strongly influences the repository performance. For a given thermal load, the temperatures, uplift, and displacements (which are good performance measures) can be calculated and then compared with their respective thermal goals.

Recommendation:

The DOE should revise the statement of the sixth thermal goal.

Section 8.3.5.1 Extraction Ratio Consideration

COMMENT 6

The ACD may overlook the potential long-term deformation and deterioration of the pillars in the area of emplacement drifts, which is one of the factors governing the surface movement.

Bases:

It is true that short-term failure of the pillars is unlikely due to the proposed extraction ratios of less than 30 and 10 percent. Long-term deformation of the pillars may occur due to the increase of the vertical stress after excavation, deterioration under thermal loading, and due to weathering resulting from, for example, fluctuation of temperature and moisture content due to ventilation. Such deformation may cause subsidence of the overlying strata. Even though such long-term subsidence may not be detectable as it may be obscured by the thermally induced uplift, the process of such rock movement exists and will continue through and after the isolation period, while the thermally induced uplift will eventually decrease (after the waste temperature reduces).

In addition, care should be taken in applying the extraction ratio concept used in the conventional room-and-pillar mining to the repository site. The proposed extraction ratios of 30 and 10 percent may be considered overly conservative for conventional mining, but they may not be appropriate for use in evaluation of the stability of the emplacement drift area due to the potential effects stated in the previous paragraph. It should be noted that openings in the conventional room-and-pillar mines are usually abandoned within a few years after excavation (only a few entries are maintained and remain open for passage), while all emplacement drifts must remain stable for several decades after excavation.

Recommendations:

The ACD should address the movement of the strata overlying the proposed repository which may be caused by the excavation of the emplacement drifts and long-term degradation of the pillars. The limitation of the application of extraction ratio concept to assess the stability of the emplacement drift area should be discussed.

Section 8.3.5.2 Drift Stability

COMMENT 7

Parameters and assumptions used in the drift stability analysis are not conservative. Not all factors that may affect drift stability are considered in the analysis.

Bases:

Parameters and assumptions used to determine and analyze the stability of intact rock around the drift may not be conservative. The ACD states that "...no intact rock failure was predicted (under thermal loading) for any of the three rock mass categories used in the analysis." It is agreed that the potential mode of instability of rock mass around the emplacement drifts would likely be joint slipping near the opening boundary. However, the predicted maximum stresses of 79 to 90 MPa (as indicated on page 8-40) near the drift boundary under thermal loading also exceed the minimum value of the range of unconfined compressive strength of the intact rock (given in Table 8.2.1-1, page 8-16). This higher maximum stress indicates that potential failure of the intact rock is possible in the area of high stress concentration in which the intact rock strength is low or near the minimum strength value.

The fourth paragraph of Section 8.3.5.2 of the ACD summarizes the results of numerical simulation by Sandia National Laboratories (SNL) (Ryder and Holland, 1992), and implies that the instability zone due to joint slipping, around the drift under long-term thermal loading is limited, based on the assumptions of three rock mass qualities. It should be noted that the long-term stability of the rock mass around the drift does not depend only on the effects of thermal loading. Recognition of the effect of thermal stress alone may not be adequate to draw a conclusion that the drifts will be essentially stable up to several decades. The ACD should recognize and address other factors governing the long-term stability, such as deterioration of the support system and rock mass near the opening wall, time-dependent behavior of joints under *in situ* and excavation-induced stresses, behavior of rock and joints under thermal loads, etc.

Recommendations:

Due to the high intrinsic variability of the strength of the Topopah Spring tuff and the uncertainties with regard to the long-term behavior of the rock, the minimum value of the rock strength and joint behavior should be used in the analysis to obtain a conservative assessment of drift stability. In addition, data on intact rock and joint strength under elevated temperatures, if available, should be used to analyze the stability of the emplacement drifts under thermal loading. Justification should be provided if the strengths tested under low temperatures are used to compare with stresses in rock under thermal loads.

All factors potentially affecting the drift stability should be recognized and addressed, even though some factors remain uncertain and their influence is subject to further study.

References:

Ryder, E.E., and J. Holland. 1992. *Results of Two-Dimensional Near-Field Thermal Calculations in Support of an M7O Study on Repository Thermal Loading*. Draft Report. Albuquerque, NM: Sandia National Laboratories.

Section 8.3.5.3 Shaft and Ramp Stability

COMMENT 8

The ACD addresses the conclusions drawn from previous studies conducted by SNL (Hardy and Bauer, 1991; Richardson, 1990; St. John, 1987) to support the contention that the potential for thermally induced instability of shafts and ramps is low. For the shaft, assessment of its stability based on the impact of thermal loading alone may not be adequate.

Basis:

It is true that the direct impact of the heat released from the emplacement drifts on rock around the shaft is probably low. However, the stability of the rock mass around the shaft and shaft lining may also be affected by the differential movement of the overburden strata above the repository block and seismic loading.

Recommendations:

Assessment of the shaft stability should include the impact of the regional movement of the overburden strata and seismic load. The ACD should describe whether such impact is significant.

References:

Hardy, M.P., and S.J. Bauer. 1991. *Drift Design Methodology and Preliminary Application for the Yucca Mountain Site Characterization Project*. SAND89-0837. Albuquerque, NM: Sandia National Laboratories.

Richardson, A. 1990. *Preliminary Shaft Liner Design Criteria and Methodology Guide*. SAND88-7060. Albuquerque, NM: Sandia National Laboratories.

St. John, C.M. 1987. *Reference Thermal and Thermal/Mechanical Analyses of Drifts for Vertical and Horizontal Emplacement of Nuclear Waste in a Repository in Tuff*. SAND86-7005. Albuquerque, NM: Sandia National Laboratories.

Section 8.4 Excavation Methods and Equipment; and Section 8.7 Description of Subsurface Operations

COMMENT 9

The use of drill/blast excavation methods is retained as a contingency without specific provisions to address previously stated NRC concerns on possible impacts of large-scale drill-and-blast on repository performance.

Basis:

The conceptual design for some secondary excavations, such as the radiation door cutouts and the "crosscut" drifts between the "service main" and "launch main" drifts, is based on the assumption that mechanical-excavation technology, which is currently being researched at the Colorado School of Mines, will be "fully developed, tested, and available for repository secondary excavation tasks" (Section 8.7.1.1).

Furthermore, it was also stated in the ACD (Section 8.4.2.4) that "while mechanized excavation will undoubtedly retain favor as the preferred, principal repository excavation method, there is still the possibility that specific applications will favor the drill/blast technique because of its flexibility..." These statements suggest that the drill/blast technique is being retained as a contingency and may actually be applied for the secondary excavations, should the expected new mechanical-excavation technology fall short.

Recommendation:

The scope of possible use of drill-and-blast should be defined clearly, and the NRC concerns regarding possible impacts of large-scale drill-and-blast (which are summarized in Section 8.4) should be addressed specifically, using well-proven blasting engineering methods.

Section 8.5.1.2 Alcove Emplacement

COMMENT 10

In evaluating the alcove emplacement concepts, the stability of the pillars left in between two neighboring alcoves is an important consideration due to the effect of stress concentration. In the ACD, the width of pillars was determined using the "rule-of-thumb" that the pillar width should be two times the alcove width for the perpendicular or angled alcove concepts, or two times the alcove length for the parallel alcove concept. The use of this method of approximating does not seem to be justifiable.

Bases:

The ratio used in the ACD for the determination of pillar width in the evaluation of alcove emplacement concepts was originally developed for an ordinary underground facility or mine in which the only concern for the stability is the stress concentration induced by excavation. In the repository environment, the thermally induced stresses may be an equally important consideration in assessing the stability of a pillar. Furthermore, the stability of the pillars could be further reduced through the thermal expansion of the pillars due to the fact that there is no constraint on the sides of the pillars. Consequently, this value may not provide the conservative design for the pillars needed in the alcove emplacement concept.

Further, this method of approximating seems to be intended for maintaining stable pillars for the service life of an ordinary underground facility or mine. For a high-level nuclear waste geologic repository, the required service is relatively longer; close to or more than 100 yr of operation including emplacement and maintaining retrievability. The requirement for the long-term stability of pillars will be more stringent if the emplacement area is not going to be backfilled after permanent closure. (Not to backfill the emplacement area after permanent closure is still a viable option in the repository design.) It should also be noted that thermal loads are not a common design consideration for underground mines. It is not clear if this method for determining long-term stability of pillars can be applied to the repository design.

Recommendation:

Evaluate the applicability and conservatism of the method for designing long-term stable pillars considering the repository conditions.

Section 8.6.4 Interim Layout Description

COMMENT 11

The excavation turnoff for the TBM Launch Main/Waste Handling Main from the north ramp extension appears to be unduly close to the intersection of the Drill Hole Wash Fault structure and the north ramp extension (see Figure 8.6.4-2).

Basis:

It is most likely that there is some amount of error associated with the exact location of contact of the Drill Hole Wash Fault structure with the planned repository. As such, the design of excavations (i.e., the above mentioned TBM Launch Main/Waste Handling Main turnoff) should factor in some additional distance or offset to assure that the length of excavation in such fault zones is minimized, or at least maintain the flexibilities on lay-out, depending on what is found below the repository level. This concern has already been factored into the design of the turnoff of the north ramp extension from the main north ramp, where the initial design was modified to ensure that the turnoff was well above the contact between the north ramp and drill hole wash. This design modification also allowed the north ramp extension to intersect the Drill Hole Wash Fault structure at a higher angle, thus minimizing the extent of excavation in this fault zone. This same design methodology should likewise apply to the turnoff for the TBM launch main/waste handling main, where not only is it very close to the Drill Hole Wash Fault but presently would intersect the fault at a very low angle. This concern is further justified by the fact that the TBM launch main/waste handling main would have a diameter of 9.0 m versus only 7.62 m for the north ramp and north ramp extension. The increased diameter is also less favorable from a stability standpoint.

Recommendation:

Consideration should be given to initiating the turnoff for the TBM launch main/waste handling main further up the north ramp extension such that the Drill Hole Wash Fault structure is intersected at a higher angle and over a shorter distance. It is believed that in this layout modification, the turnoff could still be constructed to mate with the existing alignment of the TBM launch/waste handling main.

Section 8.6.4.5 Perimeter Ventilation Main and Section 8.8 Subsurface Ventilation

COMMENT 12

The perimeter ventilation main, as provided in Figures 8.8-1 and 8.8.-2, is planned to be used for various activities such as development and emplacement operations, performance confirmation, backfilling operations, and retrieval of equipment. Special design considerations required for this multipurpose ventilation system have not been provided in the ACD.

Basis:

The perimeter ventilation main (Section 8.6.4.5, page 8-98) will be used as a primary ventilation airway in both repository operations: development and emplacement. In addition, it will also be used for other purposes, when ventilation needs may be different from those required for development and emplacement operations. The design needs that meet the multipurpose ventilation requirements should be discussed in the ACD.

Recommendation:

The DOE should provide a robust and versatile design for perimeter ventilation main.

Section 8.8 Subsurface Ventilation, Section 8.12.5 Retrieval Ventilation Considerations

COMMENT 13

Section 8.8 (page 8-145) has identified activities where subsurface ventilation will control air movement. This list does not include retrievability operations. However, Section 8.12.5 (page 8-175) includes discussion regarding a retrievability period of up to 100 yr after initiation of waste emplacement. This section has not identified the final concept. Presently two separate concepts are under consideration: (i) Continuous ventilation, and (ii) Ventilation as needed. Discussion of criteria and factors affecting each ventilation option should be provided.

Basis:

The final design concept for retrievability will directly affect the proposed initial ventilation design, based on the two different retrievability design concepts. Also, the thermal loading strategy has an impact on these proposed concepts.

Recommendation:

The DOE should provide some discussion on the advantages and disadvantages of these two concepts and how they might affect the initial ventilation designs, now that revised thermal load information is available.

Section 8.12 Retrieval Considerations

COMMENT 14

The DOE retrieval considerations do not show an awareness of potential retrieval difficulties due to rock instability caused by thermal loading and thermal-hydrological-mechanical-chemical (THMC) effects.

Bases:

Instability could be exacerbated by thermally induced movement and thermal gradients between drifts during planned cooling before retrieval begins. The hazard to retrievability due to thermally induced movement is amplified if local temperatures are greater than those anticipated as the cooling effect of ventilation is precluded due to rockfalls in emplacement drifts or emplacement of backfill (if used). Factors such as the critical thermal gradient for opening instability for a given set of rock properties and stress conditions should be well understood before finalizing retrieval plans.

Due to the retrievability uncertainty associated with thermal-loading effects, it is expected that the DOE will undertake an inspection program to detect incipient rock instability in ramps and emplacement drifts, with periodic inspections. Such a program could identify problem areas and provide guidance for any maintenance of ramps and emplacement drift openings.

As noted in NUREG-0804 (Nuclear Regulatory Commission, 1983), "Failure of underground openings could result in the inability of the licensee to retrieve the wastes practicably, should such a course of action be found to be warranted. The consequence of this failure could be a transport of radionuclides to the accessible environment at levels exceeding the performance objectives."

In 10 CFR 60.133(e)(1) (Nuclear Regulatory Commission, 1991), underground facility openings are required to be designed so that "operations can be carried out safely and the retrievability option maintained."

The specific citation of thermal loads as an important criterion in the design for the underground facility [(Sec. 60.133(i)] emphasizes the NRC concern for meeting performance objectives, including retrievability, in light of large uncertainties associated with predicting the effects of thermal loading on repository performance (Nataraja, 1992). In NUREG-0804, this large uncertainty is provided as a rationale for the containment requirement. Also, from NUREG-0804, "the thermal loading of the waste in the emplacement areas will affect the temperature of the host rock and the stability of the underground structure. These factors will have a large effect on the ability to retrieve the wastes, since the structure could become too unstable or the rocks too hot to safely recover the wastes." In the development of the License Application Review Plan (LARP), a key technical uncertainty has been identified concerning the ability to retrieve, particularly in view of the uncertainty associated with repository performance under thermal loading conditions.

Recommendations:

The section on retrieval considerations should include information to describe the DOE efforts to reduce uncertainty with respect to thermal loading and its effect on underground openings stability with respect to retrieval. Any related inspection and maintenance program to maintain the integrity of underground openings for retrievability should also be described. As an alternative, the DOE may choose to refer to such discussions where they appear elsewhere in the report.

References:

Nataraja, M.S., and T. Brandshaug. 1992. *Staff Technical Position on Geologic Repository Operations Area Underground Facility Design-Thermal Loads*. NUREG-1466. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories*. NUREG-0804. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1991. *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Title 10, Energy, Part 60 (10 CFR Part 60). Washington, DC: U.S. Government Printing Office.

Section 8.12.1 Pre-Retrieval Considerations

COMMENT 15

The report section on "Pre-Retrieval Considerations" does not indicate adequate consideration of the requirements in 10 CFR Part 60 [Sec. 60.132(a) and Sec. 60.21(c)(12)] (Nuclear Regulatory Commission, 1991). On page 8-169, under "Step 2," a brief mention is made of bringing surface facilities to full operational capability and incorporating facility modifications or additions not initially constructed but incorporated into the original design.

Basis:

Plans for surface facility storage and operations for handling retrieved waste are required in 10 CFR Part 60 (Sec. 60.132(a) and Sec. 60.21(c)(12)). Such plans and related design considerations may be significant, especially if all the emplaced waste requires retrieval.

Recommendation:

The report section on "Pre-Retrieval Considerations" should indicate how the surface facility design allows safe handling and storage of retrieved wastes, up to the full inventory of emplaced HLW. Alternatively, this section of the report could refer to another section of the report in which such information is provided.

Reference:

Nuclear Regulatory Commission. 1991. *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Title 10, Energy, Part 60 [10 CFR Part 60—Section 60.132(a) and Section 60.21(c)(12)]. Washington, DC: U.S. Government Printing Office.

Section 8.12.4 Retrieval Equipment Considerations

COMMENT 16

The "current assumption of 100 years in the ACD" (page 8-175, paragraph 1) for the retrievability period is probably reasonable, but the basis for the 50-yr period cited on page 8-174 is not correct.

Basis:

The NRC has described the basis for the retrievability period in NUREG-0804. The discussion in Section 8.12.4 of the report is in conflict with the NRC description of the retrievability period. The "retrievability period of up to the statutory 50 year length after first emplacement" (page 8-174, Section 8.12.4, paragraph 6) is an inaccurate interpretation of the retrievability period identified in 10 CFR Part 60. The beginning of the period of retrievability is identified in 10 CFR 60.111(b)(1): "The geologic repository operations shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced, and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 yr after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program." Furthermore, the "reasonable schedule" for retrieval is defined in 10 CFR 60.111(b)(3): "For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes."

Retrieval must remain an option, therefore, over the longest of any of the following periods: (i) 50 yr after waste emplacement operations are initiated plus the "reasonable schedule" for retrieval that follows thereafter; (ii) the time duration, chosen by the Commission on a case-by-case basis, following the initiation of waste emplacement operations plus the "reasonable schedule" for retrieval; or (iii) the time period encompassing the performance confirmation period plus the Commission review of the performance confirmation program information.

Also, the Commission stated in NUREG-0804 (Nuclear Regulatory Commission, 1983), that "It should be noted that DOE may elect to maintain a retrievability capability for a longer period than the Commission has specified, so as to facilitate recovery of the economically valuable contents of the emplaced materials (especially spent fuel)."

Recommendation:

The discussion in Section 8.12.4 of the report should be modified so that it is in agreement with the NRC published description of the retrievability period.

Reference:

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60: Disposal of High-Level Radioactive Wastes in Geologic Repositories*. NUREG-0804. Washington, DC: Nuclear Regulatory Commission.

Section 8.12.5 Retrieval Ventilation Considerations

COMMENT 17

As shown in Figures 8.12.5-1 and 8.12.5-2, the assumed initial rock temperature of 170 °C (248 °F) may not be conservative for certain "hot repository" designs. Cooling times estimated based on nonconservative, low assumed initial rock temperature will be correspondingly shorter than expected cooling times for a "hot repository" design. Also, TMHC effects may be underestimated when compared to certain "hot repository" designs.

Basis:

Temperature profiles given on page 6-181, for example, indicate drift roof and wall temperatures may exceed 200 °C (392 °F) for 110-111 Metric Ton Uranium (MTU)/acre area mass loading after 50 yr of emplacement.

Recommendation:

The assumed initial rock temperature of Figures 8.12.5-1 and 8.12.5-2 should be made consistent with results of analyses as described in other parts of the report (e.g., page 6-181). Until the repository thermal load design is finalized, contingency plans should be included to reflect higher initial rock temperatures associated with "hot repository" designs.

References:

Figures 8.12.5-1 and 8.12.5-2 and page 6-181.

Section 12 Uncertainties, Issues, and Recommendations

COMMENT 18

Section 12 of the ACD (Uncertainties, Issues, and Recommendations) only addresses uncertainties associated with parameters influenced by thermal loading. Thermal loading is expected to influence many aspects of repository design and performance. However, THMC coupled effects as well as processes not specifically related to thermal loading must be considered in order to demonstrate compliance with design and performance requirements from 10 CFR Part 60 (Nuclear Regulatory Commission, 1991).

Bases:

Demonstrating compliance with the regulatory requirements of 10 CFR Part 60, as they relate to repository design, will necessitate addressing technical uncertainties associated with the following, among others.

- A description and discussion of the design, both surface and subsurface, of the geologic repository operations area [10 CFR 60.21(c)(2)]
- A description and analysis of the design and performance requirements for structures, systems, and components that are important to safety [10 CFR 60.21(c)(3)]
- Demonstration of compliance with the total and subsystem performance objectives including the periods prior to and following permanent closure and the performance of specific engineered barriers (10 CFR 60.111, 112, and 113)
- Demonstration that the design bases are consistent with the results of site characterization (10 CFR 60.134)
- Compliance with specific design criteria considering such issues as radiation protection, criticality control, retrievability of waste, rock excavation, waste package integrity, and selection of seals materials (10 CFR 60.131 through 135).

The items listed above require resolution of technical uncertainties that are frequently accentuated by thermal loads through coupled THMC effects (Manteufel et al., 1993).

The NRC has identified a number of key technical uncertainties that are specifically related to demonstrating compliance with requirements from 10 CFR Part 60 associated with repository design (Nuclear Regulatory Commission, 1994). These key technical uncertainties are considered to be the most important technical issues because they may significantly impact the performance of the repository and may be the most difficult technical issues to resolve. Following is a partial list of the technical issues.

- Prediction of the long-term performance of seals for shafts, ramps, and boreholes
- Prediction of the THMC responses of the host rock, surrounding strata, and groundwater system to thermal loads

- Demonstration of compliance with the requirement to maintain the ability to safely retrieve high-level waste
- Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package
- Prediction of thermomechanical effects on the waste package and the Engineered Barrier System (EBS).
- Prediction of environmental effects on the waste package and the EBS
- Prediction of criticality events in waste packages
- Prediction of release path parameters (such as size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects
- Prediction of the releases of gaseous and nongaseous radionuclides from waste packages during the containment period and from the EBS during the post containment period
- Extrapolation of short-term laboratory and prototype test results to predict long-term performance of waste packages and the EBS

While some of these key technical uncertainties may ultimately be consolidated or refined, they nonetheless represent technical issues related to repository design that are directly linked to regulatory requirements from 10 CFR Part 60. Their resolution will need to be addressed in repository design documents and in demonstrations of compliance.

Recommendations:

The advanced conceptual design should be expanded to consider technical uncertainties other than those restricted to thermal loading. Additionally, the design should be presented in such a manner that it can be linked to compliance with requirements from 10 CFR Part 60.

References:

Manteufel, R.D., M.P. Ahola, D.R. Turner, and A.H. Chowdhury. 1993. *A Literature Review of Coupled Thermal-Hydrologic-Mechanical-Chemical Processes Pertinent to the Proposed High-Level Nuclear Waste Repository at Yucca Mountain*. NUREG/CR-6021. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1991. *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Title 10, Energy, Part 60 (10 CFR Part 60). Washington, DC: U.S. Government Printing Office.

Nuclear Regulatory Commission. 1994. *License Application Review Plan for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste*. Draft Review Plan. NUREG-1323, Revision 0. Washington, DC: Nuclear Regulatory Commission.

Section 12.2 Waste Package

COMMENT 19

In Section 12.2 of the DOE ACD summary report, no mention is made of the uncertainty in the mechanical properties, specifically fracture toughness, of the waste package materials [disposal overpack and the MPC as a result of thermal exposure over long periods of time.

Bases:

Failure of waste package materials due to mechanical loads may result in loss of containment as required in 10 CFR 60.113(a)(1)(ii)(A). For example, a carbon steel outer disposal overpack may undergo temper embrittlement due to grain boundary phosphorus segregation from long-term exposure to repository temperatures. The temper embrittlement susceptibility is exacerbated by some alloying elements, such as Ni and by microstructural features such as large grain sizes found in weldments (Sridhar et al., 1994). The mechanical loading may occur through either seismic events or from residual stresses created in the weldment due to closure welding of thick components under restrained conditions.

Mechanical failure of the MPC basket material, which is designed to reduce the possibility of criticality and distribute the thermal energy within the MPC, may result in failure to meet the criticality control requirement in 10 CFR 60.131(b)((7). The basket material is proposed to be made of borated alloy, which may be susceptible to precipitation of intermetallic phases and segregation of boron to grain boundaries. In the ACD, only issues pertaining to thermomechanical performance of host rock are mentioned. Long-term exposure of waste package materials may result in the deterioration of their fracture toughness, resulting in catastrophic mechanical failure of one or more of the components. The mechanical loading may occur from a variety of sources including seismic effects, residual stresses due to closure welding, and thermal stresses due to differential cooling of some parts of the waste package.

Recommendations:

The report section on uncertainties, issues, and recommendations must include a consideration of thermomechanical performance of waste package materials in addition to that of the host rock. In terms of the assessment of waste package performance, attention must be given to potential changes in fracture toughness of the steel overpack, MPC, and basket materials as a result of extended thermal exposure and mechanical loading in the repository.

References:

Sridhar, N., G.A. Cragnolino, D.S. Dunn, and H.K. Manaktala. 1994. *Review of Degradation Modes of Alternate Container Designs and Materials*. CNWRA 94-010. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Section 12.2 Waste Package

COMMENT 20

The uncertainties and issues related to the WP contents and components address only a few areas, namely, an order of magnitude variability in the corrosion rates of WP materials, variability in types of spent fuel, and potential for the inability to take credit for the cladding in the post-closure period. However, a number of other important areas related to spent fuel and cladding have considerable uncertainties.

Bases:

In addition to the three areas of uncertainty and licensing issues discussed in Section 12, the following specific concerns related to other important areas need to be addressed and resolved satisfactorily:

- The WP design calls for use of several types of materials of construction. The compatibility of these materials needs careful evaluation. Incompatibility of materials used in the WP could lead to rapid degradation of certain components of the WP, for example, via galvanic corrosion. Such a situation calls for the identification of the potential "sacrificial" anodes in the WP, such as welds or components of dissimilar metals, and their consideration as the life-limiting components in estimating the design life of the WP.

- Spent fuel assemblies from the 1970s exhibited a considerable number of in-service failures. In some cases, particularly in boiling water reactor fuels, more than 30 percent of the discharged fuel assemblies had fuel failures (Moore et al., 1990). Since such discharged fuel is not representative of the "design-base" fuel, the disposal of such fuel needs to be specifically addressed.

- The current inventory of spent fuel samples represents less than 25 percent of the spent fuel that will eventually go into the repository. The existing data base does not have high-burnup, high-fission gas release fuel or pressurized water reactor fuel with burnable poison, such as gadolinium (Marschman et al., 1994). Use of the data from a fuel representative of only a small fraction of the disposal inventory could be a licensing concern.

Recommendation:

It is recommended that compatibility of various types of materials used in the construction of the WP as well as the contents of the waste package, that is, spent fuel and vitrified wasteform, be addressed. Areas of particular concern are welding and galvanic corrosion. The inventory of discharged fuel assemblies that have "leaker rods" is considerable. With the old fuel first disposal strategy, it is likely that such fuel assemblies will be disposed of first. Performance analyses need to include fuel assemblies with a higher fraction of leaker rods than is being currently considered. The presence of leaker rods with entrained water could lead to the possibility of internal corrosion. The current data base on the inventory, heterogeneities in the spent fuel, namely, radionuclide distribution within the fuel pellets, and the leaching characteristics of the spent fuel, needs to be expanded to include characteristics of the fuel that will form the majority of the inventory to be accommodated in the repository.

References:

Marschman, S.C., R.E. Einziger, and R.B. Stout. 1994. Rationale for determining spent fuel acquisitions for repository testing. *Proceedings of the Fifth Annual International High- Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society 2: 1,074–1079.

Moore, R.S., K.J. Notz, and C.G. Lawson. 1990. Classification of LWR defective fuel data. *Proceedings of the SPECTRUM '90 Nuclear and Hazardous Waste Management International Topical Meeting*. La Grange Park, IL: American Nuclear Society: 129-132.

Section 12.3 Geochemistry

COMMENT 21

In Section 12.3, the effect of man-made materials on the near-field environment is not considered to contribute to uncertainties in the water chemistry and its impact on waste packages and waste forms. Only the thermal effects are listed as potential areas of uncertainty. While evaporation processes can result in the concentration of certain anionic and cationic species, the introduction of man-made materials, including the waste packages and ground-control systems, can alter the near-field environment substantially.

Basis:

The evolution of the near-field environment is important in assessing the performance of the WPs toward meeting the containment requirements in 10 CFR 60.113(a)(1)(ii)(A) and release rate requirements in 10 CFR 60.113(a)(1)(ii)(B). The man-made materials that may be introduced into the repository environment include cementitious materials (e.g., grouting and shotcrete); organic fluids such as diesel fuel; iron from steel rails and overpacks; and tracer and drilling fluids. Cement used as grouting and/or shotcrete, when in equilibrium with ground water, can raise the pH to high levels. This high pH can enhance corrosion of glass waste form and change the corrosion of steel overpacks from a uniform to a localized mode of attack. The localized corrosion of overpacks can result in acidic conditions inside pits or cracks in steel due to hydrolysis of ferrous ions. Such acidic fluids, upon coming in contact with spent fuel, may increase the solubility of uranyl species. Corrosion of steel can provide the energy, and the organic fluids can provide the nutrients for sustaining microbial activity near the waste packages (Geesey, 1993). Such microbial activity may enhance corrosion as well as influence radionuclide transport. The corrosion products of WPs may also increase the possibility of colloid formation.

Recommendation:

Section 12.3 must reflect the uncertainties in the near-field environment arising from the corrosion of waste package materials, microbial activity, and the interaction of cementitious materials with ground water. In the assessment of substantially complete containment, the effect of alkaline environment on the corrosion of the steel overpacks and the effect of microbiological activity on the localized corrosion of the overpack materials must be considered. In the calculation of release rate of radionuclide, the effect of local acidification due to container corrosion on the solubility of actinides must be considered. The calculation of radionuclides release from vitrified waste form must consider the alkalinity due to the interaction of cement with ground water.

Reference:

Geesey, G. 1993. *Review of the Potential for Microbially Influenced Corrosion of High- Level Nuclear Waste Containers.* G.A. Cragnolino, ed. CNWRA 93-014. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Section 12 Uncertainties, Issues, and Recommendations

COMMENT 22

Section 12 does not address the uncertainty associated with the geologic structures that exist at the repository horizon. This uncertainty could affect the costs of ESF tunnelling and repository construction, the usable volume for repository construction, and the stability of underground excavations, including access and disposal drifts.

Basis:

Presently, a simplistic view of the geologic structure is assumed, as is illustrated in Figure 5.1.5-5. A Key Technical Uncertainty (KTU) associated with poor resolution of exploration techniques to detect and evaluate structural features is applicable to this concern (Nuclear Regulatory Commission, 1994).

Recommendation:

A discussion of uncertainties associated with geologic structures needs to be added to Section 12 (Nuclear Regulatory Commission, 1994).

Reference:

Nuclear Regulatory Commission. 1994. *License Application Review Plan for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste.* Draft Review Plan. NUREG-1323 Revision 0. Washington, DC: Nuclear Regulatory Commission.

Section 12.4 Hydrothermal

COMMENT 23

Section 12.4 of the DOE ACD initial summary report mentions only thermo-hydrological, and thermo-mechanical coupled effects uncertainties. No mention is made of the long-term thermo-mechanical-hydrological (TMH) uncertainties. The TMH coupled phenomena may affect the permeability of the jointed host rock surrounding the EBS and consequently on the performance of the EBS and the total system.

Basis:

Buscheck and Nitao (1993) have shown, through numerical calculations, that matrix-dominated flow will not result in significant vertical transport of radionclides and that fracture-dominated flow is the only credible mechanism of bringing water to the WP and transporting radionuclides to the water table. During radioactive decay of the HLW, the resulting temperature field will generate thermal stresses that produce normal and shear displacements of the fractures.

At Yucca Mountain, the change of fracture permeability may occur due to the ground motion from earthquakes. Recent observations (Hill et al., 1993) that a large earthquake can induce smaller earthquakes at great distances from its epicenter make this issue much more significant than previously thought. Cumulative effects of repetitive seismic loads may form preferential pathways connecting the emplacement area with condensation zones above the emplacement area, perched water zones, or the neighboring steep hydraulic gradient zone.

Heating of the groundwater in the near-field of the repository will produce vaporization, vapor flow, condensation, and condensate flow. Hence, the coupled system becomes one involving thermal, mechanical, and hydrological interactions. The TMH response calculations of the jointed host rock and the EBS are essential to the performance assessment of the EBS and the total system.

Recommendation:

The report section on uncertainties, issues, and recommendations must include consideration of TMH responses of the jointed host rock surrounding the EBS and the EBS.

References:

Buscheck, T.A., and J.J. Nitao. 1993. The analysis of repository-heat-driven hydrothermal flow at Yucca Mountain. *Proceedings of the Fourth Annual International High-Level Radioactive Waste Management Conference*. La Grange Park, IL: American Nuclear Society.

Hill, D.P. et al. 1993. Seismicity remotely triggered by the magnitude 7.3 Landers, California earthquake. *Science* 260: 1,617–1,623.

4.3 QUESTIONS

Section 8.2.1.1A Constructibility and Maintenance

QUESTION 1

The assumed 5-m-thick zone standoff may not be adequate for installation of rock reinforcement.

Basis:

The standoff zone at the crown and sidewalls of a 7.6 m diameter drift from the boundary of the zone containing less than 10 percent lithophysal cavities was determined assuming a nominal rockbolt length of 3 m. Section 8.2.1.1.B suggests that the rock, especially in the proposed repository horizon, is highly variable with varying degree of rock joint intensity. Consequently, a uniform length rockbolt support system will not be feasible. The height of the roof that needs to be supported at any location in the repository will be controlled by the rock joint characteristics at that location. As a result, a 5-m-thick standoff zone around the crown and the sidewalls of the excavations for a typical drift of 7.6 m diameter may not be adequate for installing rockbolts. Moreover, spatial variability of the 10 percent lithophysal cavity boundary is not known due to sparsity of data.

Recommendation:

The DOE should keep some flexibility in the design to accommodate longer than 3 m rockbolts as the available information on rock quality designation and rock joint structure, suggest that a uniform rockbolt length of 3 m may not be conservative to determine the conservative standoff zone.

Section 8.2.1.1 Stratigraphic Criteria for Constructibility and Emplacement

QUESTION 2

The strategy for assigning criteria to develop an optimum or near-optimum selection of repository location is not clearly delineated.

Basis:

Section 8.2.1.1 considers several different criteria for selecting the repository horizon, namely, percentage of lithophysal cavity density, constructibility, thermal properties, and thermal goals. For example, to satisfy thermal goals 1 and 2, the repository horizon should be at least 40 to 60 m above the TSw2/TSw3 contact, depending on local areal power density. The presence of a high lithophysal zone in the lowermost part of the TSw1 unit determines the upper bound of the repository. These criteria may have opposing constraints. Although not considered here, opening stability and constructibility will also influence the selection of repository horizon.

Recommendation:

The DOE should develop a strategy to weight different criteria, which may be conflicting at times, for locating the repository laterally and vertically, based on their relative importance to performance.

Section 8.3.2 Repository Thermal Loading

QUESTION 3

It is important to determine whether the thermal goals for disposal place more stringent limitations on the WP thermal output than the transportation and storage goals.

Basis:

On page 8-23, third paragraph, it is stated that "It may be necessary to limit the maximum initial heat output of packages for transportation and disposal through methods such as derating (limiting the number of assemblies actually loaded into a canister) or aging so that thermal limits in the very-near-field are not exceeded." From this statement, it appears possible that disposal will place requirements that negate the potential benefits of the larger waste package. This issue is very important given the DOE MPC development efforts.

Recommendation:

The DOE should clarify if the MPC will exceed thermal goals in the very-near-field, especially thermal goals 8 (emplacement drift wall temperature <200 °C) and 13 (access drift wall temperature <50 °C). In addition, the drift environment probably will provide higher ambient temperatures for the waste package (up to 200 °C drift wall temperatures). Hence it may be more difficult to maintain thermal goal 11 (fuel cladding temperatures <350 °C).

Section 8.3 Thermal Consideration

QUESTION 4

The discussion of the relative benefits of using areal power density (APD), areal thermal loading (ATL), areal mass loading (AML), and energy equivalent density (EED), appears largely irrelevant to the purpose of Section 8.3.

Bases:

A relatively long discussion is given about the relative merits of APD/ATL, AML, and EED in Section 8.3. The discussion is never related to the design choices the DOE is contemplating, which are primarily related to the waste stream (e.g., young fuel first or old fuel first), size of WP, and the spacing density of WPs.

A number of statements are made about the relative benefits of using a specific description for thermal loading. For example, on page 8-23, it is stated "... recent work utilized the concept of AML. ... the AML method recognizes that WP heat output will be nearly the same after several hundred years for packages containing equal amounts of waste." This statement is not entirely true. It is the combination of MTU, burnup, and cooling time that dictates the thermal output of spent nuclear fuel. The statement omits burnup. It is true that the variability between assemblies may be less for burnup (e.g., 30,000 to 45,000 GWd/MTU) than cooling time (e.g., 10 to 40 yr from reactor). The relative variability is not discussed as a basis for a preferred descriptor. Probably the best reason for using AML is that the repository is described as a 70,000 MTU repository so that it would be a consistent measure of waste. However, this reason is not discussed in the ACD.

Similarly, on page 8-26, the EED is described as an alternative measure that is a compromise between the APD/ATL and the AML approach. It is debatable if this added term clarifies the issues or simply makes it more difficult to understand.

Recommendation:

Avoid a semantic discussion of how to describe thermal loading (APD/ATL, AML, or EED). Instead, concentrate on analyses of the pros and cons of thermal management design options.

Section 8.8 Subsurface Ventilation

QUESTION 5

Two independent ventilation systems with separate airflow systems are to be designed for the development stage of repository and emplacement operations. The validity of the assumptions and their effects on the limitations associated with the proposed pressure differential created between the two ventilation systems need to be examined and assessed.

Basis:

Separation of airflow for these systems is the primary reason to require two ventilation systems since only one of these systems is able to control potential radiation exposures and spread of radioactive contaminants. Thus, the separation of airflow systems is a major concern and needs consideration of different design options and contingencies.

Recommendation:

Test different failure scenarios to determine whether the negative pressure differentials introduced from the proposed installation of positive pressure main fan(s) in the South Ramp and the negative pressure fan(s) at the emplacement exhaust shafts are sufficient to separate the airflow of these systems. Identify other contingency designs that are needed to support this design requirement.

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5 SUMMARY

The Initial Summary Report for Repository/WP ACD contains substantial information intended to reflect the current DOE Yucca Mountain project positions on various issues and design concepts related to the repository design and WP development. The report presents a broad scope of technical information including the underlying methodology, design input, relevant regulatory requirements, design evaluation, analyses, design alternatives and optimization, costs, and scheduling. As an initial summary report, levels of detail presented vary from conceptual and preliminary approaches to detailed evaluation and analysis (e.g., numerical modeling).

The ACD has followed the "Standard Format and Content of Site Characterization Reports for High-Level Waste Geologic Repositories" of the Nuclear Regulatory Commission. Based on the current knowledge of applicable state-of-the-art technology and conventional practices, most of the proposed concepts, technical approaches, supporting rationales, and analyses seem to be valid and justifiable. It is recognized that this ACD is an interim report, many aspects of which are preliminary and will likely be subjected to further refinement and modification. However, the report presents some inappropriate technical approaches and fails to address some relevant events and factors considered significant to repository design and WP development. Levels of concern for these technical inadequacies are reflected as "Comments," "Questions," and "General Concerns."

The current conceptual design, supporting design input, and existing information imply that the location, depth, and extent of the proposed repository block have been selected based primarily on the geology and geoengineering of the site. Not explicitly discussed are the significance and influences of geochemistry of the site on the repository and waste package performance, and the basis for omission of other site characteristics data (such as hydrology, climatology, and meteorology) from the development of the ACD.

One primary concern is related to the KTUs. Although the ACD addresses the impacts of thermal and seismic loads in many aspects of the conceptual design, other issues related to technical uncertainties associated with the regulatory requirements of 10 CFR Part 60 have not been adequately addressed. These issues include long-term performance (stability) of the shafts, ramps, and drifts; TMH response of the host rock; and long-term thermomechanical performance of the waste package and engineered barriers.

Other specific concerns and questions are raised primarily because of the inadequacy and inconsistency of the present information. These concerns include the options for waste retrieval and drift backfilling are not consistently considered in all design aspects; specific criteria and justification for the proposed repository location are not adequately discussed; joint characteristics do not support the standoff distance of 5 m determined around the drift excavation boundary; insufficient details are presented to support the required design for the separation of two independent ventilation systems; and the actual fault characteristics in the Primary Area may be more complex than those recognized and discussed in the ACD.