Department of Energy
Washington, DC 20585

QA: N/A

July 21, 2004

Ronald M. Latanison, Ph.D.
Chair, Panel on the Engineered System
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard
Arlington, VA 22201-3367

Dear Dr. Latanison:

Thank you for your letter of April 5, 2004, providing the Nuclear Waste Technical Review Board's (Board) response to the information presented by the U.S. Department of Energy (Department) on repository design at the January 20, 2004, meeting of the Board's panel on the engineered system. The Department appreciates the Board's continuing review of our activities as we work to develop and document the technical basis for the License Application for a repository at Yucca Mountain, Nevada. Our responses to the Board's views and recommendations are summarized in the enclosure to this letter.

The Department continues to benefit from the constructive views of the Board, and we look forward to further dialog on our repository design and related issues.

Sincerely,

Margaret S.Y. Chu, Ph.D.
Director
Office of Civilian Radioactive
Waste Management

Enclosure:
U.S. Department of Energy (Department) Responses to the April 5, 2004, Letter from the Nuclear Waste Technical Review Board (Board)

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ENCLOSURE

U.S. DEPARTMENT OF ENERGY (DOE) RESPONSES TO THE APRIL 5, 2004, LETTER FROM THE NUCLEAR WASTE TECHNICAL REVIEW BOARD (BOARD)

1. SPENT FUEL AGING FACILITY AT THE REPOSITORY

1.1 RECOMMENDATION

As described at the meeting, the design of the repository surface facilities includes temporary storage for up to 40,000 tons of spent fuel. We understand that the current plan is to construct only 1,000 metric tons of storage capacity and that additional storage would be constructed only as needed. We also understand that the DOE intends that the entire 40,000 metric tons of storage capacity will be included in the license application. The technical justification for a 40,000 metric ton storage facility is unclear. As pointed out in BSC's February 2002 "Thermal Operating Modes" white paper, a larger surface facilities area with a pad for extended surface aging could affect the analysis of aircraft–crash hazard. The Board recommends that the technical justification for such a large storage facility be explained.

1.2 RESPONSE

The Final Environmental Impact Statement (DOE 2002) for the repository considered up to 40,000 MTHM of aging capacity to address the potential need to age commercial spent nuclear fuel and to stage DOE spent nuclear fuel and high-level radioactive waste. In the license application (LA), the Aging Facility being designed as part of the repository surface facilities has the capacity for 21,000 metric tons of heavy metal (MTHM) and contingency to expand to 40,000 MTHM. This facility provides sufficient capacity to allow efficient loading of emplacement drifts with the required combination of DOE waste and commercial spent nuclear fuel to meet thermal management goals. It will also allow DOE to stage spent nuclear fuel and high-level radioactive waste so that the rates for waste receipt and emplacement can be decoupled, if necessary.

The Aging Facility would be constructed on an as-needed basis. Our preliminary throughput analyses support an operational need for an Aging Facility capacity from 15,000 to 17,000 MTHM. That capacity was increased to the 21,000 MTHM value to allow some margin for the early throughput estimate. The DOE intends to construct a small pad for aging up to 1,000 MTHM as part of the surface facilities needed for initial repository operations. The rest of the planned Aging Facility is designed as a series of four modules, each with a capacity of 5,000 MTHM. Our current estimates show that the 21,000 MTHM capacity of the Aging Facility will be sufficient to address all the necessary aging and staging requirements for the repository. As we approach the point where we will be receiving fuel, formal material receipt assessments will be performed to assure compliance with Nuclear Regulatory Commission (NRC) licensing specifications for both subsurface emplacement and surface aging. Locations for three additional 5,000 MTHM modules and one 4,000 MTHM module have been identified as a contingency to bring the total capacity to 40,000 MTHM should it be required. This approach will provide the regulatory basis and the flexibility to construct additional aging capacity, should it be required to support future operational needs.

The preclosure safety analysis conducted for the LA will also evaluate the consequences of various potential external hazards, including aircraft crashes, and the relevant event sequences associated with the maximum anticipated surface-aging facility size. This analysis is intended to provide the basis for the NRC to determine, with reasonable assurance, that a repository with surface-aging capacity of at least 21,000 MTHM, with potential expansion to 40,000 MTHM, will not represent an unreasonable risk to the health and safety of the public during the preclosure operating period.

2. WASTE PACKAGE PROTOTYPES

2.1 RECOMMENDATION

The Board understands that BSC recently awarded a fixed-price contract to build the first full-scale waste-package prototype. We believe that the technical information obtained during the course of performance of this contract will be very important, and we agree that more waste-package prototypes are needed. We understand that the reasons for building prototypes include reasons other than obtaining technical information. However, we would like more explanation about the technical information that will be obtained by the current plan to build 14 more prototypes.

2.2 RESPONSE

The waste-package prototype testing-program is designed to provide information regarding:

- Manufacturing process variability (fabricator to fabricator)
- Impact of transportation effects on waste packages
- Waste package weld-preparation performance
- Nondestructive examination (NDE) process confirmation and process improvement
- Confirmation of residual stress states (interaction effects, transport effects, etc.)
- Metallurgical analyses (phase-transformation data), confirmation of mechanical properties (as necessary)
- Mechanical testing related to postulated accident scenarios or credible event sequences.

2.2.1 Testing to Confirm As-Built Conditions

This testing program, described below, will aid in establishing a baseline for acceptance of production waste packages during the operation of the repository.

2.2.1.1 Nondestructive Testing

Manufacturing Process Variability - It is anticipated that multiple vendors will be required to fabricate the approximately 11,000 waste packages needed for the Yucca Mountain Project (YMP). The various fabrication processes used by the fabricators (especially solution heat-treatment and quenching), although guided by procurement requirements, industry codes and standards, and technical and quality requirements, may not be completely uniform from one fabricator to the next. Process differences between fabricators may impact the ultimate performance of the waste package. A prudent way to identify and evaluate these potential differences is to evaluate waste package prototypes from various fabricators before actual manufacture of production waste packages begins. The variability between fabricators and processes can then be identified and potentially significant differences, if any, can be addressed as early as possible in order to develop appropriate mitigation measures.

Transportation Effects on Waste Packages - The waste packages will likely be transported several thousands of miles from the fabricators' facilities to YMP facilities. Transportation over these distances could impact waste package geometry, surface condition, and, potentially, other conditions. The geometry (ovality) of the waste packages will be measured after transport. The as-built information from the fabricator before transport will be compared to the condition of the waste packages upon arrival at the YMP facilities. In addition, the waste packages will be inspected to determine if any alteration to the surface condition has occurred during transport. This information will be used to establish and refine specifications for shipping the waste packages and to address any related waste package closure issues at the repository.

Waste Package Weld Preparation Performance - When a waste package is filled with fuel, it will begin to heat up rapidly. As the waste package heats up, it may distort physically. Although the amount of distortion is expected to be small, the potential impact on weld preparation and the "fit up" to the closure lids must be confirmed as distortion; and small variations in waste package ovality may be critical to successful completion of the final closure welds. The evaluation of this potential problem will involve simulated heating of a waste package prototype and measurement of the distortion. In addition, information regarding the sufficiency of the gap between the inner vessel and the outer corrosion barrier, as well as confirmation of the interpass welding temperature, will be obtained by conducting this test.

NDE of the Outer Lid Closure Weld - The postclosure performance of the waste package will, in part, be determined by the condition of the outer corrosion-barrier closure weld. Accordingly, this weld will be nondestructively examined. Current plans include visual inspection, ultrasonic examination, and eddy-current testing. Visual inspection will provide information on the surface character of the weld, ultrasonic examination will provide volumetric data regarding the quality of the weld, and eddy-current testing will provide data regarding the surface condition (e.g., surface-breaking flaws). NDE of the waste package prototypes will be used to establish parameters for NDE during repository operations.

2.2.1.2 Destructive Testing

The following destructive tests will be performed using waste package prototypes. Depending on the extent of destructive testing, the prototypes used for these tests may be available for certain operational testing, such as demonstration of mechanical handling operations, but current planning reserves these prototypes for destructive testing only.

Confirmation of Residual Stresses of the Outer Corrosion Barrier - The current manufacturing process to control residual stresses in the outer corrosion barrier of the waste package is solution heat-treatment and subsequent quenching following completion of the fabrication process. Although this stress-mitigation process is included in the manufacture of the waste packages, subsequent destructive testing is required to verify that the solution heat-treatment and quench accomplish what was intended and to determine if any tensile stresses develop on the surface of the outer corrosion barrier during transportation.

Although nondestructive X-ray diffraction can give a general idea of what the stress state is on the surface, it cannot be used to determine the through-wall stress state of the plate material, nor can it be effectively used on welds because of the large grain sizes within the welds themselves. Only destructive testing can realistically provide the required information regarding the magnitude and depth of stress in the plate material and in the weld areas.

One destructive testing process involves the use of strain gauges affixed to the surface being examined and the use of sensitive measuring equipment. The material is either machined or chemically etched away, and the stress relaxation is measured by the strain gauge instrumentation. A set of residual stress values as a function of depth is then developed.

Destructive X-ray diffraction will be used to determine the depth and magnitude of residual stresses. This test involves measuring the surface of the material and then removing a small layer of material and repeating the X-ray measurement. This process is repeated until the stresses have been measured to the depth of interest.

Metallographic Analyses – Metallography is an analytical testing method used to evaluate the structure of metals. This destructive testing method will enable the evaluation of phase precipitation and grain size changes as a result of heating, provide assurance that the general appearance of the metallography meets the specification #SB-575 of the American Society of Mechanical Engineers (constituents based on chemical composition), and confirm other characteristics that are dependent upon material composition. Metallography will also be used to confirm that the outer corrosion barrier of the waste package has been successfully stress mitigated. In addition, weld-flaw data collected during this testing program will be combined and compared with data from a 2003 weld-flaw analysis study, and a data resource will be compiled for statistical analysis.

2.2.2 Demonstration of Fabricability

The waste package prototype strategy provides for the demonstration of fabrication processes well before manufacture of the production waste packages. This strategy is necessary to ensure that the waste packages can be manufactured as designed in an efficient, effective, and quality manner. Experience has shown that it is likely that fabrication of the prototypes will identify problems. If problems are encountered during the prototype manufacturing process, design changes can be implemented as necessary before committing funds for the actual production waste packages. Manufacturing process reviews and feedback to subcontractors will serve to improve the fabrication processes and, hence, the quality of the final product. Demonstration of fabricability will be the primary focus of at least the first two waste package prototypes. In addition, the demonstration of fabricability will be a secondary function of all other waste package prototypes.

2.2.3 Operational Testing (Verification of Process Operations)

Operational testing includes such activities as verification of mechanical handling equipment operability, fuel loading activities, subsurface handling and emplacement activities, and waste package closure activities. In addition, it will be necessary to complete an operational readiness review prior to actual operations. All of these operational testing activities will require the use of waste package prototypes.

2.2.4 Number of Waste Package Prototypes

A total of 15 waste package prototypes are planned to support the program outlined here. Table 1 provides a summary of the potential uses of the prototypes, along with the estimated number of prototypes necessary to support design, testing, start-up, and pre-operations. In Table 1, *P* indicates a primary function of a prototype, and *S* indicates a secondary function. Each waste package prototype has only one primary function but may have several secondary functions.

Table 1. Estimated Number of Waste Package Prototypes

Prototype Number (not necessarily order of fabrication)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Configuration → / Activity ↓	21 PWR AP	21 PWR AP	21 PWR AP	21 PWR AP	5 DHLW/DOE Co. long	Naval Long	44 BWR	5 DHLW/DOE Co. short	5 DHLW/DOE Co. long	5 DHLW/DOE Co. short	Not Yet Determined	Not Yet Determined	Not Yet Determined	Not Yet Determined	Not Yet Determined
Demonstrate Fabricability/Variability	P	P	P	P	S	S	S	S	S	S	S	S	S	S	S
Develop Cadre of Qualified Vendors	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Verification of Process Operations															
Mechanical Handling Verification								P	P			P			
Fuel Loading Verification				S	P	P	P	S				S			
Closure Cell Process Verification	S	S	S					S	S	S	S	S	P	P	S
Operator Training				S	S	S	S	S				S			
Nondestructive Testing	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Destructive Testing	S	S	S						S	S	P				
Mechanical Properties Testing	S	S	S							P	S				
Drop Testing (if required)															P
# Potential Uses per Prototype	6	6	6	5	5	5	5	7	6	6	6	7	4	4	5

P — Primary Function of Prototype
S — Secondary Function of Prototype
(shaded) — Configuration not yet determined

3. EMPLACEMENT DRIFT GROUND SUPPORT

3.1 RECOMMENDATION

While not unprecedented, the stainless-steel perforated plate and stainless-steel bolt system proposed as the ground-support system for emplacement drifts is highly unusual and expensive. We would like to learn more about the technical basis for the selection of stainless steel as the material of construction, particularly for the perforated plate. We also would like to know which other materials were considered for ground support and the technical bases for their rejection. We understand that the emplacement-drift ground-support system is designed for a preclosure service life of 100 years and "not to preclude" a preclosure period of up to 300 years. We would like a description of the planned inspection and maintenance activities – including a description of how those activities would be conducted – for both the first 100 years and the subsequent 200 years.

3.2 RESPONSE

Although the use of stainless steel ground support components is not typical in mining and tunneling applications, it is not unprecedented as numerous mines operating in high-sulfide ore bodies with low pH seepage waters have used stainless-steel rock bolts for ground support for their superior corrosion resistance. Both Atlas Copco and Ingersol Rand (now International Rollforms, Inc.) supply stainless-steel rock bolts as standard items.

3.2.1 Rock Mass Description

The rock types comprising the repository host horizon include nonlithophysal rock (a typical, fractured volcanic) and lithophysal rock (same matrix as nonlithophysal rock but with lithophysal void porosity as high as approximately 25 percent). The matrix of the lower lithophysal unit (about 85 percent of the repository emplacement area) is also heavily fractured, with average fracture spacings of less than 10 cm. Extensive fracture mapping studies have been conducted in both of these rock units, and detailed panel mapping of lithophysae has been conducted in the Enhanced Characterization of the Repository Block cross drift. Modeling analyses, reported in *Drift Degradation Analysis* (BSC 2004a), show that the median block sizes created in the nonlithophysal rock are around 0.15 MT (0.06 m^3). Observation of fracture spacing as well as particle sizes from coring in the lower lithophysal unit indicates that the rock fragments expected during failure are small, being on the order of the fracture and lithophysae spacing.

During the preclosure period, the combined in situ, thermal, and seismic loading to the rock mass is relatively small. Although failure is not expected, the value engineering team assembled to evaluate this issue agreed that the most likely potential failure mechanism to occur within the lithophysal rock mass would be a "raveling" mode, characterized by loosening of the rock surface and gravity-driven fall of small rock fragments. In the nonlithophysal rock mass, the potential failure mode would be formation of relatively small "key-block" or wedge-type failures, a small number of which occurred during excavation and scaling of the existing tunnels[1]. Based on the potential failure modes, particularly the raveling of small rock fragments, the preferred support method is use of a continuous-type of surface covering that "knits" the rock surface together and provides sufficient confinement to prevent loosening and raveling.

3.2.2 Value Engineering Process

The specification of the ground support was developed using the value engineering process.

A group of engineers, geologists, and performance assessment specialists, both internal and external to the YMP, were assembled to perform the initial design evaluation. External consultants included Dr. Nick Barton, Barton and Associates; George Yoggy, Master Builders; and Patrick Andrieux, Itasca Canada (formerly Noranda Mining).

A number of criteria for the ground support were established for the evaluation, based on repository performance requirements and operational and safety considerations. The criteria of greatest importance included:

1. The ground support methods must not have a significant negative impact on the capabilities of natural or engineered barriers.

2. The ground support must support the regulatory waste retrieval requirement.

3. The design of the ground support should result in the need for little or no maintenance over the entire preclosure period (taken to be approximately 100 years, with the potential to maintain the repository in an open condition for up to 300 years)[2].

4. The ground support should not impede the rock mass drying effect from forced ventilation air.

5. Personnel safety during all aspects of ground support installation and maintenance is of highest priority.

Ground support alternatives developed and evaluated by the team included standard support methods such as concrete and shotcrete linings, grouted rock bolts, wire mesh or steel plates, thin organic or cement-based spray-on linings, steel sets, and full-tube conduit-type linings. In all deliberations, the attempt was made to develop support methods with standard materials and components and to use off-the-shelf hardware, where possible.

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[1] No significant ground instabilities or ground falls have occurred since the excavations were completed.

[2] The ground support has been classified as not important to safety. Studies for unsupported tunnels, conducted as part of the preclosure safety assessment, examined rockfall potential when subjected to preclosure in situ, thermal, and seismic loading. The rockfall was found to have insufficient mass to result in a credible nuclear safety scenario.

From a purely geotechnical and mining perspective, the preferred ground support method for all excavations was the use of standard fiber-reinforced shotcrete and grouted rock bolts. However, uncertainties exist regarding the potential impact of cementitious and organic surface coatings on the chemistry of seepage waters. This uncertainty leads to greater uncertainties regarding drip shield and waste package corrosion, and near-field environment radionuclide transport mechanisms. It was determined that this uncertainty currently rules out the use of either cementitious or organic materials from ground support in emplacement drifts.

Consequently, it was determined that only steel components would be used for ground support. This determination results in the use of friction-type rock bolts (either Swellex or Split Set were considered) for general ground-reinforcement. To provide the surface confinement desired to eliminate raveling of small rock fragments, Bernold-style perforated steel sheeting was chosen for use. This type of surface support consists of thin steel sheets that are rolled to the tunnel radius and punched to create slots that allow air circulation behind the sheet. The punching process also corrugates the sheet, which results in significant structural stiffness. These sheets are overlapped for connection and predrilled for rock bolt installation. The bolts are installed through the sheets and pulled tight to the rock surface, preventing loosening and raveling. The slot dimensions can be custom designed to prevent loss of small rock fragments. A 240° coverage of the tunnel periphery is used to minimize rockfall onto the invert rail system. It is envisioned that a highly mechanized rail-based system will be developed for installation of this support system. A single piece of equipment for lifting and holding the steel sheets to the rock surface, followed by drilling of radial boltholes and installation of friction bolts, could be developed relatively easily.

3.2.3 Ground Support Materials Selection

The most effective corrosion control practice is selection of a suitable metal or alloy for the service time in a particular environment. The total service life for the ground support system is currently established at 100 years, which encompasses the NRC requirement that the waste be retrievable starting at any time up to 50 years after the start of waste emplacement operations.

Candidate steel ground-support materials, including carbon steel, high-strength low-alloy steel, and stainless steel were considered in the corrosion evaluation for the longevity of ground support materials for the LA. The potential corrosion mechanisms that may be expected in the repository environment include dry oxidation; humid-air corrosion; aqueous, pitting, or crevice corrosion; stress corrosion cracking; hydrogen embrittlement; and microbiologically influenced corrosion.

The following conclusions were reached based on the corrosion evaluation for the candidate ground-support materials in Section 7.3 of the report *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003a):

- The impact of dry oxidation on the performance of carbon steel and stainless steel is insignificant or negligible.

- For humid-air corrosion, ground-support components made of carbon steel will fail after a service life of 30 years, whereas a rock bolt made of high-strength, low-alloy steel will not fail for a service life of 100 years. Ground-support components made of stainless steel 316 will not fail for a service life of 100 years.

- Carbon steel and high-strength, low-alloy steel will fail because of aqueous corrosion within 10 years, whereas stainless steel 316 will not fail for 100 years of service life.

- Stainless steel 316 indicates superior performance against pitting and crevice corrosion. The potential effect of higher temperatures on general and localized corrosion for stainless steel 316 is insignificant.

- Based on the stress level, temperature, and ground water conditions, it is expected that stress corrosion cracking of friction-type rock bolts will probably not occur during preclosure. The potential impact of hydrogen embrittlement on friction-type rock bolts is minimal or insignificant.

- The effect of microbiologically influenced corrosion is significant on carbon steel, whereas it is insignificant on stainless steel 316.

The following paragraph is cited from Section 7.4 of the report *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003)

> . . . for a service life of 100 years during the preclosure, both the friction-type rock bolts (Split Sets and/or Swellex bolts) and the perforated steel sheets need to be made of stainless steel, such as 316 (equivalent or better), from the viewpoint of corrosion control. This result confirms the current design on materials for rock bolts and perforated sheets in emplacement drifts. Rock bolts and perforated steel sheets made of stainless steel with thickness of 3 mm will not fail due to corrosion for a service life of 100 years. Furthermore, Swellex bolts may perform better than Split Sets in terms of corrosion attack due to its tubing configuration. Among all friction-type rock bolts, Super Swellex bolts have the highest holding capacity, which is desirable from the viewpoint of structural stability. Moreover, the Super Swellex bolt has a larger tube thickness compared with others, which is also desirable from the viewpoint of minimizing the effects of corrosion.

3.2.4 Maintenance and Cost

The ground support has been classified as not important to safety. Examination of potential preclosure rockfall size shows that waste package breach is not credible. To facilitate waste package retrieval, should it be required, emplacement drift stability will be monitored during the 100-year design-basis preclosure period from the initiation of waste emplacement. A preliminary observation and ground-support maintenance plan has been developed, however, the details of this plan can only be developed as the subsurface design proceeds. The specific observation equipment and intervals have not been determined, but the current thinking is that observation of the ground support will be performed using remote-controlled video cameras. Observations will center on examination of areas of deformation that would indicate extensive yield behind the ground-support system. A determination of the need to maintain the support in that area will be made on a case-by-case basis based on an evaluation of the significance of the changes in the affected ground support. Although the repository design will include provisions that support deferral of closure for up to 200 years beyond the end of the design-basis preclosure period, the monitoring and maintenance program for this contingency is not needed at this time.

A primary objective for the use of full tunnel-support coverage and stainless steel components with an expected service life in excess of 100 years was to eliminate or minimize the need for maintenance. Although the initial cost of the planned stainless-steel ground support system is higher than for standard carbon-steel components, the added cost is outweighed by the cost and potential worker safety issues that would be associated with moving waste packages for reentry into emplacement drifts to maintain ground support.

4. "COLD TRAP" EFFECTS IN THE EMPLACEMENT DRIFT TURNOUTS

4.1 RECOMMENDATION

The Board notes that changes have been made in the subsurface repository design to increase the radius of each emplacement drift turnout and to move the ventilation control door to the outer end of each turnout. These changes will affect the postclosure waste package temperatures, particularly the temperature of packages close to the turnouts. In addition, these changes are likely to exacerbate "cold trap" effects near and in the turnouts. We strongly recommend that temperature and relative humidity calculations be revised to reflect the design changes, if that has not been done already.

4.2 RESPONSE

The DOE agrees that changes in the subsurface repository design, specifically the increase in the radius of the emplacement-drift turnout and relocation of the ventilation control door, need to be evaluated as to the effect on predictions of temperature and relative humidity inside the drift, especially in the postclosure time frame. The YMP has recently modeled the natural convection and condensation of in-drift moisture during the postclosure period and the associated redistribution of energy, documenting the results in the forthcoming analysis and model report on in-drift natural convection and condensation. This model reflects the recent design changes and provides predictions of temperature, moisture content, and condensation patterns. This analysis and model report will be completed in the near future.

In general, a longer turnout and relocated ventilation door provide additional, cooler rock surfaces outside of the emplacement section of the drifts and on which condensation of moisture may occur (cold trap effect). The warm, moist air that moves from the emplacement drifts into the turnouts as a result of natural convection processes will be depleted of most of its vapor content by condensation on the cooler rock-surfaces. At the same time, relatively dry air circulates back toward the emplacement sections of the drifts, thereby reducing the vapor mass and the relative humidity in these areas. The energy transport associated with the movement of in-drift air also affects the waste package temperatures, particularly those close to the turnouts. However, compared to the reduction in relative humidity, the changes in temperature are rather small.

5. NATURAL VENTILATION AND DRIFT ENVIRONMENT

5.1 RECOMMENDATION

The Nye County work on the evolution of chemistry in the engineered barrier system and on the topic of natural ventilation is very interesting. These topics are important because they influence both waste package corrosion and transport from the engineered barrier system. It is clear that the environment in drifts is not a quasistatic or slowly changing one but a dynamic one driven in part by temperature differences among waste packages and along the drifts. Such differences will always exist but will be greater during the thermal pulse period. A repository at Yucca Mountain will have some degree of natural ventilation or natural circulation regardless of whether it is deliberately engineered into the repository design or not. Models for temperature and relative humidity predictions must take these natural processes into account fully.

5.2 RESPONSE

Nye County's work on the in-drift chemical environment and natural ventilation are undoubtedly important alternative concepts enriching the knowledge base that supports DOE's analyses of the performance of the repository system.

During the preclosure period, a large volume of air will move through the drifts at high velocity due to active ventilation. During the postclosure period, the volume and velocity of air moving through the drifts will drop substantially because only intrinsic natural circulation augmented by temperature differences along the drifts will sustain air movement. YMP models take air and moisture exchange between the fracture system and the in-drift environment into account. The only way that temperature differences along the length of the drift and between waste packages could increase or become more uneven following closure is if there was an impediment to the flow of heat, such as backfill cover. There could also be some advection of moisture (inevitably carrying some heat) from the rock into the drift caused by fluctuations in barometric pressure. However such moisture movement would be limited and would decrease with time, because of the continued increase in the size of the dry-out zone surrounding each emplacement drift during the thermal pulse.

6. REFERENCES

6.1 DOCUMENTS CITED

BSC 2003a. *Longevity of Emplacement Drift Ground Support Materials for LA.* 800-K0C-TEG0-01200-000 REV00A. Las Vegas, Nevada. Bechtel SAIC Company.

BSC 2003b. *Technical Basis Document No. 5: In-drift Chemical Environment.* Las Vegas, Nevada. Bechtel SAIC Company.

BSC 2004a. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 03A. Las Vegas, Nevada. Bechtel SAIC Company.

DOE 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.*

DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

6.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.