ITASCA
Consulting Group, Inc.

1 December 1986

Dinesh Gupta
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

Dear Dinesh:

Enclosed with this letter is our draft of "Suggested Review Approach to In-Situ Testing at Yucca Mountain (Section 8.3.3, Planned Tests, Analyses, and Studies—Seal System Program)".

We look forward to discussing these drafts. Please call me, Jaak Daemen, or Roger Hart if you have any questions.

Sincerely,

for Loren J. Lorig

cc: D. Tiktinsky

Encl.
ljl/ks

P.O. Box 14806 • Minneapolis, Minnesota 55414 • (612) 623-9599

3541

DRAFT

SUGGESTED REVIEW APPROACH TO IN-SITU TESTING AT YUCCA MOUNTAIN (Section 8.3.3, Planned Tests, Analyses, and Studies — Seal System Program)

TABLE OF CONTENTS

PAGE

D R A F T

SUGGESTED REVIEW APPROACH TO IN-SITU TESTING AT YUCCA MOUNTAIN
(Section 8.3.3, Seal System Program)

8.3.3 PLANNED TESTS, ANALYSES, AND STUDIES – Seal System Program

I. Areas of Review

The applicant must present information concerning the sealing products, methods, and procedures that will be used to seal an eventual repository in unsaturated tuff at Yucca Mountain, Nevada. Performance of the seals in accordance with minimum required performance as determined by performance analysis must be demonstrated. This will require demonstration of seal system component performance in the environment in which the components are to be emplaced, as well as demonstration of acceptable emplacement methods and technology. Stability of the sealing materials and of the rock in which they are emplaced must be demonstrated. The assessment of the properties and stability of the rock should be consistent with related SCP Sections. Much of the information discussed in this section may be presented in other sections—in which case, it may be cross-referenced rather than repeated here.

The staff review covers the following specific areas:

(1) Seal System Environment (Subsection 8.3.3.2);

(2) Seal System Components and Interaction Tests (Subsection 8.3.3.3);

(3) Seal System Design Optimization (Subsection 8.3.3.4); and

(4) Seal System Modeling (Subsection 8.3.3.5)

Coordination will be required to ensure that the information provided as input for sealing is deemed adequate by the primary reviewers of geology, geoengineering, hydrology, geochemistry, climatology and meteorology, and repository design.

II. Acceptance Criteria

A. Applicable Rules and Basic Acceptance Criteria

The applicable rules and basic acceptance criteria pertinent to this SCP Review Plan are:

(1) 10CFR60 §60.17 — Contents of Site Characterization Plan.

The Site Characterization Plan shall contain "a description of such site characterization activities, including the following—. . . (iii) Plans for any investigation activities that may affect the capability of such area to isolate high-level radioactive waste; (iv) Plans to control any adverse impacts from such site characterization activities that are important to safety or that are important to waste isolation . . ."

If a narrow definition of Acceptance Criteria is to be followed, the next sections will be referenced: NWPA (1982), Regulatory Guide 4.17, and GTP Borehole and Shaft Sealing. If a broad definition of Acceptance Criteria is to be followed, various relevant sections of 10CFR60 will be identified.

(2) 10CFR60 Part 60 §60.21 — Content of License Applications

(a) An application shall consist of general information and a Safety Analysis Report.

(b) The general information shall include

"(5) A description of site characterization work actually conducted by DOE at all sites considered in the application and, as appropriate, explanations of why such work differed from the description of the site characterization program described in the Site Characterization Report for each site.

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geomechanical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site.

(B) Analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they affect isolation within the controlled area.

(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, given the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future geologic setting shall be supported by using an appropriate combination of such methods as field tests, in situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

(4) A description of the quality assurance program to be applied to the structures, systems, and components important to safety and to the engineered and natural barriers important to waste isolation.

(6) An identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of license specifications. Special attention shall be given to those items that may significantly influence the final design.

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

(14) An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, which require research and development to confirm the adequacy of design. For structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

(vi) Plans for permanent closure and plans for the decontamination or dismantlement of surface facilities."

3. 10CFR Part 60, §60.31 — Construction Authorization

"Upon review and consideration of an application and environmental report submitted under this part, the Commission may authorize construction if it determines:

(a) Safety. That there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository operations area of the design proposed without unreasonable risk to the health and safety of the public. In arriving at this determination, the Commission shall consider whether:

(1) DOE has described the proposed geologic repository including but not limited to: . . . (iv) construction procedures which may affect the capability of the geologic repository to serve its intended function."

4. 10CFR Part 60, §60.43 — License Specification

"(a) A license issued under this part shall include license conditions derived from the analyses and evaluations included in the application, including amendments made before a license is issued, together with such additional conditions as the Commission finds appropriate.

(b) License conditions shall include items in the following categories:

. . .

(5) Controls to be applied to restricted access and to avoid disturbance to the controlled areas and to areas outside the controlled area where conditions may affect isolation within the controlled area."

5. 10CFR Part 60, §60.46 — Particular Activities Requiring License Amendment

"(a) Unless expressly authorized in the license, an amendment of the license shall be required with respect to . . .

(6) Permanent closure."

6. 10CFR Part 60, §60.51 — License Amendment for Permanent Closure

(a) The DOE shall submit an application to amend the license prior to decommissioning. The application shall consist of an update of the license application and environmental report submitted under §§60.21 and 60.22, including: . . .

(4) The results of tests, experiments, and any other analyses relating to backfill of excavated areas, shaft sealing, waste interaction with the host rock, and any other tests, experiments, or analyses pertinent to the long-term isolation of emplaced wastes within the geologic repository."

7. 10CFR Part 60, §60.72 — Construction Records

"(a) DOE shall maintain records of construction of the geologic repository operations area.

(b) The records required under paragraph (a) shall include at least the following:

(1) Surveys of the underground facility excavations, shafts, and boreholes referenced to readily identifiable surface features or monuments;

(2) A description of the materials encountered;

(3) Geologic maps and geologic cross-sections;

(4) Locations and amount of seepage;

(5) Details of equipment,methods, progress, and sequence of work;
(6) Construction problems;

(7) Anomalous conditions encountered;

(8) Instrument locations, readings, and analysis:

(9) Location and description of structural support systems;

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used."

8. 10CFR Part 60, §60.112 — Overall System Performance Objective for the Geologic Repository After Permanent Closure

"The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events."

9. 10CFR Part 60, §60.122 — Siting Criteria

"(a)(1) A geologic setting shall exhibit an appropriate combination of the conditions specified in paragraph (b) of this section so that, together with the engineered barriers system, the favorable conditions present are sufficient to provide reasonable assurance that the performance objectives relative to isolation of the waste will be met.

(b) Favorable conditions

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide—

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units;

(ii) A water table sufficiently below the underground facility such that fully-saturated voids contiguous with the water table do not encounter the underground facility;

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility;

(iv) A host rock that provides for free drainage . . .

(c) Potentially adverse conditions. The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity or construction of large scale surface water impoundments.

. . .

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

. . .

(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment."

10. 10CFR Part 60, §60.134 — Design of Seals for Shafts and Boreholes

"(a) General Design Criterion. Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives or the period following permanent closure.

(b) Selection of Materials and Placement Methods. Materials and placement methods for seals shall be selected to reduce, to the extent practicable:

(1) The potential for creating a preferential pathway for groundwater to contact the waste packages or

(2) For radionuclide migration through existing pathways."

11. Regulatory Guide 4.17 — Standard Format and Content of Site Characterization Plans for High-Level Waste Geologic Repositories

This guide provides information, recommendations and guidance and, in general, describes a basis acceptable to the staff that may be used to implement the requirements of 10CFR Part 60, §60.17 — Contents of Site Characterization Plan.

The specific requirements of Regulatory Guide 4.17 relevant to sealing are found on p. 4.17-35 and require the applicant to

- Describe the proposed treatment of the disturbed section of rock around openings and excavated surfaces.
- Describe proposed design measures to control groundwater movement into the facility.
- Provide laboratory and field data when available and inferred site conditions on which the selection of the treatment measures was based.
- Describe the proposed design for the sealing of boreholes and shafts.
- Provide laboratory and field data and inferred site conditions on which the design was based.
- Provide the mechanical, chemical, and hydrologic properties of proposed sealing materials.

12. Annotated Outline for Site Characterization Plans, Revision 4, February 15, 1985" Prepared by Mutual Agreement of BWIP, NNWSI, SRP, and DOE-HQ

This document presents a detailed outline of the SCP in accordance with 10CFR Part 60, §60.17 and Regulatory Guide 4.17.

13. NRC SCP Reviews As Specified in the Nuclear Waste Policy Act of 1982, Public Law 97-425-January 7, 1973, Sec. 113,(b),(1),(A),(ii).

14. Generic Technical Positions (GTPs)

Borehole and Shaft Seals (Final), February 1986

Design Information Needs in Site Characterization Plans (Final), December 1985

B. Specific Technical Criteria

1. Technical Review Preliminaries

Review of Section 8.3.3, Seal Systems Program, will require familiarity with a number of directly-related sections—in particular,

- Section 1.6 — Drilling and Mining — This section will tabulate the location and characteristics of all drill holes and excavations at and near the site and will provide available information on the effects of the active and abandoned wells, boreholes, and excavations on the principal hydrogeologic units.

  This information will provide guidance as to the type of sealing equipment that might be required at the site. It will assist in identifying the need, if any, for demonstrating:
  (1) sealing of active and abandoned wells, boreholes, and excavations;

  (2) re-entry of same; and

  (3) remedial action (e.g., cleaning) of same

- Section 2.8.3 — Changes in Geoengineering Properties Due to Excavation

  Changes in hydraulic conductivity and porosity of the rock adjacent to excavations could influence sealing performance and requirements—e.g., by sealing enhanced bypass flow paths around seals or by reducing free draining.

- Section 6.1.5 — Barriers Important to Waste Isolation

  This section will provide a description of the repository barriers such as tunnel backfill and repository and borehole seals.

- Section 6.2.5 — Shaft and Ramp Design

  Construction (excavation, reinforcement-support) and lining concepts under consideration will be of particular concern. These openings could provide direct (waterflow, airborne) paths to the accessible environment.

- Section 6.2.7 — Backfill of Underground Opening

  This section will identify the need for backfill and decommissioning seals. If required, preliminary materials, specifications, the functions, handling, and emplacement concepts will be provided.

- Section 6.2.8 — Shaft and Borehole Seals

- Section 6.3.5 — Sealing of Shafts, Boreholes, and Underground Openings

- Section 6.3.6 — Construction

  This section will describe how the construction of exploratory workings at the site will not compromise the integrity of the site.

- Section 8.3.5.2 — Strategy for Postclosure Performance Assessment

  In particular: 8.3.5.2.1 (Engineered Barrier Subsystem); and 8.3.5.2.2 (Seal Systems Performance Goals)

  Supplementary or supporting sections will need to be reviewed, or an assessment of this validity provided by other reviewers, or it is certain that essential input information will have to be obtained from a variety of sources (including, for example, Geoengineering, Hydrology, Geochemistry, Climatology and Meteorology, Repository Design). In sum, seal program review requires fairly comprehensive understanding of a variety of repository aspects. As such, an in-depth seal program review can be obtained only through a multi-disciplinary effort.

2. Seal System Program Review

Section 8.3.3 will summarize the seal systems test program and provide an overview of the research and development activities required to ensure that the repository seals and backfill system is capable of satisfying applicable design and performance objectives.

According to the "Annotated Outline", the planned studies and tests will explain

- why the test, study or analysis is planned and what data and information will be obtained
- how the results will be used to help resolve specific information needs
- what methods techniques, and data analysis will be used
- limitations and uncertainties of test methods and data analysis
- representativeness, precision, and accuracy of proposed test methods and data analysis
- significant options or alternative test methods and data analysis to those proposed

The discussion of in-situ testing of seals will include

- a description of tests that might use radioactive materials
- a description of tests that might affect the capability of the site to isolate waste
- a summary of instrumentation and monitoring.

If no such tests are planned, Chapter 8 will explain why these tests are unnecessary in order to provide sufficient data for licensing. If the final decision on such tests will depend on results of preceding tests, the SCP will describe the logical steps which lead to the decision.

- Section 8.3.3.1 — Overview

The overview section will state the purpose of the seals program and will provide an overview of the seals program. The section will describe the interrelations and the sequencing of the primary activities of the program.

- Section 8.3.3.2 — Seal System Environment

This section will identify and describe the lists and analyses needed to establish the repository seal and backfill environments. These lists and analyses will define the physical and chemical characteristics that influence the design, installation (construction), and performance of the repository seals.

The major concern for the NRC seal program reviewer will be the completeness of this section as well as the prioritization of various information needs.

It is likely, and acceptable, that much of the information needed for the characterization of the seal systems environment will be provided by reference to other sections of the SCP—i.e., the necessary information is likely to be obtained as part of the general site characterization investigations rather than specifically and exclusively within the sealing program. Providing assurance of completeness about the information, therefore, will require particular care. Obtaining assurance about the adequacy of specific information items will require confirmatory review input from other disciplines (in particular, geochemistry, hydrology, geology, geophysics, meteorology, and geoengineering).

The following aspects of the seal system environment need to be determined:

(1) physical environment

- temperature
- deformations (Deformations to which seals are likely to be, or might be subjected subsequent to emplacement. This might include seismically- or tectonically-induced deformations.)
- stresses/loads (Stresses applied to emplaced seals—e.g., as a result of continuing or re-activated rock deformation, backfill load, water and/or gas pressure and/or flow.)
- chemical environment

  — temperature
  — rock chemistry (mineralogy)
  — water chemistry
  — reaction products form rock/seal/water interactions
  — water/gas flow rates and/or pressures

- hydrological environment

  — degree of saturation
  — waterflow/pressure
  — groundwater chemistry
  — precipitation/infiltration
  — perched water

- construction influence parameters

- Section 8.3.3.3 — Seal System Components and Interaction Tests

  This section will identify and describe the following.

  - seal system component tests, including component-environment interaction testing

  - repository backfill tests and studies.

    Of particular concern in this regard should be the influence of emplacement procedures on eventual seal system performance.

    Other factors that need to be evaluated include

    - completeness of component-environment interaction testing (completeness of environment simulations)

      Particularly difficult are likely to be

      — simulations of rock/liner/support/seal deteriorations over prolonged periods of time

      — long-term hydrological changes (e.g., drainage, changes in the hydrological environment as a result of waste-induced thermal pulse—for example, drying-wetting cycles)

    - correlation between design/performance requirements and tests

  An evaluation of the adequacy of the proposed seal component testing will require a determination of the required components. This, in turn, will require an identification of the types of seals needed. This depends on the types of structures to be sealed—particularly as identified in the following sections:

Section 1.6 (Drilling and Mining)

3.2.2 (Flood Protection)

6.1.1 (Repository Design Requirements)

6.1.4 (Barriers Important to Waste Isolation)

6.2.2 (Overall Facility Design)

6.2.4.2 (Flood Protection)

6.2.5 (Shaft and Ramp Design)

6.2.6 (Subsurface Design)

6.2.7 (Backfill of Underground Opening)

6.2.8 (Shaft and Borehole Seals)

6.3 (Assessment of Design Information Needs) — particularly,

6.3.5 (Sealing of Shafts, Boreholes and Underground Openings)

6.3.6 (Construction)

6.3.8 (Repository System Component Performance Requirements)

Component Tests

- physical, mechanical, hydrological, thermal, chemical component characterization
- emplacement tests

Component/Environment Interaction Tests

- mechanical (swelling/shrinkage, stress/displacement, interface strength, relative strength, relative stiffness)
- thermal (hydration heat-confinement effect)
- hydrological (interface flow paths)
- geochemical (bond, interaction)

- Section 8.3.3.4 — Seal System Optimization

This section will identify and describe seal system design optimization activities that will require site characterization data. Potential subjects include:

- studies and tests to assist in design concept selection
- development of design requirements
- studies to translate design requirements into specific design descriptions
- development tests to demonstrate the feasibility of fabrication processes and to help verify the designs.

Note: Although "optimization", as such, might not be an NRC interest, this section actually deals with the overall seal system design, particularly as it relates to site-specific features (i.e., as it depends on site characterization data).

NNWSI seal system design topics that will be of particular interest to the NRC seal program reviewer include:

- ramp seal system design
- shaft seal system design
- borehole seal system design
- backfill design
- fault seal system design

At least conceptually, all of these form different systems and, hence, need to be addressed separately. Site characterization data required will be the environmental data identified in Section 8.3.3.2. Included, also, will be the "engineering" aspects of the seal design (e.g., seal geometry, seal emplacement, and sealing of the rock around seals)

Of particular interest to the NRC sealing program reviewer will be "development tests to demonstrate feasibility of fabrication processes". Topics to be addressed include

- whether the tests will be full scale
- whether in situ (at depth)
- description of the performance testing procedures and duration

- Section 8.3.3.5 — Seal System Modeling

This section will describe planned modeling and code development studies associated with seal system development, utilization, verification, and validation for those tests and studies requiring data from site characterization.

Note: In principle, this could be an extremely broad aspect of the program—in essence, a miniature version of the repository modeling program. Examples include

- thermodynamic (geochemical) modeling of long-term seal behavior (component changes, consequences for component/hydraulic conductivity, strength)
- flow modeling
- mechanical interaction modeling

Many of the NRC sealing program reviewer concerns will be identical to overall program review concerns —e.g., "validation" in the traditional sense is exceedingly difficult and probably impossible for very long term. Presumably, much of the modeling will be performed with codes developed for other purpose. If so, the review will benefit from multidisciplinary review.

REFERENCES

Fernandez, 1985

Fernandez and Freshley, 1984

U.S. Nuclear Regulatory Commission, 1983

U.S. Nuclear Regulatory Commission, 1985

Vieth et al, 1985