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Dr. V. Rajaram
Engineers International, Inc.
98 E. Naperville Road
Westmont, IL 60559

Dear Dr. Rajaram:

We have completed our review of your draft letter report for Task 1 of Task Order 004 under the Nuclear Regulatory Commission (NRC) Contract No. NRC-02-82-030. This work involved preparation of design site technical positions for the Nevada Test Site. A marked-up copy of the draft report is attached providing general comments and specific comments which shall be addressed prior to preparing the final letter report as required in the contract. The final report shall be submitted to NRC by August 5, 1983. We expect that following resolution of these comments, the report will assist NRC in assessing site characterization plans for the Nevada Test Site. If you have any questions regarding these comments, please contact the NRC Project Manager, T. L. Seamans, at (301) 427-4679.

The action taken by this letter is considered to be within the scope of the current contract No. NRC-02-82-030. No change to costs or delivery of contracted products is authorized. Please notify me immediately if you believe this letter would result in changes to costs or delivery of contract products.

Sincerely,

/s/

Trueman L. Seamans, Project Manager
High-Level Waste Technical
Development Branch
Division of Waste Management

Attachment:
Marked-Up Draft Report

cc: M. M. Singh, EI

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DATE	83/07/08	83/07/13				

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INCORPORATE ENTIRE SET OF DESIGN
ISSUES INTO FORMAT FOR ONE
SITE TECHNICAL POSITION.

BACKGROUND. REQUIREMENTS OF 10CFR60
TECHNICAL POSITION: LISTING OF DESIGN ISSUES
DISCUSSION: JUSTIFICATION FOR ISSUES
REFERENCES:

NTS DESIGN ISSUES

4.0 Design of Facility

4.1 Prior to permanent closure, are the repository design criteria and the functional description shown to be complete and accurate with respect to the performance objectives?

4.1.1 How do the design criteria and conceptual design address releases of radioactive materials to unrestricted areas within the limits specified in Part 20?

4.1.2 How do the design criteria and conceptual design accommodate the retrievability option?

4.2 Can stability of the repository be maintained in the presence of coupled in situ, excavation induced and thermal stresses during construction and operation of the repository?

4.2.1 How is the conceptual design shown by analysis to accommodate in situ stresses, and mechanical and thermal effects due to construction of the repository and waste emplacement?

4.2.2 What are the in situ stress conditions and how do stress conditions vary with time and temperature?

4.2.3 What are the rock mass strength properties and how do they vary with time ~~and~~, temperature? AND LOCATION

4.2.4 What are the rock mass deformation characteristics and how do they vary with time and temperature?

4.3 How can isolation capability of the underground facility be maintained in the presence of coupled in situ, excavation induced, and thermal stresses?

4.3.1 Is sustained groundwater inflow expected in the underground facility and how does construction and waste emplacement modify groundwater (including vapor phase) movements in and around the facility?

4.3.2 What are the anticipated physical conditions (e.g., temperature, pressure, stress) in and around the repository through time?

4.3.3 How will post emplacement thermal loads modify groundwater (liquid and vapor phase) movements in and around the underground facility?

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4.4 What is the maximum expected radionuclide release rate from the engineered system and is this rate in compliance with NRC technical criteria?

4.4.1 What is the release rate from the waste form with time?

4.4.2 What is the release rate from the waste package with time?

4.4.3 What is the release rate from the engineered barrier system with time under unsaturated conditions?

4.5 Can repository shafts and exploratory boreholes be constructed and sealed adequately?

4.5.1 How is repository performance expected to be affected by repository shafts?

4.5.~~2~~3 How is repository performance expected to be affected by exploratory boreholes?

4.6 What structures, systems and components are provided that are important to safety?

4.7 What Quality Assurance procedures and what personnel training and certification have been adopted to provide adequate confidence that the geologic repository and its subsystems and components perform adequately?

4.5.2 HOW IS REPOSITORY PERFORMANCE EXPECTED TO BE AFFECTED BY CONSTRUCTION OF THE EXPLORATORY SHAFT.

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INSURE THAT THERE IS A CONSISTENT FORMAT FOR ALL DESIGN STP'S.

SITE TECHNICAL POSITION

NNWSI - STP (1A) 4.1.1

MINIMUM INFORMATION NEEDED AND FACTORS TO BE CONSIDERED IN DETERMINING HOW RADIATION DOSES AND LEVELS, AND RELEASES OF RADIOACTIVE MATERIALS TO UNRESTRICTED AREAS WILL BE MAINTAINED WITHIN THE LIMITS IN 10CFR20 PRIOR TO PERMANENT CLOSURE

Background:

THIS DISCUSSION CONCERNS LONG-TERM RELEASES TO THE ACCESSIBLE ENVIRONMENT AND NOT THE SUBJECT OF THIS STP, WHICH IS RELEASES TO THE OPERATIONS AREA PRIOR TO PERMANENT CLOSURE.

The EPA has proposed a standard for releases of radioactivity to the general environment, and 10CFR60 requires that this standard be satisfied by any geologic repository. In essence, the EPA standard requires that over a 10,000-year period, cumulative releases of radio-activity to the accessible environment be less than one in ten thousand. As defined in Section 60.102(c) of 10CFR Part 60, the accessible environment is the atmosphere, land surface, surface water, oceans, and the portion of the lithosphere that is outside the controlled area.

Subpart E of 10CFR60 sets out performance objectives, and site and design criteria which, if satisfied, will support a finding that issuance of a license for a geologic repository for nuclear waste will not constitute an unreasonable risk to the health and safety of the public. This implies that there is a "reasonable assurance" that the EPA standard for releases of radioactivity to the general environment will be met.

Section 60.111 of Subpart E of 10CFR60 outlines the performance objectives for the geologic repository operations area through permanent closure. Two specific areas of concern are identified:

INSURE THAT ALL REFERENCES TO THE REGULATION ARE CONSISTENT WITH THE FINAL

- protection against radiation exposures and releases of radioactive material
- retrievability of waste.

With regard to the first area of concern, Section 60.111(a) requires that, until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas will satisfy the limits specified in 10CFR20 and such standards for radioactivity that have been set by the EPA.

To assure that the performance objectives in Section 60.111 are met, Sections 60.131 through 60.134 specify minimum criteria for the design of the geologic repository operations area. Section 60.131(a) contains general criteria for radiological protection, while Sections 60.132, subsections (b), (c), and (d) contain design criteria pertaining to surface facility ventilation, radiation control and monitoring in the surface facilities, and surface waste treatment facilities, respectively. Section 60.133, subsections (a), (d) and (g) contain general criteria for underground design, criteria for control of water and gas intrusions, and criteria for design of the underground ventilation system, respectively.

In order to have reasonable assurance that the aforementioned performance objectives and criteria for the geologic repository operations area for the period up to and including permanent closure are met, it is essential to determine how radiation doses and levels, and releases of radioactive materials to unrestricted areas will be maintained within the limits in 10CFR 20. This document presents the NRC staff's position on what information is needed and what factors must be considered in order to do so.

Technical Position

It is the NRC staff's position that the following information must be supplied so that it can be verified that the performance objectives of Section 60.111 will be met - that is, that the radiation doses and levels and releases of radioactive materials will satisfy 10CFR20:

1. The layout of the repository including the number and dimensions of entries, storage rooms, returns, and shafts

2. The design of the development and waste emplacement (confinement) ventilation systems in the underground facility including the air flows supplied to the various openings

3. The condition of the storage rooms after completion of waste placement, that is:

   - open and ventilated
   - bulkheaded and backfilled
   - bulkheaded but unbackfilled and with leakage through the bulkheads

4. The design and location of filtration units for the removal of airborne radionuclides from the underground ventilation system exhausts

5. The design of monitoring systems for detection of radionuclides in the airways

6. Design of underground handling systems for contaminated water

7. Design of surface handling systems for contaminated water from the underground facility

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INSURE THAT ALL TECHNICAL POSITIONS ARE COMPREHENSIVELY BACKED-UP BY JUSTIFICATIONS IN THE DISCUSSION SECTIONS OF ALL STP'S.

REWORD TO REFLECT BASIS OF THIS STP, RELEASE TO OPERATIONS AREA PRIOR TO ...

8. The radiation levels at the waste package and in the operators' cabins on the equipment (both underground and surface)

9. The design of the ventilation system for surface facilities including monitoring systems for radiation levels and concentrations of airborne radionuclides and the airflows in waste handling facilities.

Discussion:

The basis of the NRC staff's position is presented below. There are two means by which releases of radioactive materials and radiation from the geologic repository operations area would reach the accessible environment:

- Diffusion through rock and soil
- Transport by fluids.

Diffusion occurs only over very limited distances in solid media (a few feet or less) and hence is not a credible means of releasing radiation and radionuclides to the accessible environment.

Hence, release of radiation and radionuclides would occur due to fluid transport, the transport media being air and water. In the case of water transport, there are two possible alternatives:

- Transport by surface watercourses
- Transport by seepage of ground water

ALSO CONSIDER TRANSPORT BY SEEPAGE OF GROUNDWATER THROUGH THE ROCK MASS IN THE REPOSITORY NEAR-FIELD (INSIDE THE LIMITS OF THE ACCESSIBLE ENVIRONMENT).

The second alternative can be eliminated during the period prior to permanent closure because of the requirement that the pre-waste emplacement ground water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1000 years or such other travel time as may be approved or specified by the Commission (Section 60.113(a)(2)). However, there will be some water in the storage rooms, which could come in contact with radioactive materials. The usual procedure for handling water underground is to drain it toward sumps whence it is pumped to the surface. If this water has been contaminated by radiation or radionuclides, it should be handled in an enclosed system (not open ditches) in order to limit exposures to individuals. Similarly, effluents from surface impoundments must meet the limits of 10CFR20 whether the water originated in surface operations or underground.

MOVE TO TECHNICAL POSITION SECTION.

The other possible transport medium from the underground facility is the exhaust air from the underground ventilation system. Section 60.133(g)(3) requires that separate ventilation systems be provided for the "excavation and waste emplacement areas." Hence, radionuclide releases would normally be expected in the waste emplacement ventilation system. However, there will be locations where the two ventilation systems occupy adjacent airways and leakage between systems could occur. It is thus necessary to ensure that the two systems are designed so that leakage is toward the waste emplacement system. To limit the releases to the atmosphere, filtration systems are required should any radionuclides be detected in the exhaust air. If these systems are to function intermittently rather than full time, monitoring systems are required so that the filtration systems are activated when radionuclides are detected.

MOVE TO TECHNICAL POSITION SECTION.

Futhermore, the concentrations of radioactive materials in the airways within the underground facility must be within the limits for restricted areas given in 10CFR20. The dilution time required to satisfy this requirement depends on the airflow rate and the initial concentration of the contaminant in the airstream. The initial concentration will depend on the condition of the room into which the release occurred:

- open and ventilated
- bulkheaded and backfilled
- bulkheaded but unbackfilled and with leakage through the bulkheads.

EXPLAIN WHY VOLUME OF AIR CONTACTING CONTAMINANT IS SMALL, BUT THE CONCENTRATION OF THE AIR IS HIGH.

In the open and ventilated case, the volume of air which contacts the contaminant is small, so the initial concentration in the airstream will be high. The concentration will diminish as mixing occurs with exhaust air from other rooms. Depending on the velocity of the airflow and the location of the room in which the release occurred, dilution to the allowable concentration could occur before the contaminated air reaches the exhaust shaft. Where rooms are bulkheaded and backfilled, the release would be primarily contained within the backfill. In the case of bulkheaded but unbackfilled rooms, the airborne radionuclides would diffuse throughout the room and some of the release would be carried into the exhaust airways through leakage. Dilution to within the limits in 10CFR20 would be required if it were necessary to breach the bulkheads and enter the room. Since personnel should not be present unless the concentration of radioactive materials in the airstream falls within the EPA limits, it is important that one be able to estimate the time required for sufficient dilution to have occurred. Thus it is also important, if rooms are bulkheaded, to be able to monitor the concentrations of any radionuclide releases contained within them.

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MOVE TO TECHNICAL POSITION SECTION

The limits for releases to unrestricted areas are as much ~~as 30 times~~ less than those for the restricted areas. Hence, airflows and effluents whose concentration of radioactive materials are within the limits for restricted areas may require treatment before release to unrestricted areas so that the concentrations meet the limits for unrestricted areas.

The releases of radioactive material are accompanied by releases of ionizing radiation. To satisfy the performance objectives, it must also be assured that the doses and levels of radiation also meet the limits in 10CFR20. As with releases of radionuclides, the standards for radiation doses and levels for the general public (unrestricted areas) are set well below those in restricted areas. However, as the attenuation of radiation levels follows an inverse square law (Glasstone and Sesonske, 1981), it can be shown that radiation doses and levels which meet 10CFR20 limits in the storage rooms will result in satisfactory levels in the accessible environment.

References:

10CFR20 "Standards for Protection Against Radiation," Nuclear Regulatory Commission, U. S. Code of Federal Regulations, ~~10 November 1978.~~ JANUARY 1, 1983

10CFR60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," TECHNICAL CRITERIA Nulcear Regulatory Commission, 198~~1~~3.

Glasstone, S., and Sesonske, A., Nuclear Reactor Engineering, Third Edition, Van Nostrand Reinhold Co., New York, 1981, Ch. 9.

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SITE TECHNICAL POSITION

NNWSI - STP ~~1B~~ 4.1.2

MINIMUM INFORMATION NEEDED AND FACTORS TO BE CONSIDERED IN DETERMINING HOW THE DESIGN CRITERIA AND CONCEPTUAL DESIGN ACCOMMODATE THE RETRIEVABILITY OPTION

Background:

Section 60.111 of Subpart E of 10CFR60 ~~outlines~~ CONTAINS the performance objectives for the geologic repository operation area through permanent closure. Two specific areas of concern are identified:

- protection against radiation exposures and releases of radioactive material
- retrievability of waste

With regard to the second area of concern, Section 60.111 (b) requires that the option of waste retrieval be preserved throughout the period during which wastes are being emplaced, and thereafter until completion of a performance confirmation program and NRC review of the information obtained from such a program.

To satisfy this retrievability objective, the repository 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 years after waste emplacement operations are initiated, unless the NRC approves or specifies a different time period. In addition, this requirement shall not preclude decisions by the NRC to allow backfilling part or all of, or permanent closure of, the repository prior to the end of the retrievability period.

To assure that the performance objectives in Section 60.111 are met, Sections 60.131 through 60.134 specify minimum criteria for the design of the geologic repository operations area. Of these, the sections specific to waste retrieval are 60.132(a) and 60.133(c). Section 60.132(a) requires that surface facilities in the geologic repository operations area be designed to allow safe handling and storage of waste in the operations area, whether these wastes are on surface before emplacement or as a result of retrieval from the underground facility. Section 60.133(c) requires that the design permit retrieval in accordance with 60.111(b).

In order to have reasonable assurance that the aforementioned performance objectives and criteria for the geologic repository operations area through ~~performance~~ PERMANENT closure ~~shall~~ ARE be met, it is essential to determine how the retrievability option is accommodated by the design. This document presents the NRC staff's position on what information is needed and what factors must be considered in order to do so.

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Technical Position:

It is the NRC staff's position that the following information must be obtained and considered in determining how the design criteria and conceptual design accommodate the retrievability option.

A. **Storage Rooms**

1. Will the storage rooms be open and ventilated, bulkheaded, or immediately backfilled?

2. Will canisters be stored in vertical or horizontal drilled holes or in THE EXCAVATED AREA OF THE STORAGE rooms. ~~with bentonite blocks encompassing the canisters?~~

3. Will drilled storage holes be lined?

4. How many canisters will be stored per hole?

B. **Equipment**

1. How will breached canisters be handled?

2. What kind of equipment will perform overcoring of drilled holes or remining of backfill, if found necessary?

C. **Retrieval**

1. How will repository operations handle retrieval from a local area concurrent with CONSTRUCTION AND storage?

2. How will contaminated material be handled?

[IN]CLUDE RETRIEVAL FROM THE ENTIRE REPOSITORY.

D. **Ventilation**

1. How will thermal loading in the storage rooms be controlled during retrieval?

2. What effect will thermal loading and cycles of cooling and heating have on stability of openings?

Discussion:

The basis for the NRC staff's position is presented below. Each question is discussed in terms of why an adequate response would be needed to show that THE NTS design and design criteria satisfy the technical criteria of 10CFR Part 60.

A.1. Will the storage rooms be open and ventilated, bulkheaded, or immediately backfilled?

These options affect storage room environment after full canister emplacement. All three have different impacts on retrievability, open rooms having the least impact, and backfilled rooms having the greatest. Because impact on rate of retrieval varies with each method, a storage procedure must be selected so that retrievability REQUIREMENTS ~~associated with the concepts~~ can be ~~designed to approximately equal the rate of emplacement.~~ DEVELOPED TO ALLOW RETRIEVAL ON A REASONABLE SCHEDULE.

A.2 Will canisters be stored in vertical or horizontal drilled holes, or in rooms ~~with bentonite blocks encompassing the canisters~~? THE EXCAVATED AREA OF THE STORAGE

Canister emplacement configuration strongly affects equipment design for retrieval, and, once adopted, will permit design and testing of equipment in a timely manner. It also affects retrieval in that retrieval from rooms is decidely different than from drilled holes, and stability considerations are different for horizontal and vertical holes.

A.3 Will Storage holes be lined?

FURTHER EXPLAIN THIS STATEMENT

Lined storage holes may interfere with retrieval if overcoring is required. In long horizontal holes, lining may be required to maintain hole stability during the retrieval period.

A.4 How many canisters will be stored per hole?

Multiple canisters per hole will interfere with retrieval of breached canisters, if ~~the middle~~ AN INTERIOR canister in the chain is breached.

B.1 How will breached canisters be handled?

This is a real possibility during retrieval and therefore a plan must be integrated with any chosen storage concept. A breached canister could delay the retrieval of other canisters, thereby slowing the retrieval rate. Operators must be protected from radionuclide release. This will require shielded cabs, and monitoring systems. These systems must withstand high temperatures and other characteristics of the mine environment.

MOVE TO TECHNICAL POSITION SECTION

B.2 What kind of equipment will perform overcoring of drilled holes, or remining of backfill, if found necessary?

Overcoring vertical or horizontal holes will require decidely different pieces of equipment, in that storage rooms dimensions are

EXPLAIN BASIS FOR THIS STATEMENT ON OVERCORING.

significantly different, thus limiting the working space. Overcoring should not significantly slow the rate of retrieval. Remining backfill will be done in a hostile environment. Protection of personnel from radionuclide release must be assured, while maintaining the required retrieval schedule.

C.1 How will repository operations handle retrieval from a local area, concurrent with CONSTRUCTION AND storage?

All operating variables must be defined to enable a retrieval SCHEME AND schedule to be developed. Because local retrieval will be concurrent with storage operations, it is necessary to allow FOR coordination of these activities in the repository design.

C.2 How will contaminated material be handled?

Radionuclide release during storage ~~will~~ COULD require local retrieval. The retrieval process in any storage room concept may uncover contaminated material, both liquid and solid, associated with the breached canister. Handling this material will be a separate operation and, if not well planned, can interfere with retrieval efficiency.

D.1 How will thermal loading in storage rooms be controlled during retrieval

With the exception of open storage rooms, ventilation during retrieval must provide for the thermal impact of stored canisters on host rock and ambient air temperatures. Pre-cooling is suggested for bulkheaded but unbackfilled rooms. Handling hot backfill material must be properly planned. Weakened ground support and thermal spalling may prolong retrieval operations.

(E TO TECHNICAL POSITION SECTION.

D.2 What effect will thermal loading, and cycles of cooling and heating have on stability of openings?

Rehabilitating rooms for safe entry will complicate the retrieval process. Thermal impacts on stability of openings must be identified in order to DEVELOP SCHEMES AND schedule FOR retrieval in a timely manner.

REFERENCES:

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SITE TECHNICAL POSITION

NTS-STP 2 8 4.2

MINIMUM INFORMATION NEEDED AND FACTORS TO CONSIDER IN DESIGNING REPOSITORY OPENINGS

Background

The design of stable openings in a repository is governed by a number of parameters, such as in situ stresses, rock mass strength, and rock mass deformation. The parameters vary with time, and are significantly affected by excavation and temperature conditions. 10CFR60 requires that the DOE provide assurance that the stability of the repository openings will be maintained at least during the retrievability period. Sections 60.111, 60.112, and 60.113 stipulate the performance objectives for a geologic repository. Section 60.133 provides additional design requirements for the underground facility, and 60.141 requires confirmation of geotechnical and design parameters during the repository construction and operation period. In order to achieve the design of stable repository openings, an extensive geotechnical investigation program needs to be implemented. This involves detailed data collection with respect to geology, hydrogeology, and geomechanics. From these studies, the baseline information on subsurface stratigraphy and associated structural features, groundwater regime, mechanical and thermo-mechanical properties can be determined for use in repository design. This document presents the NRC staff's position on what information is required to substantiate the assurance of stable openings within the repository.

OVE TO ECHNICAL OSITION ECTION

Technical Position:

In general, the essential steps in performing the stability analysis of underground openings are (a) computing stresses, before and after excavation, in the rock mass around the opening; (b) estimating rock mass strength; (c) comparing stresses and strength to determine if stresses are within the strength values; and (d) estimating the deformation of the opening to determine if the resulting deformations are within predetermined limits.

ARIFY IAT THIS ORK ALSO VOLVES BORATORY VD FIELD ORK.

It is therefore, the NRC staff's position that the following information, at the Yucca Mountain Site, must be obtained and carefully evaluated as a basis for appropriate engineering design to maintain the stability of repository openings in the presence of coupled in situ, excavation induced, and thermal stresses during construction and operation of the repository.

1. The in situ stress conditions need to be determined and their spatial variation needs to be established.

2. The rock mass strength properties and their variation with time, ~~and~~ temperature AND LOCATION need to be ~~estimated~~ DETERMINED.
3. The rock mass deformation characteristics and their variation with time and temperature need to be analyzed.

Discussion:

The basis for the NRC staff's position is presented below:

1. The in situ state of stress at the repository horizon is an important parameter in the assessment of the stability of the repository openings. Subsequent changes in the in situ stress conditions due to (a) excavation and other construction activities, (b) temperature fluctuation from waste emplacement, (c) time effect, and (d) any other human-induced or natural causes have to be considered in designing the repository. Stability of the underground openings during construction and operation, integrity of the waste canisters, and ~~thus~~ the isolation capability of the repository will be affected by the in situ stresses (virgin and induced).

   The present state of knowledge about in situ virgin stresses is limited to results of a few measurements which have not officially been released by DOE. These measurements were conducted using the hydrofracturing technique which has certain inherent limitations that one has to consider in analyzing the test data. Since the hydrofracturing is the only viable means to predetermine the in situ stresses before the repository horizon is accessible, emphasis must be placed on correlat~~ion~~ING the in situ stress with surface and subsurface structural geology. In addition, some stress measurements by various techniques at the G-Tunnel may be beneficial, but may not necessarily be representative of the in situ stresses at the Yucca Mountain Site. However, any proposed stress-measurement methods at G-tunnel will certainly verify their applicability at the repository horizon. These methods, then, can be readily adopted underground as soon as access is available.

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The commercial instruments that are currently available to monitor the in situ stress changes due to excavation and thermal effect fail to completely fulfil the long-term performance requirements. Some of the instruments are especially subject to high-temperature effect and are currently being improved.

2. Rock mass strength is the level of stress concentration (resulting from in situ stresses and excavation, thermal, hydrological, and earthquake loadings) at which rock will fail. Therefore, the determination of rock mass strength properties and their variation with time and temperature is very important to the design of stable openings. Rock mass strength is a combination of the individual components of the intact rock, joints/discontinuities, and interstitial fillings. Once the in situ stress concentration exceeds the rock mass strength, the rock mass will fail. There are three possible modes of failure - compressive, tensile and shear. At the Nevada Test Site, shear failure is generally applicable to the stability analyses due to the jointed nature of the rock mass, even though failure may occur in the other two modes.

   Shear strength of the intact rock, the joints, and the interstitial fillings can be determined in the laboratory and in situ. A wide range of strength values can result by performing tests on different-sized samples and by imposing different boundary conditions during testing. Different empirical approaches exist for accounting for the fractures and other imperfections, and estimating the rock mass strength from small-scale testing.

   MOVE TO TECHNICAL POSITION SECTION

   Review of DOE's currently available documents clearly indicates that additional tests are necessary on different-sized samples to determine the joint shear strength in terms of cohesion and friction angle. The data base for an intact rock shear strength seems sufficient but may be improved by conducting more tests on specimens under simulated in situ conditions. The effect of creep on intact and jointed rocks has not been addressed, and may play a central role in governing the long-term stability of the openings. Since the geological setting in the G-tunnel differs from that at Yucca Mountain in the extent and distribution of

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welded tuff as well as apparent differences in rock mass properties, much care should be exercized and a rationale should be established for application of the G-tunnel data to the Yucca Mountain Site for any conceptual design.

A reliable estimate of rock mass strength of tuff in the repository horizon needs to be established. There are several empirical approaches available for preliminary assessment of the rock mass strength. These approaches have their own inherent deficiencies, and require the determination of joint spacings, nature of interstitial fillings and their spatial variability, persistence of fractures, and groundwater conditions. Hence, sensitivity analysis should be incorporated in these approaches to best determine the rock mass strength value.

As suggested above, upper and lower bounds of strength parameters should be established by means of a detailed laboratory and field study. Effects of time and temperature on strength properties should be established. All of the above should be established using standardized testing procedures or by developing new methods which have been reviewed and fully documented.

MOVE TO TECHNICAL POSITION SECTION

3. With respect to rock mass deformation, it is generally recognized that a meaningful analysis of the stability of underground openings can be made only after establishing what constitutes instability or failure. This requires the determination of the level of deformation that can be tolerated such that no significant impairment of repository function occurs. Establishing representative stress-deformation characterizations of the rock mass is a first step in assigning limits for tolerable levels of deformation, and thus defining "failure". Deformation analyses based on experimental data and analytical models thus become a very important issue in designing the repository and assessing its performance through time.

Most laboratory studies performed so far have involved intact rock specimens of very small sizes. However, the actual stress-deformation behavior is mainly controlled by the geologic imperfections which cannot generally be represented in small scale test specimens. Therefore, investigations

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into the stress-deformation characteristics for the intact rock and rock mass should concentrate on large-scale, in situ testing supplemented by small scale, laboratory test. Non-linearity, time dependence, and spatial and directional variability with respect to stress-deformation need to be better characterized so that a representative set of input parameters can be used for numerical modeling to optimize repository design. It is essential that the establishment of a limit to the allowable deformations under excavation and thermally induced stresses be an essential objective of in situ testing and subsequent modeling.

MOVE TO TECHNICAL POSITION SECTION

Constitutive models need to be developed for predicting rock mass deformations and sensitivity analyses should be performed to examine the rock-support interaction. A failure criterion should be developed to incorporate rock mass discontinuities.

To confirm performance of engineering design, various instruments are being considered for installation at the key locations in the repository to monitor, for example, the changes in deformation. Some of the instruments are limited in their longevity, especially at elevated temperature. This deficiency needs to be rectified before the instrumentation plan is instituted.

REFERENCES:

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SITE TECHNICAL POSITION

NNWSI - STP 5 8.4.5

MINIMUM INFORMATION NEEDED AND FACTORS TO CONSIDER IN CONSTRUCTING AND SEALING REPOSITORY SHAFTS AND BOREHOLES

Background:

10CFR60 requires that a mined geologic repository meet EPA standards concerning the release of radioanuclides to the accessible environment. Shafts and boreholes are of particular concern because they are potential pathways for radionuclide travel. Isolation of the nuclear wastes will require the sealing of all penetrations into or nearby the underground repository.

Two sections of 10CFR60 address the design of shafts, boreholes and seals. These are:

DISTINGUSH BETWEEN SEAL EQUIREMENTS 60.134(a)) AND MATERIAL AND PLACEMENT METHODS (60.134(b)).

- 60.134, Design of Seals for Shafts and Boreholes, which states that the seals, seal materials, and placement methods must be designed so that seals do not become preferential pathways for ground water.
- 60.72, Construction Records, which states that records are required of construction activities and problems.

MORE SPECIFICALLY 60.72(11)

Technical Position:

The technical position put forth below outlines the approach that, in the opinion of the NRC staff, will be necessary to satisfy the 10CFR60 requirements. The technical position includes the two sub-issues under NTS Design Issue 5, namely:

SEPARATE REPOSITORY SHAFTS AND EXPLORATORY SHAFTS (SEE COMMENT ON ISSUES STP)

- How is repository performance expected to be affected by repository shafts?
- How is repository performance expected to be affected by exploratory boreholes?

Much of the Technical Position applies to both shafts and boreholes. Shaft sealing is more complex than borehole sealing, and so the emphasis of the Technical Position is on shafts (both exploratory and repository). Special concerns related to borehole sealing are discussed at the end.

Information necessary on shaft and borehole sealing includes:

1. A description of the pre-existing hydrologic system, including (but not limited to):

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i) Formation permeabilities, particularly vertical permeabilities

ii) The character of vertical hydraulic connections between aquifers at depth, perched water tables, and other permeable zones

iii) Flow rates and travel times along pre-existing flowpaths from the repository to the outside environment.

iv) The thickness and location in the stratigraphic column of aquifers, perched water tables, and other permeable zones

v) The hydraulic heads measured in each water bearing zone

vi) Anticipated effects of ground water on shaft construction.

!) EFFECT OF SHAFT CONSTRUCTION ON THE EXISTING HYDROLOGIC SYSTEM.

2. A description of the rock mass characteristics of the rock units to be encountered, including:

i) The rock mass strength, and the variation in the rock mass strength down the stratigraphic column WITH TIME, TEMPERATURE, AND LOCATION.

ii) Fracture characteristics in each rock unit, including spacing, orientation, frequency, and condition

(INCLUDE ROCK MASS DEFORMATION

iii) The in situ stress state, AND ITS VARIATION WITH TIME AND TEMPERATURE.

3. An approach to characterization of the Disturbed Rock Zone (DRZ) that will be formed around the shafts, to include:

i) A theoretical prediction of the permeability increase in the DRZ, based on site-specific information

ii) A description of tests planned during and after shaft construction to fully characterize the DRZ and other changes in the hydrologic system

4. A discussion of the proposed shaft construction technique, including blasting patterns, pre-grouting plans, temporary support, materials and construction specifications, and QA procedures.

DRAFT

5. A discussion of the proposed shaft Short Term Seal (STS) design, including:

   i) The relationship between the STS and the conceptual design for the Long Term Seal (LTS)

   ii) Construction plans for the STS, including lining or casing technique, plans for grouting the liner or casing to the wall rock, and chemical seals

   iii) The materials that will be used in the STS, and their long term characteristics and compatibility with the repository environment.

   iv) Incorporation of testing of LTS materials in the STS program

INCLUDE THE FOLLOWING; PLANS FOR REMEDIAL SEALING TESTING TO DETERMINE CONTINUITY OF GROUTED ZONES.

6. A discussion of long term shaft sealing aspects, including:

   i) A conceptual design of the LTS, based on performance assessment modelling.

   ii) Information about the host rock and sealing materials that will be required for a complete LTS design, and a discussion of the research that is currently being performed to meet those requirements.

7. A discussion of the borehole drilling and sealing program.

Discussion:

NOT A PROPER REFERENCE

~~The primary~~ A concern of 10CFR60 is that shafts should not become preferential pathways for groundwater movement. A knowledge of the pre-existing hydrologic system is necessary to assess the changes resulting from shaft construction. Because a shaft may provide a vertical connection between permeable zones, particular attention should be given to pre-existing vertical permeabilities.

MOVE TO TECHNICAL POSITION SECTION

Hydrologic MONITORING AND modeling of the groundwater system before and after shaft construction may be necessary to determine the effect of the shaft.

The hydrologic system is also important to shaft construction. If the shaft is to be constructed by conventional methods, highly permeable water-bearing zones could cause water to flow into the shaft, slowing construction. Pre-grouting might be required which

BLIND
BORING IS
NOT BEING
CONSIDERED
AT NTS

could later affect hydrologic testing and rock mass sealing. Blind drilling a shaft through permeable zones could result in substantial mud losses, which also might affect hydrologic testing. The presence of perched water bearing layers, and other structures such as faults and intersecting fracture zones at the NTS should be identified by careful subsurface exploration.

Shaft construction creates a Disturbed Rock Zone (DRZ) which may constitute a preferential pathway for groundwater. A major mechanism of permeability enhancement in the DRZ is stress relief which may open pre-existing fractures. Rock response to the shaft will also be affected by the rock mass strength and the in situ stress state.

Rock mass mechanical characteristics are important to the proper design of blasting rounds to limit damage to the rock. Rock quality may also determine the amount and type of short term support required, which could in turn affect seal design. For drilled shafts, weaker rock units may require special treatment to prevent their sloughing into the hole.

MOVE TO
TECHNICAL
POSITION
SECTION

A preliminary, theoretical estimate of the extent of the DRZ in the different rock units encountered should be obtained through modeling. The modeling should take into account the rock mass strength, fracture characteristics, in situ stress state, and the effects of blasting and temporary support.

The theoretical estimate of the DRZ obtained through modeling should guide the characterization of the actual DRZ. The goal of the characterization program should be to determine the magnitude of the increase in permeability within the DRZ, the variation of the DRZ with depth, and the physical characteristics of the DRZ that will be needed for the design of the LTS. A complete characterization program should be carried out both during and after shaft construction and should include instrumentation inside the shaft, hydrologic testing, exploratory coreholes drilled from the shaft, and crosshole seismic surveys. The DRZ should be characterized in the exploratory shaft (ES) and in all repository shafts.

Construction specifications must be reviewed to determine that the construction technique does not interfere with site characterization and shaft sealing operations. With conventional shaft sinking, the concern is that blast damage to the rock be minimized, which will require controlled blasting designed on the bases of site-specific geologic information. Pre-grouting to limit water inflow or enhance rock structural stability may affect the long term sealing characteristics of the rock, which should be considered in the choice of grouting materials and techniques. Similarly, temporary shaft support such as shotcrete or rock bolts must also be designed in a manner which will not compromise the effectiveness of the sealing program. With drilled shafts, the loss of drilling fluid to the formation may affect subsequent hydrologic testing and sealing programs.

ITS IS NOT CONSIDERING DRILLED SHAFTS

Strict QA procedures must be established for all phases of the construction program. Maintenance of the construction records required by 10CFR60 should also be covered by QA procedures.

The two primary purposes of the STS (which incorporates the shaft lining) are to maintain stability and dry working conditions during the operating life of the shaft. Neither of these tasks is directly related to the long term maintenance of radionuclide isolation. However, the STS will be present during permanent closure of the repository, and will have to be either removed or incorporated into the LTS. Therefore long term sealing must be considered in the design of the STS.

MOVE TO TECHNICAL POSITION SECTION

Construction technique may affect the long term effectiveness of the STS. Most of the shaft lining techniques (e.g. conventional slip-forming or pre-cast segments) leave numerous joints in the liner which may later require grouting. Plans for grouting behind the liner or for using chemical seals may later affect sealing of the DRZ and the rock-cement interface. If the shaft is drilled and a steel casing is used, another interface is created between the casing and the cement. Plans for possible remedial sealing measures during the operating phase are also relevant.

NTS IS NOT CONSIDERING DRILLED SHAFTS

The properties of the materials that will be used in the STS will be important to long term sealing, especially if the STS is not removed at permanent closure. The required information about the long term durability of the STS materials and their compatibility with the host rock may be obtained from case histories and from testing.

The STS provides a unique opportunity for testing LTS materials in the actual repository environment over a relatively long time period.

Consideration should be given to using several different potential LTS materials in the STS and observing their effectiveness during the operating phase.

A complete LTS design would be premature at present, because much needed information on the site and on sealing materials is not available. A conceptual design of the LTS is however essential to guide research on sealing materials and site characterization activities. The conceptual design should address sealing of all three of the potential ground water pathways created by shaft construction, which are:

- The shaft itself
- The annulus between the concrete liner and the shaft wall
- The disturbed rock zone around the shaft resulting from blasting and stress relief

The ongoing site characterization program should be designed to provide the information necessary for the development of a complete LTS design. Some of the more important site specific data necessary to adequately design a long term sealing system are:

- In situ stress field and stress concentration factors to assist in determining necessary seal material strength
- Extent of existing and blast-induced fractures around the ES
- Geological data including lithology ' rock structure
- Hydrological data that identify local and regional waterflows and also the porosity and permeability of the tuff rocks
- Geochemical data including ground water geochemistry and rock-ground water interaction to determine chemical compatibility with a seal material.

A testing program should also be undertaken to develop appropriate materials for the LTS. The long term sealing materials testing program should address the following issues:

- The seal materials should be capable of absorbing both water and radionuclides.
- The seal materials should be compatible with the rock, concrete, and ground water. For this, the mechanical, chemical, and hydrologic properties of the seal materials must be known.
- High temperature durability of the seal materials must be assessed.
- The methods of seal placement must be assessed such that an effective long term seal can be constructed.

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Sealing of boreholes is less of a concern than shaft sealing. Boreholes are much smaller in size, and the DRZ around boreholes is not substantial owing to the small size of boreholes relative to the fracture spacing. In addition, advanced borehole sealing techniques have been developed by the oil industry.

Nevertheless, boreholes do represent potential preferential ground water pathways. The total number of boreholes penetrating the repository horizon should be kept to a minimum, and so the purpose of each borehole should be carefully defined.

The information required to assess the borehole sealing program includes:

- The total number of boreholes
- The purpose of each borehole, and the tests to be performed
- The location, depth, and size of each borehole
- Casing and sealing plans, and the materials to be used in casing and sealing.

Two areas of special concern are:

- The casing and casing cement should be incorporated into the long term seal
- The sealing materials should be compatible with the repository environment.

REFERENCES: