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Center for Nuclear Waste Regulatory Analyses

6220 CULEBRA ROAD • P.O. DRAWER 28510 • SAN ANTONIO, TEXAS, U.S.A. 78228-0510
(210) 522-5160 • FAX (210) 522-5184

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Account No. 20-5702-621

U.S. Nuclear Regulatory Commission
ATTN: Dr. Banad N. Jagannath
Division of Waste Management
TWFN Mail Stop T7J-2
Washington, DC 20555

Subject: RDCO Intermediate Milestone No. 20-5702-621-601: CDM for RRT 4.3—Shafts and Ramps Design

Dear Dr. Jagannath:

The subject document is specified as a deliverable in the Operations Plan for the RDCO Program Element. Attached is the Center for Nuclear Waste Regulatory Analyses (CNWRA) document entitled "Compliance Determination Method for Review Plan No. 4.3: Assessment of Compliance with Design Criteria for Shafts and Ramps." To better reflect the content of the document, the title has been changed from that originally identified in the operations plan.

This technical document fulfills the requirements for the subject milestone which is due January 15, 1996.

If you have any questions on this report, please contact Goodluck Ofoegbu at (210)522-6641 or me at (210)522-5151.

Sincerely yours,

Asadul H. Chowdhury, Manager
Repository Design, Construction, and Operations

AHC/yl
Enclosure

cc: J. Linehan, J. Greeves, M. Federline, B. Morris, F. Costanzi, S. Fortuna, B. Meehan, B. Stiltenpole (2), P. Justus, J. Holonich, J. Austin, M. Bell, D. Brooks, M. Nataraja, K. McConnell, S. Wastler, J. Randall, J. Philip, T. McCartin, C. Interrante, S. Bahadur, J. Thoma, W. Patrick, CNWRA Directors, CNWRA EMs, M. Ahola, S. Hsiung, A. Ghosh, R. Chen, G. Ofoegbu, H. Karimi, S. Rowe (SwRI Contracts)

Washington Office • Twinbrook Metro Plaza, #210 • 12300 Twinbrook Parkway • Rockville, Maryland 20852-1606

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COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN NO. 4.3
ASSESSMENT OF COMPLIANCE WITH DESIGN CRITERIA FOR SHAFTS AND RAMPS

3.0 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the license application (LA) concerning shafts, ramps, boreholes, and their seals (SRBS) with the corresponding section of the Format and Content Regulatory Guide (FCRG) for the License Application for the High-Level Waste Repository and with the staff's resolution status of objections to LA submittal in the Open Item Tracking System (OITS). The staff will determine if this information meets the following criteria.

(i) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(ii) The U.S. Department of Energy (DOE) has either resolved, at the staff level, the Nuclear Regulatory Commission (NRC) objections to LA submittal that apply to this regulatory requirement topic, or provided all the information requested in Section 1.6 of the FCRG for unresolved objections, namely, the DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

In addition, unresolved objections, individually or in combination with others, will not prevent the staff from conducting a meaningful Compliance Review and the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by the NRC staff will consider if the Acceptance Criteria specified for each of the following Compliance Reviews have been met. The results of the compliance determinations shall be documented by the staff to provide the basis for actual Evaluation Findings documented in the Safety Evaluation Report (SER).

These review procedures are written so that they can be used for any SRBS systems identified in the LA. For the designs of the SRBS, the staff should evaluate if the LA acceptably demonstrated compliance with the applicable regulations for the following systems: (i) waste shafts or ramps, (ii) muck shafts or ramps, (iii) ventilation intake shafts, (iv) ventilation exhaust shafts, (v) personnel and material shafts, (vi) decommissioning system, and (vii) any other systems of the SRBS. The staff should recognize that for each of these systems of SRBS, only the specific regulatory requirements applicable to that SRBS

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system will be reviewed and evaluated. For example, if shafts are designed and constructed only for exhaust ventilation purpose, such shafts will be reviewed and evaluated only for the regulations applicable to ventilation exhaust shafts. The designs of the portals and collars are not considered here but are considered as part of the designs/analyses (e.g., engineering proofs, models, calculations, drawings, and specifications) of surface facilities in Review Plan 4.2.

The FCRG has suggested a format for separating the regulatory requirements applicable to this Review Plan, and it is anticipated that the DOE will use this format to prepare the LA. To have a more efficient review, this Review Plan follows the suggested FCRG format to the extent practicable. This Review Plan focuses on the review of shafts, ramps, boreholes, and their seals for compliance with both the preclosure and postclosure aspects of 10 CFR Part 60.

The procedural steps for review of the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this review plan, are in Review Plan 4.1.2. The procedural steps for review of 10 CFR 60.111(a), and 60.131(a)(1-6) are in Review Plan 4.2. The procedural steps for review of 10 CFR 60.137 and 60.131(b)(1-8) are in Review Plan 4.4. The procedural steps for review of 10 CFR 60.111(b) are in Review Plan 4.5.2. The review for 10 CFR 60.131(b)(9), to determine SRBS compliance with applicable Mine Safety and Health Administration regulations, will use a three-step approach:

- Review of conditions, operations, events, and scenario descriptions relevant to SSCIS
- Review of design bases, criteria, requirements, and engineering specifications of the SSCIS for the applicable mining regulations
- Selected focused safety review of SSCIS for the applicable mining regulations

Due to the anticipated lack of use of shaft conveyance in radioactive waste handling in the DOE conceptual design, no review is required for 10 CFR 60.131(b)(10). The review for 10 CFR 60.134 will be conducted in four steps. This regulatory requirement involves the engineering design of each structure, system, and component of SRBS. The four steps are:

- Review of site characteristics, processes, and events relevant to the SRBS design
- Review of design bases, criteria, requirements, and engineering specifications of the SRBS
- Review of analysis and design process and methodology
- Selected focused safety review for compliance of representative design samples

The structures, systems, and components important to safety (SSCIS) are identified in Review Plan 4.1.2.

A Key Technical Uncertainty (KTU) has been identified for 10 CFR 60.134. Relevant discussion for this KTU is given in Section 3.2.10 of this Review Plan.

For each review procedure step, the staff is to prepare a summary statement as to whether or not the acceptance criteria are satisfied. These summaries form part of the bases for the evaluation finding for the regulatory requirements. If the acceptance criteria are not satisfied, the staff should document the deficiencies.

3.2.1 Safety Review for Compliance With 10 CFR 60.112

The scope of this safety review consists of an evaluation of post-closure releases of radioactive material to the accessible environment, considering the characteristics of the geologic setting, the engineered barrier system, and the shafts, ramps, boreholes, and their seals. The review procedure and acceptance criteria for this safety review are provided in Review Plan 6.1. The performance of the seals may have an impact on the overall assessment for compliance with 10 CFR 60.112. Therefore, the staff should consider the assumptions on seals used in Review Plan 6.1 along with the results of determination of compliance with 10 CFR 60.134 to determine if the shafts, ramps, boreholes, and their seals support compliance with 10 CFR 60.112.

3.2.2 Safety Review for Compliance With 10 CFR 60.130, 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A),(C),(E) and (F), 10 CFR 60.21(c)(2), 10 CFR 60.21(c)(3), 10 CFR 60.21(c)(6), 10 CFR 60.21(c)(7), and 10 CFR 60.21(c)(12)

The scope of this part of the safety review encompasses two different perspectives of the SRBS designs, as expressed in 10 CFR 60.130. First, the design bases for SRBS must be consistent with results of site characterization activities. Second, although SRBS are not part of the underground facility as per 10 CFR 60.2, and, as a result, are not directly subject to the provisions of 10 CFR 60.133, specific sections of 10 CFR 60.133, namely, 60.133(a), (b), (c), (d), (e), (f), (g), and (i), address safety features that are not addressed in 10 CFR 60.131, 60.134, and 60.137 but may be necessary to ensure that SRBS satisfy their performance objectives. Inasmuch as 10 CFR 60.130 requires that provisions be made for such safety features that are necessary to achieve the performance objectives for a specific facility, the design of SRBS will be reviewed against the specified sections of 10 CFR 60.133 to determine compliance of SRBS with 10 CFR 60.130.

The review procedure and acceptance criteria for the applicable regulatory requirements of 10 CFR 60.21(c), listed above, are given in Review Plans 4.1.2 and 4.4.

For the first part of this safety review, the staff should evaluate the design bases for SRBS to determine if they are consistent with the results of site characterization activities. The staff should determine if the design bases are consistent with applicable site characterization data before the safety reviews in Sections 3.2.3 to 3.2.10 of this Review Plan have been completed. There should be interaction with the reviewers of the relevant Review Plans identified in Section 4.2.1 of this Review Plan, to ensure that the information used in the designs/analyses is a reasonable interpretation of the data acquired during site characterization. Review of the adequacy of the site characterization data is addressed in Sections 3.1 and 3.2 of the LARP. It is expected that the license application will identify and describe the site characterization data uncertainties and describe how these uncertainties are addressed in the SRBS designs/analyses. The acceptance criteria for the first part of the safety review for compliance with 10 CFR 60.130 include the following.

- The site characterization data are in a form that relates directly to the needed design information (e.g., earthquake motion is expressed as a time history) and that the site data are appropriate and in sufficient detail to arrive at the design bases.

- The design bases are consistent with applicable site characterization data, which is reviewed as per Review Plans 3.1 and 3.2, and iteratively during the safety review of SRBS in Sections 3.2.3 through 3.2.10 of this Review Plan.

For the second part of the safety review for compliance with 10 CFR 60.130, the staff should evaluate the additional design criteria and safety features considered to be necessary for the designs of SRBS to comply with the performance objectives. The safety review of the additional safety features should be conducted concurrently with the review of SRBS as per Sections 3.2.3. to 3.2.10 of this review plan. This section provides a review process and acceptance criteria for the shaft, ramp, and borehole designs, with the main emphasis on the shaft designs. The staff will use the acceptance criteria of Section 3.2.8 of this Review Plan to evaluate the adequacy of the seal designs. To review the adequacy of the ramp designs, for features of the ramp that are common with the underground facility and portion of ramp that are applicable for retrieval operation, the staff will use the acceptance criteria identified in Review Plans 4.4 and 4.5.2.

The procedure and acceptance criteria for reviewing the design of shafts, ramps, and boreholes against 10 CFR 60.133, in order to determine compliance with 10 CFR 60.130 as was explained earlier, are taken from those developed in Review Plan 4.4 for the design criteria of 10 CFR 60.133 ("Additional design criteria for the underground facility"). The specific regulatory requirements adopted for SRBS are 10 CFR 60.133(a), (b), (c), (d), (e), (f), (g), and (i). Therefore, the staff should use the applicable acceptance criteria in Review Plan 4.4 to review the SRBS designs against these requirements.

3.2.3 Safety Review for Compliance With 10 CFR 60.111(a) and 60.131(a)(1) through 60.131(a)(6)

The review procedures and acceptance criteria to evaluate compliance with 10 CFR 60.111(a) and 60.131(a)(1–6) are provided in Review Plan 4.2. Therefore, the staff should use the applicable acceptance criteria in Review Plan 4.2 to determine if the SRBS designs comply with the requirements of 10 CFR 60.111(a) and 60.131(a)(1–6).

3.2.4 Safety Review for Compliance With 10 CFR 60.111(b)

The review procedures and acceptance criteria to evaluate compliance with 10 CFR 60.111(b) are provided in Review Plan 4.5.2. Therefore, the staff should use the applicable acceptance criteria in Review Plan 4.5.2 to determine if the SRBS designs comply with 10 CFR 60.111(b).

3.2.5 Safety Review for Compliance With 10 CFR 60.131(b)(1) through 60.131(b)(8)

The review procedures and acceptance criteria to evaluate compliance with 10 CFR 60.131(b)(1–8) are provided in Review Plan 4.4. Therefore, the staff should use the applicable acceptance criteria in Review Plan 4.4 to determine if the SRBS designs comply with 10 CFR 60.131(b)(1–8).

3.2.6 Safety Review for Compliance With 10 CFR 60.131(b)(9), 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A) and (F), 10 CFR 60.21(C)(2), 10 CFR 60.21(c)(3), and 10 CFR 60.21(c)(12)

The scope of this part of the safety review is focused on the designs of the SRBS for preclosure compliance with applicable Mine Safety and Health Administration (MSHA) regulations (Mine Safety and Health Administration, 1994) for allowing determination of compliance with 10 CFR 60.131(b)(9), for the environmental conditions and events associated with normal operations and anticipated conditions and events, such as those events referred to in American Nuclear Society Standard, ANSI/ANS-57.9-1984, as Design Events I, II, and III (American Nuclear Society, 1984). Forthcoming NRC rules on Design Basis Events will require update of this CDM.

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Some of the MSHA regulations (Mine Safety and Health Administration, 1994) cited here apply only to the shafts and ramps, while other MSHA regulations apply to the shafts and ramps, surface facilities, and underground facility. To determine compliance with 10 CFR 60.131(b)(9) for the underground facility, Review Plan 4.4 will refer to the review procedure and applicable acceptance criteria in this Review Plan. The staff will use Review Plan 4.2, which is developed separately, to determine compliance with 10 CFR 60.131(b)(9) for the surface facilities.

Review procedures and acceptance criteria for the applicable provisions of 10 CFR 60.21(c), listed above, are in Review Plan 4.1.2.

Although the GROA is not a mine, mining regulations are cited so that GROA systems perform their intended functions. DOE may demonstrate that the system can still perform the intended functions even though it does not comply with one or more of the mining regulations. The regulations (10 CFR 60) allow that DOE may rebut the presumption that noncompliance with mining regulation is of concern. The staff should keep this provision in mind during the review of compliance with 10 CFR 60.131(b)(9).

The LA should clearly list the MSHA regulations that the design complies with, and those regulations that DOE asserts need not be complied with in meeting NRC's Part 60 requirements.

The mining regulations in Table 3.2.6-1 were drawn from Subchapters B and N of 30 CFR (Mine Safety and Health Administration, 1994). Subchapters D and E of 30 CFR, which are cited in 10 CFR 60.131 (b)(9), were merged into Subchapter B during the 1987 revision of 30 CFR.

3.2.6.1 Review of Conditions, Operations, Events, and Scenario Descriptions Relevant to Structures, Systems, and Components Important to Safety

The staff should evaluate the environmental conditions, operations, events, and scenarios [that are used in the designs of the SRBS to include provisions for worker protection to the extent that may be necessary to provide reasonable assurance that the SSCIS can perform their intended functions] to determine if they are adequately described to allow determination of compliance with 10 CFR 60.131(b)(9) and the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan. The acceptance criteria for this step include, but are not limited to, the following.

(1) Design basis events and environmental conditions used as the basis for the designs of SSCIS of SRBS to provide compliance with the applicable mining regulations identified in Table 3.2.6-1 are consistent with applicable site characterization results.

(2) Operations (e.g., routine and emergency operations, testing, and maintenance) relevant to the applicable mining regulations identified in Table 3.2.6-1 are considered in the designs of SSCIS.

Table 3.2.6-1. Applicable mining regulations for SRBS and underground facility

Topic	*Regulatory Citation*
General Personnel Protection:	

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Topic	*Regulatory Citation*
Respirators and Gas Masks, Approval by MSHA Sufficient	30 CFR 11.2, 11.2-1, and 11.30
Electric Cap Lamps, Approval by MSHA Sufficient	30 CFR 19.1-13
Electric Mine Lamps Other Than Standard Cap Lamps, Approval by MSHA Sufficient	30 CFR 20.0-14
Traffic Safety for Operation of Self-Propelled Mobile Equipment	30 CFR 57.9100-9104 and 57.9160
Traffic Safety for Transportation of Persons and Materials	30 CFR 57.9200-9261
Safety Devices; Provisions and Procedures for Roadways and Devices; and Procedures for Safety of Personnel Along Roadways, Railroads, and Material Transfer Sites	30 CFR 57.9300-9362
Travelways and Escapeways	30 CFR 57.11001-11017
Travelways—SRBS and Underground Only	30 CFR 57.11036-11041
Escapeways—SRBS and Underground Only	30 CFR 57.11050-11059
Personal Protection Equipment, e.g., Hard Hats, Footwear, Safety Belts, Eye Glasses, etc.	30 CFR 57.15001-15031
Safety Programs	30 CFR 57.18002-18014
Safety Programs—SRBS and Underground Only	30 CFR 57.18025 and 57.18028
Intoxicating Beverages and Narcotics	30 CFR 57.20001
Housekeeping	30 CFR 57.20003
Prohibited Areas for Food and Beverages	30 CFR 57.20014
Explosives:	
Explosives and Sheathed Explosive Units, Approval by MSHA Sufficient	30 CFR 15.6-11
Storage of Explosives	30 CFR 57.6001-6012

Topic	*Regulatory Citation*
Storage of Explosives—SRBS and Underground Only	30 CFR 57.6027-6030
Transportation of Explosives	30 CFR 57.6040-6057
Transportation of Explosives—SRBS and Underground Only	30 CFR 57.6075-6077
General Use of Explosives	30 CFR 57.6090-6168
Use of Explosives—SRBS and Underground Only	30 CFR 57.6175-6182
Sensitized Ammonium Nitrate Blasting Agents	30 CFR 57.6193-6200
Sensitized Ammonium Nitrate Blasting Agents—SRBS and Underground Only	30 CFR 57.6220
Miscellaneous Precautions for Explosives, e.g., Smoking and Open-Flame Restrictions	30 CFR 57.6250
Blasting in Hazardous Areas—SRBS and Underground Only	30 CFR 57.20031
Equipment and Locomotion:	
Electric Motor-Driven Mine Equipment and Accessories, Approval by MSHA Sufficient	30 CFR 18.2 and 18.11-13
Diesel Mine Locomotives, Approval by MSHA Sufficient	30 CFR 31.1, 31.2, 31.3(d) and 31.6(c)
Mobile Diesel-Powered Equipment for Non-coal Mines, Approval by MSHA Sufficient	30 CFR 32.1, 32.2, 32.3(d) and 32.6(c)
Mobile Diesel-Powered Transportation Equipment, Approval by MSHA Sufficient	30 CFR 36.2, 36.4, 36.10 and 36.11
Compressed Air, Boilers, and Pressure Vessels	30 CFR 57.13001-13030
Machinery and Equipment Safety Devices and Maintenance Requirements and Design; Installation and Maintenance of Safety Devices Installed on Equipment	30 CFR 57.14100-14162

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Topic	*Regulatory Citation*
Safety Practices and Operational Procedures for Equipment	30 CFR 57.14200–14219
Telephone and Signaling Devices:	
Telephone and Signaling Devices, Approval by MSHA Sufficient	30 CFR 23.2, 23.11, 23.12 and 23.14
Signaling Procedures	30 CFR 57.19090–19096
Two-Way Communications—SRBS and Underground Only	30 CFR 57.20032
Ground Control:	
Scaling and Support	30 CFR 57.3200–3203
Scaling and Support—SRBS and Underground Only	30 CFR 57.33360
Precautions	30 CFR 57.3400 and 57.3401
Precautions—SRBS and Underground Only	30 CFR 57.3460 and 57.3461
Retaining Dams	30 CFR 57.20010
Unattended Mine Openings	30 CFR 57.20020
Abandoned Mine Openings	30 CFR 57.20021
Fire Protection:	
Electrical Fires	30 CFR 57.4011 and 57.4057
Prohibitions, Precautions, and Housekeeping for Fire Prevention	30 CFR 57.4100–4161
Fire-Fighting Equipment	30 CFR 57.4200–4263
Fire-Fighting Procedures, Alarms, and Drills	30 CFR 57.4330–4363
Flammable and Combustible Liquids and Gases	30 CFR 57.4400–4463
Installation, Construction, and Maintenance for Fire Prevention	30 CFR 57.4500–4561
Welding, Cutting, and Compressed Gases for Fire Prevention	30 CFR 57.4600–4660

Topic	*Regulatory Citation*
Ventilation Control Measures for Fire Prevention	30 CFR 57.4760 and 57.4761
Smoking and Open Flames for Fire Prevention	30 CFR 57.22101-22105
Air Quality and Ventilation:	
Air Quality	30 CFR 57.5001-5006
Air Quality—SRBS and Underground Only	30 CFR 57.5015 and 57.5016
Radon—SRBS and Underground Only	30 CFR 57.5037-5046
Noise Exposure Limits	30 CFR 57.5050
Ventilation	30 CFR 57.8518 and 57.8519
Ventilation—SRBS and Underground Only	30 CFR 57.8520-8535
Electrical and Illumination:	
Electricity	30 CFR 57.12001-12053
Electricity—SRBS and Underground Only	30 CFR 57.12080-12088
Illumination	30 CFR 57.17001 and 57.17010
Other Mining Safety Provisions:	
Materials Storage and Handling	30 CFR 57.16001-16017
Carbon Tetrachloride Prohibited	30 CFR 57.20005
Barricades and Warning Signs	30 CFR 57.20011
Labeling of Toxic Materials	30 CFR 57.20012
Drilling-Surface and Underground	30 CFR 57.7050-57.7054

3.2.6.2 Review of Design Bases, Criteria, Requirements, and Engineering Specifications of SSCIS for the Applicable Mining Regulations

The staff should evaluate the SRBS designs, design bases, and specifications to determine if they comply with 10 CFR 60.131(b)(9) (related to applicable mining regulations identified in Table 3.2.6-1 for worker protection). Specific design provisions for worker protection are set out by MSHA in Title 30 of the Code of Federal Regulations, (Mine Safety and Health Administration, 1994) and the applicable regulatory citations are grouped under the following topics (Table 3.2.6-1): (i) General

Personnel Protection, (ii) Explosives, (iii) Equipment and Locomotion, (iv) Telephone and Signaling Devices, (v) Ground Control, (vi) Fire Protection, (vii) Air Quality and Ventilation, (viii) Electrical Illumination, and (ix) Other Mining Safety Provisions. The acceptance criteria will include the following.

(i) The engineering specifications developed for SSCIS meet the applicable mining regulations identified in Table 3.2.6-1. The engineering specifications that are related to SSCIS should include layout drawings, SSC design bases, criteria, plans, loads, capacities, safety devices (number, types and effective life), etc.

(ii) The interconnections among, redundancies of, and locations of the SSC that impact the safe performance of SSCIS are identified.

(iii) The applicability of the mining regulations related to the designs of SSC for safe performance of SSCIS is provided and adequately explained. The mining regulations applicable to the designs for safe performance of SSCIS include those grouped by topic in Table 3.2.6-1.

(iv) The designs of SSCIS of SRBS are consistent with mining guidelines and practices [such as those described by Hartman (1992) on the chapters related to environment, health, and safety].

3.2.6.3 Selected Focused Safety Review of SSCIS for the Applicable Mining Regulations

Design samples of the SSCIS and applicable mining regulations identified in Table 3.2.6-1 should be selected for focused safety review(s). The number and types of SSCIS and applicable mining regulations selected for review should be sufficiently representative to support an evaluation finding for the acceptability of the designs of the SSCIS.

The staff should evaluate the selected designs and analyses of SSCIS of SRBS to determine if the criteria of 10 CFR 60.131(b)(9) are met. The designs and analyses of SSCIS of SRBS are to ensure compliance with the regulations cited in Table 3.2.6-1, as a minimum. The acceptance criteria will include the following.

(i) Applicable mining regulations cited in Table 3.2.6-1 are incorporated into the designs and analyses of SSCIS.

(ii) All proposed safety devices are approved by MSHA (as indicated by "Approval by MSHA Sufficient" in Table 3.2.6-1).

(iii) Input data and assumptions used for analyses and design calculations of SSCIS are interpreted correctly and are consistent with those used to develop the design bases and design requirements.

(iv) The design methods have been implemented correctly. This implementation also includes correct interpretation and application of charts, curves, tables, equations, relevant guidelines, etc.

3.2.7 Safety Review for Compliance With 10 CFR 60.131(b)(10)

The scope of 10 CFR 60.131(b)(10) is the design of shaft conveyances (shaft hoists) used for waste handling. It is noted that 10 CFR 60.131(b)(10) does not address waste transfer methods (such as vehicles in ramps or in the underground facility) other than shaft hoists (Nuclear Regulatory Commission, 1991). Waste transfer methods, other than shaft hoists, are addressed in a number of regulations relevant to the design features of the repository. For example, protection against dynamic effects of equipment failure [10 CFR 60.131(b)(2)], instrumentation and control systems [10 CFR 60.131(b)(8)], and the design criteria of 10 CFR 60.130 all address the safe design of waste transfer methods, other than shaft hoists. Since the DOE intends to move waste to the underground facility by vehicles and not use shaft hoists, this regulatory requirement does not apply. The design features relevant to waste movement and emplacement are reviewed in other Review Plans or in another section of this Review Plan, as indicated in Table 3.2.7-1.

Table 3.2.7-1. Design features and regulations for movement, transfer, and emplacement of waste

Design Feature/Regulatory Citation	*Review Plan No.*
Safe Handling of Wastes/10 CFR 60.132(a)	4.2
Carry Out Operations Safely/10 CFR 60.133(e)(1)	4.4
Protection Against Dynamic Effects of Equipment Failure/10 CFR 60.131(b)(2)	4.2
Instrumentation and Control Systems/10 CFR 60.131(b)(8)	4.2
Waste Package Design for Handling/10 CFR 60.135(b)(3)	5.2
Safety Features/10 CFR 60.130	4.3, Section 3.2.2

3.2.8 Safety Review for Compliance With 10 CFR 60.134, 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A), (C), (D) and (F), 10 CFR 60.21(c)(2), and 10 CFR 60.21(c)(14)

The scope of this part of the Safety Review is focused on the designs for various types of seals, which includes the selection of seal materials and selection of placement methods. This safety review will include reviewing development of alternative concepts for seals, backfills, and drainage; location, number, and geometry of seals; alternate seal materials and recommendations for final material selection; test results on seal materials (both laboratory and *in situ*); proposals for performance confirmation testing [portions of this review will be conducted under the performance confirmation review plan (Review Plan 8.2), and the results will be input to this review]; and supporting analyses, calculations, and assumptions (Gupta and Buckley, 1989). Any overall design strategy that accounts for minimizing the number of surface openings, tactically placing surface openings to minimize water inflow, and providing underground dams and diversion ditches to direct flow away from the waste packages will also be reviewed under this review plan. The determination of compliance with 10 CFR 60.134(a) is based on the demonstration that seals will not become preferential pathways that would compromise the ability of the repository to meet the postclosure performance objectives described in 10 CFR 60.112 and 10 CFR

60.113(a). The DOE will have established design goals for seals that will be used as input in the performance assessments that will be reviewed by NRC under Review Plans 6.1, 6.2, and 6.3. The objective of this Review Plan is to determine if the DOE seal design meets these design goals. The overall finding for 10 CFR 60.134(a) will be based on the results of this review and considerations of the assumptions used in Review Plans 6.1, 6.2, and 6.3. The determination of compliance with 10 CFR 60.134(b), however, will be made entirely within this review plan. In the event DOE demonstrates that the seals for shafts, ramps, and boreholes do not affect the ability of the geologic repository to meet the performance objectives, the seal design will still be reviewed to satisfy the requirements of 10 CFR 60.134(b). The Safety Review of this section will be conducted in coordination with the detailed safety review of Section 3.2.10 of this Review Plan.

Review procedure and acceptance criteria for the applicable regulatory requirement of 10 CFR 60.21(c), listed above, are in Review Plan 4.1.2.

3.2.8.1 Review of Site Characteristics, Processes, and Events Relevant to Seal Designs

The staff will review the DOE designs of seals to determine if all pertinent site characteristics, processes, events, and combinations of these processes and events are adequately and appropriately considered in the design of seals. This review will be performed by comparing site characteristics information to the design events used in the DOE design. The site characteristics, processes, and events that are considered relevant to the design of seals for containment and isolation periods may include, but are not limited to, the following. The Review Plans providing the description of site characteristics, processes, and events are presented in brackets. The staff responsible for the corresponding review plans will determine the appropriateness and adequacy of the information presented. The staff responsible for this review plan will use that information in the subsequent review steps.

- Characteristics and frequency of occurrence of dynamic loads (including earthquakes, blasting, and nuclear explosion) [3.2.1.6, 3.2.1.8, 4.4]
- Fluctuation of groundwater table [3.2.2.6, 3.2.2.9]
- Surface flooding [3.2.2.5]
- Natural and repository-induced perched water formation [3.2.2.12]
- Estimated local annual rate of rainfall and water chemistry [3.2.2.1, 3.2.2.9, 3.2.3.2]
- Tectonic movement and faulting [3.2.1.5]
- Sources and pressures of gas and liquid imposed on seals [3.2.2.1, 3.2.2.9]
- Rock mechanical, hydrological, and chemical properties surrounding SRBS [3.2.1.14, 3.2.2.1, 3.2.2.10, 3.2.3.2]
- Fractures and faults information surrounding SRBS [3.2.1.5, 3.2.1.14]

3.2.8.2 Review of Design Bases, Criteria, Requirements, and Engineering Specifications of Seals and Selection of Seal Materials and Placement Methods

The NRC staff will determine if the design requirements for seals are adequately translated from the design goals considering the site characteristics, processes, events, and combinations of the processes and events. The DOE design will be acceptable if the following acceptance criteria are met.

(i) Design Requirements.

- Seals and backfill are designed for specific seal locations. At each seal location, physical, petrological, mechanical, chemical, and hydrological properties of the rock mass and the local *in situ* stress state are taken into consideration.

- Effective permeability of seal system (seals, seal/rock interface, grout, and backfill) for shafts, ramps, and boreholes is of the same order of magnitude as that of the surrounding rock mass.

- Strength and stiffness of the seal system are adequate to provide mechanical support to the surrounding rock mass through the isolation period.

- The impact of liners, rock supports, and casing removal on the surrounding rock mass is taken into consideration in the design.

- The seal system is designed considering the existing conventional and state-of-the-art technologies, if and when applicable, such as those given by the American Petroleum Institute (1986) and Smith (1986, 1990) for cement; Auld (1983), Garrett and Campbell Pitt (1958, 1961), and Gray and Gray (1992) for concrete; Pusch (1987, 1988, 1990) for bentonite; and U.S. Bureau of Mines (1994) for backfill.

- If cementitious seals are used in boreholes, they are installed in intact portions of the boreholes, to the extent practicable.

- Cementitious seals, plugs, or bulkheads in boreholes and shafts are designed such that the shearing resistance between the cement seal and surrounding rock mass is adequate to sustain the axial load induced by the cement seal itself and by the overlying backfill.

- For cementitious seals or plugs, length-to-diameter ratio of the seal or plug is greater than four (Akgun and Daemen, 1991; Greer and Daemen, 1991).

- Mechanical and thermal interactions between the cementitious seals and the adjacent backfill and grouted fractures (or grout bulb) are taken into consideration in the design.

- The impact of the nearby or intersecting excavations (open or sealed) on the seal system behavior is taken into consideration, where applicable.

- The seals are designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through *in situ* monitoring, testing, and excavation.

(ii) Engineering Specifications. The engineering specifications for seals are developed to satisfy the design requirements. The supporting rationales are adequate.

(iii) Selection of Seal Materials.

- The methods of testing and modeling conducted to support the seal material selections, where applicable, follow standard practices or well-established guidelines. Potentially applicable standards or test methods include ASTM D 427-83, ASTM D 4943-89, ASTM D 854-92, ASTM D 2845-90, ASTM D 2664-86, ASTM D 698-78, ASTM D 4611-86, ASTM D 5313-92, ASTM D 5084-90, ASTM D 5311-92, ASTM D 4525-90, ASTM D 5334-92, ASTM D 5335-92, ASTM D 2434-68, ASTM D 5298-92, ASTM D 3999-91, ASTM D 4535-85, and Brown (1981).

- Seal materials are selected for specific seal locations considering the local *in situ* stresses and their subsequent changes, as well as the geomechanical, thermal, chemical, petrographical, and hydrological characteristics of the surrounding rock mass.

- Seal materials are selected taking into consideration the physical and chemical compatibility among seals, backfill, and surrounding rock so that the originally intended seal functions are maintained through the isolation period.

- Granular materials (sand, gravel, or crushed rock), if used for backfill, are sufficiently well graded. A value of coefficient of uniformity equal to or greater than 16 is recommended by Ouyang and Daemen (1992).

- The maximum particle sizes of backfill are sufficiently small. For example, the U.S. Bureau of Mines (1994) and Gray and Gray (1992) recommend that particle sizes should be smaller than one-fifth of the opening diameter for shaft and ramp sealing and one-tenth of the hole diameter for borehole sealing.

- If a mixture of bentonite and crushed rock (or sand and gravel) is used to form a seal, the percentage of bentonite is large enough to allow effective compaction of the mixture (e.g., Ouyang and Daemen, 1992) but small enough that the shear strength of the compacted seal meets the strength requirements listed earlier in this section.

(iv) Placement Methods.

- Methods for removing liners and casings are developed such that damage to the surrounding rock mass is limited.

- Methods used for seal placement are such that damage to the surrounding rock mass is limited.

- Detailed methods and plans for *in situ* measurements, opening wall preparation and reconditioning, and seal and backfill installation, where applicable, are consistent with well-established guidelines and standards. Potential applicable guidelines and standards may include, for example, American Petroleum Institute (1977), U.S. Environmental Protection Agency (1975), U.S. Department of Interior (1977), ASTM D 5195-91, ASTM D 2922-91, ASTM D5092-90, ASTM D 3404-91, ASTM D 4395-84, ASTM D 4971-89, ASTM D 4506-90, ASTM D 2937-83, ASTM D 4959-89, ASTM D 4944-89, ASTM D 1558-84, ASTM D 5080-90, ASTM D 2844-89, ASTM D 3017-88 and ASTM D 5220-92. Deviations from the standards and technology used in the industry are described, and supporting rationales are adequate.

- Compaction is required for installation of backfill or any seals formed by bentonite, clay, sand, gravel or crushed rock, or by combinations of these materials.

3.2.8.3 Review of Analysis and Design Processes and Methodologies Relevant to Seal Designs

The NRC staff will review the DOE analysis and design processes and methodologies to determine if the following acceptance criteria are met.

- The computer codes used for the analysis of seals have been acceptably controlled in accordance with the applicable quality assurance criteria as determined in Review Plan 10.0. If nonstandard (i.e., not well known in the profession or not commercially used) codes are used, rationale supporting their validity and applicability for the intended use (to be provided by DOE in the LA) will be verified.

- Potential cumulative effects due to repetitive dynamic loads (Hsiung et al., 1992) are considered and factored into the design of seals.

- Long-term behavior of rock mass, seals, grout, and backfills is considered in the design. The long-term behavior includes, for example, stress fatigue, chemical alteration and degradation, settlement, consolidation, dehydration, piping, erosion, channelling, particle segregation, shrinkage, dislocation, deformation, and failure.

- Rock mass models applied in the analyses account satisfactorily for the effects of intact rock and discontinuities (e.g., fractures, joints, bedding, etc.) on rock-mass behavior.

- The effects of coupled heat and fluid flow are appropriately considered in the seals designs, using models that account satisfactorily for the effects of intact rock and discontinuities on the flow of heat and fluids..

- Models used to specify the values of *in situ* stress (e.g., lithostatic and tectonic stress models) are site-specific and supported by measurements.

- Limitations and constraints associated with the design methods and the models and computer codes used for the analyses are considered in the interpretation of calculated results.

- The design analyses of the effectiveness/performance of the seals, backfill, and plugs for shafts, ramps, and boreholes also include the potential effects of damage to the surrounding rocks (e.g., due to construction, liner removal, instrumentation, etc.), and settlement of backfill.

- Methods used for data reduction to generate input values for the analysis and design of seals are commonly accepted and used in the engineering community. If nonstandard methods are used, supporting rationales are adequate.

- The approaches used for the analysis and design of seals are rigorous and consistent with available industry guidelines, and the uncertainties associated with such approaches are considered in the interpretation of the analysis results. The staff should make a judgment as to whether these approaches are accepted in the engineering community and are applicable to the designs of seals for shafts, ramps, and boreholes relevant to the geologic repository.

- The design meets the design goals used by DOE in performance evaluation (in Review Plans 6.1, 6.2, and 6.3).

3.2.8.4 Selected Focused Safety Review

The NRC staff will perform focused reviews on representative design samples to determine if the items of Subsections 3.2.8.1, 3.2.8.2, and 3.2.8.3 have been implemented properly. Specific acceptance criteria include, but are not limited to, the following.

- Site characteristics, processes, and events identified in Subsection 3.2.8.1 are appropriately used to develop design bases and design requirements.

- Design bases, criteria, requirements, and engineering specifications developed/adopted in Subsection 3.2.8.2 are appropriately considered in the design processes, methodologies, and calculations.

- Input data for analyses and calculations are interpreted correctly and are consistent with those used to develop the design bases and design requirements.

- The analysis and design processes and methodologies developed/adopted in Subsection 3.2.8.3 are correctly applied and calculations are carried out correctly. This includes correct interpretation of design charts, curves, tables, etc.

- Analysis results are interpreted correctly, and uncertainties associated with the analyses and input data are appropriately considered in the interpretation.

- The designs and selection of the orientation, geometry, layout, and depth of seals are supported by the interpreted analysis results and satisfy the engineering specifications.

3.2.9 Safety Review for Compliance With 10 CFR 60.137

The review procedure and acceptance criteria to evaluate compliance with 10 CFR 60.137 are applicable to the SRBS, surface facilities, and underground facility; however, the review procedures and acceptance criteria are provided only in Review Plan 4.4. Therefore, the staff should use Review Plan 4.4 to determine if the SRBS designs comply with 10 CFR 60.137.

3.2.10 Detailed Safety Review Supported by Analyses for Compliance With 10 CFR 60.134 for Key Technical Uncertainty-Predicting Long-Term Performance of Seals for Shafts, Ramps, and Boreholes

The scope of this Detailed Safety Review Supported by Analysis is focused on the extrapolation of short-term data for prediction of long-term performance of seals, including the long-term interaction between seals and the surrounding rock mass. A detailed Safety Review of this section will be conducted in coordination with the Safety Review in Section 3.2.8 of this Review Plan.

The staff will perform selected independent analyses and interpretations in the following areas to address the uncertainties associated with the long-term performance of seals:

- Long-term thermal-mechanical effects on the performance of seals.
- Long-term thermal-hydrological effects on the chemical properties of the seal materials.
- Long-term thermal-mechanical (including repetitive seismic loads) effects on the surrounding rock mass and seal-rock interface.
- Long-term thermal-hydrological effects on water and gas flow in the disturbed zones around seals.

(Note that the methods to address these uncertainties are not currently available and require future development.)

The input for these independent analyses should be consistent with site characteristics, processes, events, and combinations of the processes and events that are relevant to the design of seals. The DOE extrapolation of short-term data for prediction of long-term performance of seals will be considered acceptable if the independent analyses of the NRC staff support the DOE prediction, or if DOE has provided sound technical justification that explains the differences.

Acceptance criteria for reviewing this KTU will be developed when additional knowledge on these issues is obtained.

3.3 Rationale for Review Procedures and Acceptance Criteria

3.3.1 Rationale for Safety Review for Compliance With 10 CFR 60.112

Shafts, ramps, and boreholes may constitute pathways for fluid flow and radionuclide migration. Therefore, it is important that the geometry and layout of shafts, ramps and boreholes and the fluid-flow properties of their seals be considered in evaluating possible release of radioactive materials to the accessible environment. However, the evaluation of post-closure radioactive release to the accessible environment is part of Performance Assessment, which is reviewed under Review Plan 6.1. The assumptions made in Review Plan 6.1 regarding the geometry and layout of shafts, ramps, and boreholes and the properties of their seals should be considered in the determination of compliance with 10 CFR 60.134. Also, the results of the review for compliance with 10 CFR 60.134 should be provided as input to Review Plan 6.1.

3.3.2 Rationale for Safety Review for Compliance With 10 CFR 60.130, 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A),(C),(E) and (F), 10 CFR 60.21(c)(2), 10 CFR 60.21(c)(3), 10 CFR 60.21(c)(6), 10 CFR 60.21(c)(7), and 10 CFR 60.21(c)(12)

The safety review for compliance with 10 CFR 60.130 covers two requirements for the SRBS designs. First, it is required that the design bases for SRBS be consistent with the results of site characterization. This requirement is to ensure that the SRBS for the proposed repository are site-specifically designed and that the collected data are in a form that can be directly used for the design.

The rationale for the second requirement of this safety review is that any safety features not addressed by 10 CFR 60.131 and 60.134 (note that 10 CFR 60. 132 and 60.133 do not apply to shafts, ramps, boreholes, and seals) of the SRBS must be identified and that the staff should ensure that the design bases are adequate. Also the staff should confirm that these safety features have been incorporated into demonstrating that the performance objectives are met. This part of the safety review involves the designs of SRBS. However, only the designs of shafts, ramps, and boreholes that have been considered as specific facilities requiring safety features will be reviewed in this section. The review process and acceptance criteria for safety review for the seal design are provided in Section 3.2.8, and corresponding rationale in Section 3.3.8. Review Plans 4.4 and 4.5.2 will also be used to review the adequacy of the ramp design because the design requirements for the ramps are virtually identical to those of the underground facility (i.e., drifts).

3.3.3 Rationale for Safety Review for Compliance With 10 CFR 60.111(a) and 60.131(a)(1) through 60.131(a)(6)

See Review Plan 4.2.

3.3.4 Rationale for Safety Review for Compliance With 10 CFR 60.111(b)

See Review Plan 4.5.2.

3.3.5 Rationale for Safety Review for Compliance With 10 CFR 60.131(b)(1) through 60.131(b)(8)

See Review Plan 4.4.

3.3.6 Rationale for Safety Review for Compliance With 10 CFR 60.131(b)(9), 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A) and (F), 10 CFR 60.21(C)(2), 10 CFR 60.21(c)(3), and 10 CFR

The demonstration of compliance of the SRBS design with 10 CFR 60.131(b)(9) consists of either a demonstration of compliance with the applicable MSHA regulations or a demonstration that noncompliance with MSHA regulations has no negative impact on the capacity of the SSCIS to perform their intended functions.

The acceptance criteria given in Subsection 3.2.6.1 (for the first step of the review process) are to ensure that the designs of SSCIS for compliance with the applicable mining regulations have taken into account the repository operations and conditions, as well as the credible events and scenario at the proposed repository site. This step is important because the operations, conditions, and the relevant preclosure requirements for the SRBS at the proposed repository are considerably different from those of other underground mines for which the conventional rules and guidelines are fully adequate and applicable (i.e., repository operations and conditions are more severe, and preclosure requirements are more rigorous than those of other underground mines). For the second step of this review, the acceptance criteria will be used to determine if the designs and analyses for SSCIS relevant to worker protection are consistent with or better than the existing mining guidelines and practices, whether all engineering specifications developed for the SSCIS have been identified, and whether the design and analysis results, and implementation have addressed the applicable mining regulations.

Most applicable mining regulations are broad and allow a wide range of design conditions and implementation. Therefore, focused safety reviews of representative design and sample analyses of SSCIS of SRBS relevant to worker protection are necessary to ensure that the proposed designs and analyses are not only compliant with the applicable mining regulations, but also site specific. The acceptance criteria developed for the focused safety review (the third step) are to ensure that the designs and analyses of SSCIS take into consideration the operations, conditions, credible events and preclosure requirements of the repository; the analyses, calculations, and implementation have been carried out correctly; and the proposed designs of the SSCIS comply with the applicable mining regulations. The DOE may demonstrate that the SSCIS can still perform the intended functions even though one or more of the mining regulations are not satisfied.

3.3.7 Rationale for Safety Review for Compliance With 10 CFR 60.131(b)(10)

The rationale for not including a compliance review procedure for evaluating the design of the SRBS to allow determination of compliance with 10 CFR 60.131(b)(10) is that the current DOE designs for the facility do not contain shaft conveyances (shaft hoists) used in radioactive waste handling, but instead will use transport vehicles.

3.3.8 Rationale for Safety Review for Compliance With 10 CFR 60.134, 10 CFR 60.21(c)(1)(i), 10 CFR 60.21(c)(1)(ii)(A), (C), (D) and (F), 10 CFR 60.21(c)(2), and 10 CFR 60.21(c)(14)

The review of the SRBS design for compliance with 10 CFR 60.134 should determine whether the assumptions made in Performance Assessment regarding the properties of seals for shafts, ramps, and boreholes will be satisfied by the design and proposed placement procedures for the seals. It should also be determined whether the sealed shafts, ramps, or boreholes may constitute preferential pathways for water flow to the waste packages. The review uses some of the guidelines and practices developed or used by the oil and gas industry, mining companies, civil engineers, and ASTM, which may be judged to be applicable for the material selection and placement of seals for shafts, ramps, and boreholes in the repository environment. Furthermore, this safety review utilizes the relevant technical positions, strategy documents, and other guidance prepared by the NRC (Gupta and Buckley, 1989).

3.3.8.1 Rationale for Review of Site Characteristics, Processes, and Events Relevant to Seal Designs

Consideration of the effect of each individual event or process alone may not be sufficient for a design because the potential combined effect of applicable events and processes may often be the controlling factor to determine if a system will continue to perform its intended function. Consequently, the combined effects should be considered in the design as well. A list of potential credible events and processes is provided in Section 3.2.8.1 to facilitate the design review of seals for the shafts, ramps, and boreholes. This list represents the current thinking regarding the potential environmental conditions at Yucca Mountain that may affect seal performance. This list should be updated as new information becomes available.

3.3.8.2 Rationale for Review of Design Bases, Criteria, Requirements, and Engineering Specifications of Seals and Selection of Seal Materials and Placement Methods

To prevent boreholes, ramps, and shafts from becoming preferential flow paths for air or water, the effective permeability of the seal system (including cementitious and bentonitic seals, grout, and backfill) should not be larger than that of the surrounding rock mass. The permeability of the seals should be such as would essentially eliminate the tendency for concentrated fluid flow through the sealed openings. In addition, the strength and stiffness of the seal system should be as close to those of the surrounding rock mass as possible to minimize the inward movement of the surrounding rock, which could create a preferential flow path for water or air to bypass the seals.

Seals and backfill should be designed for specific seal locations because mechanical and hydrological behavior of the rock adjacent to the seals and backfill has a direct impact on the sealing effectiveness. For example, Akgun and Daemen (1991) and Fuenkajorn and Daemen (1987) experimentally demonstrated that the swelling stress of expansive cement increases with decrease of boundary deformation, thereby increasing the mechanical and hydraulic bond between the seal and the surrounding rock. However, the swelling pressure should not be so high as to cause tensile failure of the surrounding rock. Any damage or weakness zone around the opening, which has been induced by drilling or excavation, weathering, deterioration, or by lining and casing removal, could soften the surrounding rock and hence reduce the mechanical and hydraulic bonds at the seal rock interface.

There are some potentially applicable guidelines, conventional practices, and research results related to the design of seals or plugs in underground openings, such as the American Petroleum Institute (1986) on borehole cementing; Dixon and Gray (1985), Ouyang and Daemen (1992), Ran and Daemen (1991), and Pusch et al. (1987), Pusch (1987, 1988, 1990) on bentonite backfill; and Crouthamel (1991), Greer and Daemen (1991), Chekan (1985), and Auld (1983) on underground plugs. Although the objective of those designs is not waste isolation, some design approaches and results from previous research and practice should be used, on a case by case basis, as guidelines to assess the suitability and feasibility of the DOE design.

Experimental research conducted by South and Daemen (1986), Greer and Daemen (1991), Crouthamel (1991), Akgun and Daemen (1991), and Fuenkajorn and Daemen (1991) has indicated that mechanical and hydraulic performance of cement borehole seals is enhanced when they are installed at the intact portion of the boreholes. Therefore, it is preferable that rock around the seals in the boreholes is free of fractures.

The length-to-diameter ratio of seals should be sufficiently large to ensure the mechanical and hydraulic performance of seals. Based on the results from laboratory testing and numerical analyses on shearing strength of a borehole plug in welded tuff, Akgun and Daemen (1991) conclude that permanent abandonment borehole seals or plugs should be designed with a length-to-diameter ratio of four or greater. This length criterion will prevent development of excessively detrimental tensile stresses within and near an axially loaded seal. The similar geometrical design is also recommended by Greer and Daemen (1991), who assess experimentally the *in situ* hydraulic performance of borehole seals in rock.

If a mixture of bentonite and crushed rock is used to form seals, the amount of bentonite should be sufficient to permit effective compaction but also small enough to ensure sufficient shear strength for the seal mixture. Experimental results obtained by Ouyang and Daeman (1992) indicate that, for a bentonite-crushed rock mixture, compaction and amount of bentonite are decisive factors in producing good mixture seals. The sealing performance of such mixtures can be degraded by dynamic disturbance during compaction if the bentonite fraction is smaller than about 25 percent. Ouyang and Daeman (1992) showed that mixtures containing more than about 35 percent bentonite can be compacted effectively. Their results also suggest that well-graded granular materials (with coefficient of uniformity equal to 16 or more) have a lower permeability than those with narrow particle-size gradation.

Sealing effectiveness of backfill can be enhanced by compaction. Compaction reduces the permeability and potential settlement, and increases the bulk density and strength of the backfill. *In situ* compaction of backfill is recommended, but not required for conventional mine closure practices. However, compaction should be a requirement for backfill installation for the proposed repository site. Compaction is needed because the expected performance requirements of the backfills for conventional mine closure are not as rigorous as those of the repository, particularly for the long-term performance.

For multicomponent seals (i.e., forming a seal system using different seal materials, such as cement plug, clay backfill, sand backfill, crushed rock backfill, and grout bulb), different seal components or types may exhibit different thermal and mechanical impacts on the adjacent and surrounding media. Such impacts should therefore be considered in the design of the seal system.

The seal design should also consider the impact of nearby or intersecting excavations (such as existing or future boreholes and shafts near or intersecting the ramps or drift). Such impacts may include, for example, stress interference, alteration of rock mass characteristics, and excavation process.

3.3.8.3 Rationale for Review of Analysis and Design Processes and Methodologies Relevant to Seal Designs

The interpretation and reduction of data, including site specific and design specific data, for the preparation of input for the analysis and design of seals will have significant technical impact on the design and performance of seals for shafts, ramps, and boreholes. The interpretation and reduction of data should be defensible based on commonly acceptable engineering practice. Furthermore, the approaches and assumptions used for the analysis and design of seals need to be based on a defense-in-depth philosophy that could be achieved through conservatism, redundancy, and diversity in analysis and design.

3.3.8.4 Rationale for Selected Focused Safety Review

The staff should select as many representative seals as required because the design conditions associated with shafts, ramps, or boreholes will vary from location to location. Therefore, the seals may be classified into groups based on the prevailing conditions at the locations, the opening type, and special conditions that may warrant unique design considerations or material selection. The design criteria, seals materials selection, and the placement methods may require substantially different analytical approaches because of the thermal, mechanical, hydrologic, and chemical conditions of the location. The models themselves may originally have been developed for purposes other than the repository-related calculations. Therefore, it is imperative that the applicability of these models and the assumptions under which they are used be defensible. The long-term behavior of materials is a typical example. Because of the lack of data, short-term data or predictive models are often used assuming that they represent long-term behavior. This practice may not always be appropriate. For example, because of prolonged exposure of the rock mass to heat in the presence of moisture, the rock strength properties may deteriorate (Althaus et al., 1994) to the extent that the reduced strength over time may not satisfy the design calculation at longer times. Uncertainties in input data and analysis results should be considered in the interpretation of such results.

The method used in modeling jointed rock mass in the vicinity of seals invokes the classical problems encountered in fracture representation. Single equivalent continuum, dual continuum, dual equivalent continuum, and discrete fracture, etc., are the general concepts applied to fracture representation in modeling, which are also relevant to fluid flow at the interfaces. Therefore, the model approach should be accompanied by the details of the rationale.

If settlement of the backfill occurs below the plug, the loss of support and potential failure of the surrounding rock could result. Therefore, the DOE should investigate the potential of such a failure and incorporate it in the design. Also, the possibility that saturation of the backfill may cause ponding should be investigated.

The perched water zones in the rock units above the repository horizon should also be considered in the design of seals. The potential flow of water from these zones into the sealed boreholes, shafts, and ramps will alter the hydrological conditions of the seals and will increase the amount of discharge on the seals beyond what is expected from the surface infiltration.

The liners of shafts and ramps and their removal process are likely to impact the postclosure mechanical and hydraulic performance of the seals. If the liners are left in place, then the corrosion of the liner may eventually give rise to preferential flow path. If the liners are removed, then the process of removal may disturb the seal as well as the surrounding host rock. The extent of the disturbed zone within the host rock will have to be assessed and factored into the design. Therefore it is imperative that the decision regarding removal or nonremoval of the liners should be accompanied by supporting rationale and analyses with regard to the performance objectives. Presentation of detailed test methods, test plan, data interpretation, and instrumentation will substantiate the supporting rationale.

3.3.9 Rationale for Safety Review for Compliance With 10 CFR 60.137

See Review Plan 4.4.

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3.3.10 Rationale for Detailed Safety Review Supported by Analyses for Compliance with 10 CFR 60.134

Acceptance criteria to determine if the DOE adequately addresses the KTU associated with the long-term performance of seals are not available at this time. Conducting Type 3 safety review alone is insufficient for the staff to decide if the DOE design of seals is in compliance with the requirements of 10 CFR 60.134. Thus, selected independent analyses and interpretations are necessary to address the uncertainties stated in Section 3.2.10 of this Review Plan.

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4.0 IMPLEMENTATION

4.1 Review Responsibilities

Lead:	NMSS-DWM-ENGB-GGES
Support:	NMSS-DWM-PAHB-HTS NMSS-DWM-PAHB-PAHPS NMSS-DWM-ENGB-EMS NMSS-DWM-HLUR-HQAS

4.2 Interfaces

4.2.1 Input Information

Information derived from activities related to other Review Plans will provide input important to this Review Plan. A list of Review Plans for which this interface may be anticipated is presented in Table 4.2.1-1. The degree of applicability of each of these Review Plans to provide input to this Review Plan will depend upon how the DOE organizes the information in the LARP and how it cross-references this information.

Table 4.2.1-1. List of review plans that will provide input

Input Information	*Review Plan No.*
Plans for research and development, seal placement, and seal material selection	1.3, 2.4
A description of the site-characterization work completed, related to the mechanical, hydrological, and thermal properties of the rock mass	1.6
Compliance with the performance objectives related to seals for shafts, ramps, and boreholes	1.7
A description of the kinds, amounts, and specification of radioactive materials	2.5
Technical and design specifications for SRBS	2.6
Description of the geologic, hydrologic, and geochemical systems	3.1
Description of tectonic movements and characterization of faults and fractures	3.2.1.5, 3.2.1.14

Input Information (Cont'd)	*Review Plan No.*
Description of the characteristics and frequency of occurrence of dynamic loading (including earthquakes, blasting, and nuclear explosion)	3.2.1.6, 3.2.1.8, 4.4
Thermal, mechanical, and hydrological properties of the rock mass	3.2.1.14, 3.2.2.10
Estimates of annual rainfall	3.2.2.1, 3.2.2.9
Probability of surface flooding	3.2.2.5
Fluctuation of groundwater table	3.2.2.6, 3.2.2.9
Natural and repository-induced perched water formation	3.2.2.12
Geochemical properties of rock and groundwater	3.2.3.2
Description of layout, size, and shapes of shafts, ramps, and boreholes. Identification of SRBS structures, systems and components important to safety	4.1.2
Assessment of compliance with the design criteria for ramp portals and collars for shafts and boreholes	4.2
Assumptions regarding the effects of shafts and ramps on waste retrievability	4.5.2
Performance-assessment assumptions regarding geometry and layout of shafts, ramps, and boreholes and properties of their seals	6.1
Operational procedures for shafts and ramps	7
Performance confirmation program for seals	8
Quality assurance of design and site-characterization activities related to SRBS	10
Emergency program for shafts and ramps	11

4.2.2 Output Information

The safety review conducted as per this Review Plan will provide information necessary for the review of other sections of the LA. The review plans that will most likely use output from this review plan include plans listed in Table 4.2.2-1.

Table 4.2.2-1. List of review plans that will use the output

Output Information	*Review Plan No.*
Assessment of SRBS compliance with the prevention of preferential pathways for flow to the EBS	5.4
Assessment of compliance with the requirement for performance of seals [60.134(a)] and evaluation of compliance with the design goals for seals assumed in DOE's Total System Performance Assessment	6.1, 6.2, 6.3

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5.0 EXAMPLE EVALUATION FINDINGS

5.1 Finding For Acceptance Review

The NRC staff finds that the information presented by the DOE on the design of SRBS is acceptable (not acceptable) for docketing and compliance review.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.112

See Review Plan 6.1.

5.2.2 Finding for 10 CFR 60.130

The NRC staff finds that the design of the SRBS to provide such safety features in a specific facility needed to achieve the performance objectives is (is not) adequate, and that the design bases are (are not) consistent with the results of site characterization activities, and that there is (is not) reasonable assurance that 10 CFR 60.130 will be met for the SSC of the SRBS used to meet the performance objectives.

5.2.3 Finding for 10 CFR 60.111(a) and 60.131(a)(1) through 60.131(a)(6)

See Review Plan 4.2.

5.2.4 Finding for 10 CFR 60.111(b)

See Review Plan 4.5.2.

5.2.5 Finding for 10 CFR 60.131(b)(1) through 60.131(b)(8)

See Review Plan 4.4.

5.2.6 Finding for 10 CFR 60.131(b)(9)

The NRC staff finds that it has (has not) been acceptably demonstrated that the design of the SRBS is in compliance with mining regulations related to assuring continued functioning of SSCIS, and that there is (is not) reasonable assurance that 10 CFR 60.131(b)(9) will be met for the SRBS SSCIS. In cases where the mining regulations have not been complied with, the DOE has (has not) demonstrated that the system can still perform the intended functions and can be considered to comply with 10 CFR 60.131(b)(9) with reasonable assurance.

5.2.7 Finding for 10 CFR 60.131(b)(10)

No review required.

5.2.8 Finding for 10 CFR 60.134

The NRC staff finds that the design of the SRBS to meet the general design criteria for seals has (has not) been acceptably demonstrated and that there is (is not) reasonable assurance that 10 CFR 60.134(a) will be met for the SRBS SSC for the range of scenarios of seal performance for the applicable performance objectives.

The NRC staff finds that the selection of seal materials and placement methods has (has not) been acceptably demonstrated and that there is (is not) reasonable assurance that 10 CFR 60.134(b) will be met for the SRBS SSC to reduce, to the extent practical, the potential for creating a preferential pathway for groundwater to contact the waste packages or for radionuclide migration through existing pathways.

5.2.9 Finding for 10 CFR 60.137

See Review Plan 4.4.

5.2.10 Finding for Detailed Safety Review for Compliance With 10 CFR 60.134

The NRC staff finds that the evaluation of long-term performance of seals for shafts, ramps, and boreholes has (has not) been acceptably demonstrated and that there is (is not) reasonable assurance that 10 CFR 60.134(a–b): (i) will be met for the methodology for the design of seals, backfill, and drainage systems for shafts, ramps, and boreholes, including the assessment of long-term seal performance and the impact of environmental conditions, repository-generated thermal loads, and repetitive seismic loadings on such performance, to reasonably ensure that they will remain effective during the postclosure period; and (ii) the staff's independent analyses or interpretations of the DOE models or data, as well as those relevant research results conducted by the NRC Office of Nuclear Regulatory Research regarding design, construction, and performance of seals are consistent with results presented by the DOE.

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