RAI Volume 2, Chapter 2.1.2, First Set, Number 1:

> Provide a monitoring plan for the ground support system that explains what will be monitored, frequency of monitoring, criteria for selecting drifts to be monitored, spatial frequency of measurements within the drift, and the technical approach for processing information collected through monitoring to assess the performance of the ground support system and the need for maintenance to ensure access to waste packages through the preclosure period.
>
> SAR Section 1.11 states that DOE will rely on developing a maintenance plan to test, inspect, and repair ground support as necessary to ensure functionality of the underground openings through a 100-year preclosure period. Also, SAR section 1.3.4.4 states that the need for ground-support maintenance will be determined based on the results of drift inspection and monitoring. However, the SAR did not provide sufficient details to explain how the ground support will be monitored to determine the need for maintenance or how information obtained through monitoring will be used to plan for maintenance. This information is needed to verify compliance with 10 CFR 63.111(e).

1. RESPONSE

The concepts presented in this response are the project's approaches to the inspection, monitoring, and maintenance programs for ground support systems.

The SAR presents two distinct approaches for inspections, monitoring, and maintenance of repository ground support systems, depending on the classification of the repository openings for personnel accessibility as shown in Figure 1. These classifications are based on the expected thermal and radiation environments for the different openings. The specifics of the RAI are addressed separately for both accessible and inaccessible openings. Further differentiation is made in the response between those accessible and inaccessible openings directly used for a potential waste package retrieval operation and other repository openings not directly related to retrieval but still needed for support functions (i.e., ventilation). The monitoring and maintenance approaches for both types of openings are based on the robustness and the longevity of the materials selected for the type of opening. Monitoring and maintenance activities in inaccessible openings rely mostly on the use of remotely operated vehicles. Conceptual designs for two of these remotely operated vehicles are shown in Figures 2 and 3.

As stated in SAR Section 1.3.2.4.4.3, the ground support for emplacement drifts and inaccessible nonemplacement areas is designed to function without planned maintenance during the preclosure period (100 years) while allowing for the performance of unplanned maintenance in emplacement drifts and inaccessible nonemplacement areas on an as-needed basis. Accordingly, with respect to ground support monitoring for the subsurface facility, a systematic approach is used to monitor inaccessible underground openings, including annual remotely operated inspections initially, with reduced frequency of those inspections over time. The exception would be in areas where indicators of potential problems are observed, in which case the inspection frequency could be increased if warranted by the observations.

The approach for monitoring and maintenance in accessible openings, as stated in SAR Section 1.3.3.3.2, consists of visually inspecting the openings by qualified personnel on a regular basis so that operational support systems can be kept functional at an acceptable level, daily operations can be performed without interruption, and openings can be kept safe for personnel access. A geotechnical instrumentation program designed to provide field measurements for drift convergence, ground support loads, and potential overstressed zones will supplement the observations. Inspection, monitoring, and maintenance in accessible openings will be performed using methods similar to those used in underground mines and in the tunneling industry.

The approaches for monitoring and maintenance of accessible and inaccessible repository openings, although different, both preserve the option of retrieving any or all of the emplaced waste throughout the preclosure period. The repository ground support, as well as ventilation, rail, and other support systems, are designed to remain effective for up to 100 years after the initiation of waste emplacement and ensure that the occurrence of rockfall or off-normal events do not preclude retrieval (SAR Section 1.3.2.4.8).

As part of the *Performance Confirmation Plan* (BSC 2004, Section 3.3.2.1; SAR Chapter 4), detailed geologic mapping of repository openings will be performed during repository excavation. The use of photography for documentation of initial conditions is anticipated during excavation, with unexpected conditions to be mapped in detail. The performance confirmation activities will provide information to support the basis for evaluating the performance of the Upper Natural Barrier and Lower Natural Barrier in the vicinity of the repository openings by observing subsurface conditions with respect to those in the geologic framework model, which was used to develop the unsaturated zone flow models. These models are based on surface geologic interpretation and spatially limited *in situ* formation data obtained from exploratory boreholes, the Exploratory Studies Facility, and the Enhanced Characterization of the Repository Block Cross-Drift tunnels.

The information collected from the geologic mapping will include fracture characteristics, fault zone characteristics (i.e., offset, location, and age), stratigraphic contacts, and lithophysal characteristics. This information will be compared to the models and may be incorporated into the models for a more accurate representation of the rock conditions and characteristics throughout the subsurface facility, if the information collected during the geologic mapping activity results in observed variation from the expected geologic conditions equal or greater than that determined to be significant. This information will be used to support the bases for inspections and monitoring, temporal and spatial monitoring frequencies, and identification of areas of special interest (i.e., geologic anomalies, seepage) that may affect waste package emplacement plans. The construction effects monitoring activity, as well as the seismicity monitoring activity, also call for visual observation and monitoring of convergence in accessible openings, especially with respect to the time period following a seismic event equivalent to a design basis event.

1.1 MONITORING PLAN FOR GROUND SUPPORT SYSTEMS IN ACCESSIBLE OPENINGS

1.1.1 Emplacement and Retrieval Accessible Openings: North Ramp, Access Mains, and Entrance to Turnouts

There are no restrictions on personnel or equipment access to the nonemplacement openings used for emplacement and retrieval operations, except when a loaded transport and emplacement vehicle is operating in the subsurface facility. The ground support inspection and maintenance approach for these openings is, therefore: to perform planned periodic visual inspections by direct observation by qualified personnel; and, to deploy geotechnical instrumentation during the preclosure period. These inspections and measurements will provide the information to evaluate the need for any necessary repairs. This inspection, monitoring, and maintenance approach is similar to that used in underground mines and in the tunneling industry.

Monitoring Parameters—The following parameters will be the subject of planned inspections and monitoring:

- Corrosion of rock bolts, wire mesh, or lattice supports
- Sagging or ruptured wire mesh
- Accumulation of rock debris on invert
- Defects or deterioration indicators of shotcrete liner such as application flaws, cracks, delamination, spalls, void development, and chemical alteration
- Rock bolt failure
- Geotechnical instrumentation program to provide field determinations for drift convergence, ground support loads, and potential overstressing zones.

Monitoring Locations—The entire lengths of these openings will be inspected. Instrumentation and testing locations will be selected by geotechnical engineers commensurate with rock and ground support conditions and previous inspection results history.

Monitoring Frequency—The inspection frequency for these openings will be daily, monthly, or semiannually, depending on the type of opening, current operations, and systematic analyses of periodic observations in areas with no routine operations.

Data Interpretation—If visual inspections indicate that the replacement or repair of ground support components is warranted, the necessary repairs will be made by maintenance crews. Maintenance activities could include scaling loose rock from the opening walls, removing rock debris from the opening floor, removing damaged or defective ground support components, and installing new ground support components. Information gained from inspections and maintenance of the accessible openings also provides insight into potential problems that may be occurring at similar but inaccessible repository openings.

1.1.2 Other Repository Accessible Openings: South Ramp and Other Repository Intake Airways

Keeping other accessible openings, such as the South Ramp, the intake shafts, and their access drifts functional throughout the preclosure period is important because these other accessible openings are utilized as repository ventilation airways. Maintaining or repairing a failed ground support component can be accomplished when identified by regular inspections or testing, but such repair may not be as pressing as when it involves an accessible opening used for the waste emplacement operation (transport and emplacement vehicle transportation route). Ground support inspections, testing, and maintenance for the repository accessible openings not used directly by waste emplacement operations are the same as those procedures for the emplacement and retrieval accessible openings, as described in Section 1.1.1.

Access of the intake shafts by personnel is accomplished using hoists deployed at the intake shaft collars. The hoists are used to lower personnel platforms for visual inspections down the entire length of the shafts to the shaft stations at the access main level. Inspection frequency of the intake shaft concrete liners will vary between monthly and semiannually depending on the time elapsed since the completion of the openings, and the results of previous inspections.

1.2 MONITORING PLAN FOR GROUND SUPPORT SYSTEMS IN INACCESSIBLE OPENINGS

1.2.1 Emplacement and Retrieval Inaccessible Openings: Turnouts and Emplacement Drifts

Inspections of the emplacement drifts will occur during two phases: preemplacement and postemplacement. The initial preemplacement inspections will be visual and associated with the geologic mapping effort. These inspections will document rock characteristics exposed at the drift wall and will supplement digital photographic coverage and other surveys performed before the permanent ground support structures are installed (and the drift walls covered from view). As in previous surveys performed during the excavation of the Exploratory Studies Facility and Enhanced Characterization of the Repository Block Cross-Drift tunnels, the observations and surveys will, to an appropriate extent, document the characteristics of lithophysae, fracture and fault characteristics such as amounts of offset, thickness, and types of fault breccias or rubble, and areas of visible seepage. After installation of the emplacement drift structures (ground support, invert, rails), a final preemplacement inspection will identify possible defects or the failure of any ground support components, or indications of drift instability. Postemplacement inspections will be limited to remotely-operated equipment such as the remotely operated vehicle concepts presented in Figures 2 and 3, and will focus on in-drift environmental parameters and waste package integrity as part of the Performance Confirmation Program.

Monitoring Parameters—The postemplacement remotely operated vehicle inspections will be used to detect any indications of rock fall, drift deterioration, or instability within the emplacement drifts and turnouts that may require unplanned maintenance. Monitoring of the emplacement drift ground support will include taking opening convergence measurements using laser targets and digital processing, material sampling, and other measurements related to drift condition, seepage, and ground support observations noted below. Video cameras mounted on the remotely operated vehicle will record high resolution images of the drift crown and rib walls for possible water seepage, areas of drift deterioration, and ground support degradation. Inspection of the turnouts will be performed using the same remotely operated vehicles that are used for the emplacement drift inspections, and with the same frequency. Turnout inspections by the remotely operated vehicles will yield information on the rock wall visible through the stainless steel wire mesh, and rock flaking falling on the invert. The stainless steel liner will prevent such observations in the emplacement drifts.

Groundwater chemical composition characteristic of the emplacement drifts and other repository openings is determined from sampling of seepage in seepage alcoves and other accessible locations where seepage may occur. Corrosion testing of stainless steel, based on applicable American Society for Testing and Materials standards and selected specimens from candidate materials exposed to groundwater, will provide information or confirmation of expected performance of stainless steel ground support components in the emplacement drift environment. The approximate environmental conditions inside the emplacement drifts, exhaust mains, and exhaust shafts are estimated with analytical models (i.e., FLUENT), using the intake and air discharge characteristics. Air temperature and relative humidity are measured for the airstream entering the turnouts and emplacement drifts and at the exhaust fan locations (Section 1.3.5). Monitoring of radiation inside the emplacement drifts is not necessary because it has been determined that the cumulative neutron fluence and gamma dose on steel ground support are too small to cause appreciable mechanical damage over the preclosure period (BSC 2003, Section 6.2.4).

Representative performance of ground support components in the inaccessible areas of the repository will be obtained by testing similar components in surrogate areas, such as in dedicated alcoves or in the performance confirmation observation drift. The following testing has been identified in the conceptual monitoring and maintenance programs as testing that could be performed before and during repository development:

- Corrosion testing of stainless steel components and correlation of results with monitoring digital imagery from emplacement drifts and turnouts

- *In situ* rock bolt pull-out tests (primarily in lithophysal rock) to verify anchorage capacity and bolt performance

- Over-coring of installed rock bolts and splitting the cores for detailed examination of areas of interaction between bolt material and lithophysal cavities, and detection of signs of stress corrosion cracking.

Monitoring Locations—Emplacement drifts and their turnouts will be inspected over their entire lengths during the preemplacement and postemplacement phases.

Monitoring Frequency—The proposed inspection frequency for emplacement drifts and turnouts during the postemplacement phase is annually. The frequency of these inspections will be reduced if conditions indicate that opening stability and ground support are performing as expected. The inspection frequency determination will also depend upon comparison with the geologic models and number of unexpected conditions encountered in specific drifts. The initial focus will be on those areas where features of interest are noted.

Additional inspections will be performed after design-basis seismic events.

Data Interpretation—Some indicators of ground support failure could include bulging or torn stainless steel sheets, rock fragments, blocks, or rock debris on the invert or waste packages. An estimation of the volume of observed rockfall debris will be used to assess the magnitude of the problem. Repeated inspection results will be used to determine trends of progressive deterioration and plan remedial action based on criteria that define unacceptable levels of ground support deterioration if such criteria are established in the future.

The wire mesh in the turnout allows observations of potential drift degradation (i.e., rock flaking) that are not possible to observe in the same rock type if covered with steel liner in the emplacement drift portion of the opening. Evidence of flaking may not be directly observed in the emplacement drift because of the reduced size of the liner perforations that prevent the rock debris from falling on a visible surface.

1.2.2 Other Repository Inaccessible Openings: Exhaust Mains, Exhaust Shafts, and Exhaust Shaft Access Drifts

Inspection and monitoring activities in exhaust mains, exhaust shafts, and their connecting exhaust shaft access drifts after initiation of emplacement activities will be restricted from personnel access because of the thermal and/or radiological environment in these openings. These activities will be performed with remotely operated vehicles. The exhaust shafts will be inspected by a specialized device equipped with cameras and laser measuring systems. Conceptually, such a device will be lowered and lifted with a tether attached through the exhaust fan ductwork by an operator on the exhaust shaft pad surface. Alternatively, the device could travel in or out of a shaft along a vertical rail attached to the shaft wall.

Inspection of the exhaust mains and exhaust shaft access drifts will be performed by tracked or rubber tire remotely operated vehicles for all-terrain capability and will be battery operated. These remotely operated vehicles will also be equipped with cameras and laser measuring systems. Access to the exhaust mains from the access mains will be through ports in the permanent isolation barrier bulkheads. These inspections will also include the intersections of the emplacement drifts and the exhaust mains.

Monitoring Parameters—The exhaust shaft concrete liners are inspected for cracks, voids, and spalling in the concrete. The exhaust mains and exhaust shaft access drifts are inspected for indicators of ground support degradation or defects such as excessive sagging of the welded wire mesh, noticeable corrosion of any metal components, and loosened rock bolts. Shotcrete at the intersections of the exhaust main and emplacement drifts is inspected for cracks, delamination, spalls, void development, and chemical alteration.

Monitoring Locations—Remotely operated inspections of the repository exhaust airways will be performed along their entire length.

Monitoring Frequency—Inspection frequency of the exhaust airways will be annually for the first few years and progressively on a less frequent basis, if warranted. In addition, monitoring will be performed after design-basis seismic events.

Data Interpretation—Ground support systems for these inaccessible repository openings are designed to last for the 100-year preclosure period without planned maintenance. Maintenance of the exhaust airway openings will be carried out only as a contingency measure in cases of significant failure or deterioration. Areas of failed ground support and rockfall can be inspected more frequently, if needed, to determine the appropriate time to initiate repair or maintenance. The maintenance activities will be scheduled to preclude impacts to the repository nuclear safety functions. Maintenance activities can be performed using remotely operated equipment, and on the rare occasion when personnel involvement may be necessary, planning and design of remediation activities and engineering controls will precede any action so that personnel safety can be assured.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2003. *Longevity of Emplacement Drift Ground Support Materials for LA.* 800-K0C-TEG0-01200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030922.0004; ENG.20050816.0017.

BSC 2004. *Performance Confirmation Plan.* TDR-PCS-SE-000001 REV 05. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041122.0002.

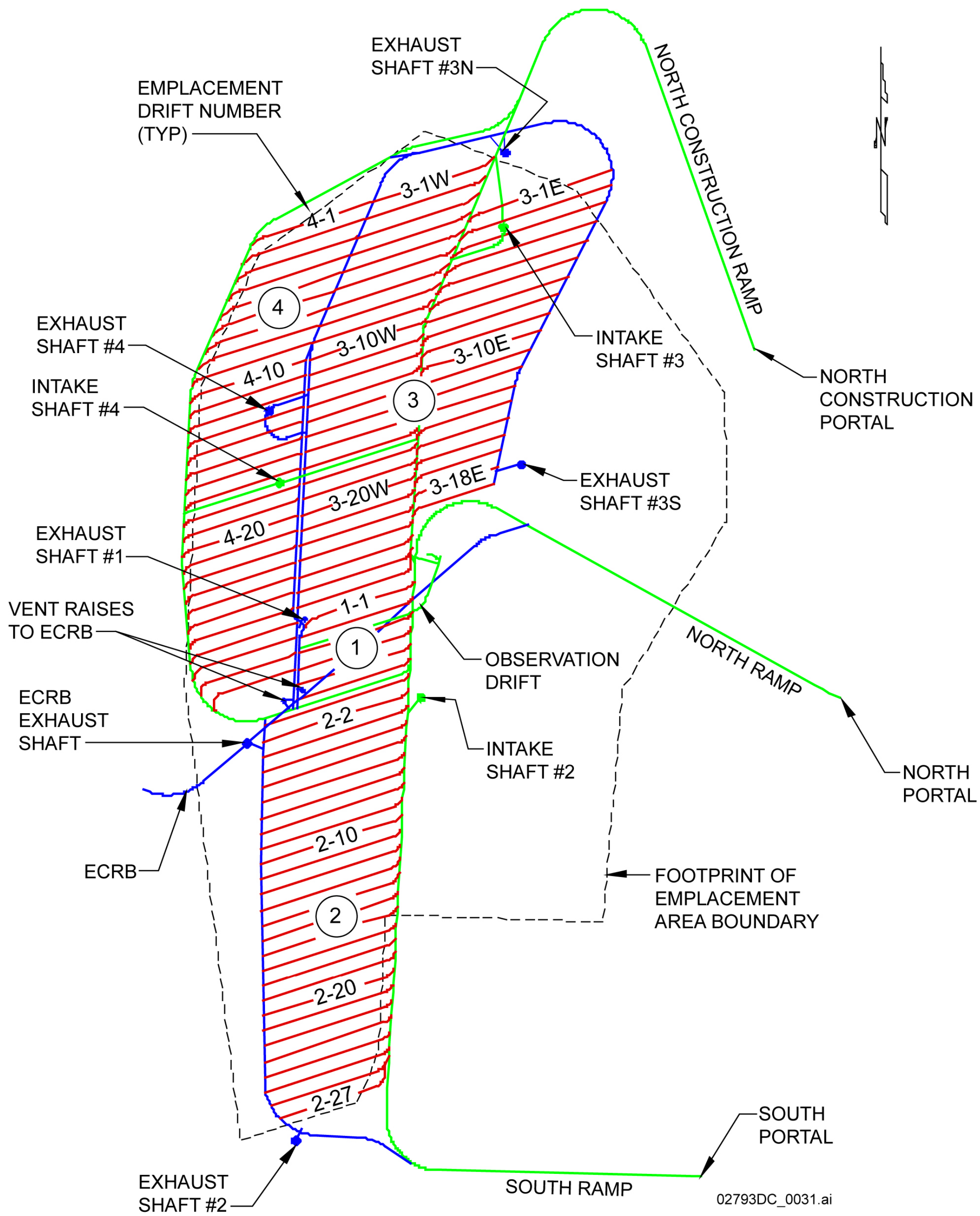

Figure 1. Classification of Repository Openings According to Accessibility

NOTE: Red lines indicate emplacement drifts, including their turnouts and are inaccessible once waste is emplaced. Blue lines and dots indicate nonemplacement openings, including exhaust shafts and their access drifts that are inaccessible. Green lines and dots indicate nonemplacement openings, including intake shafts and their access drifts that are accessible.

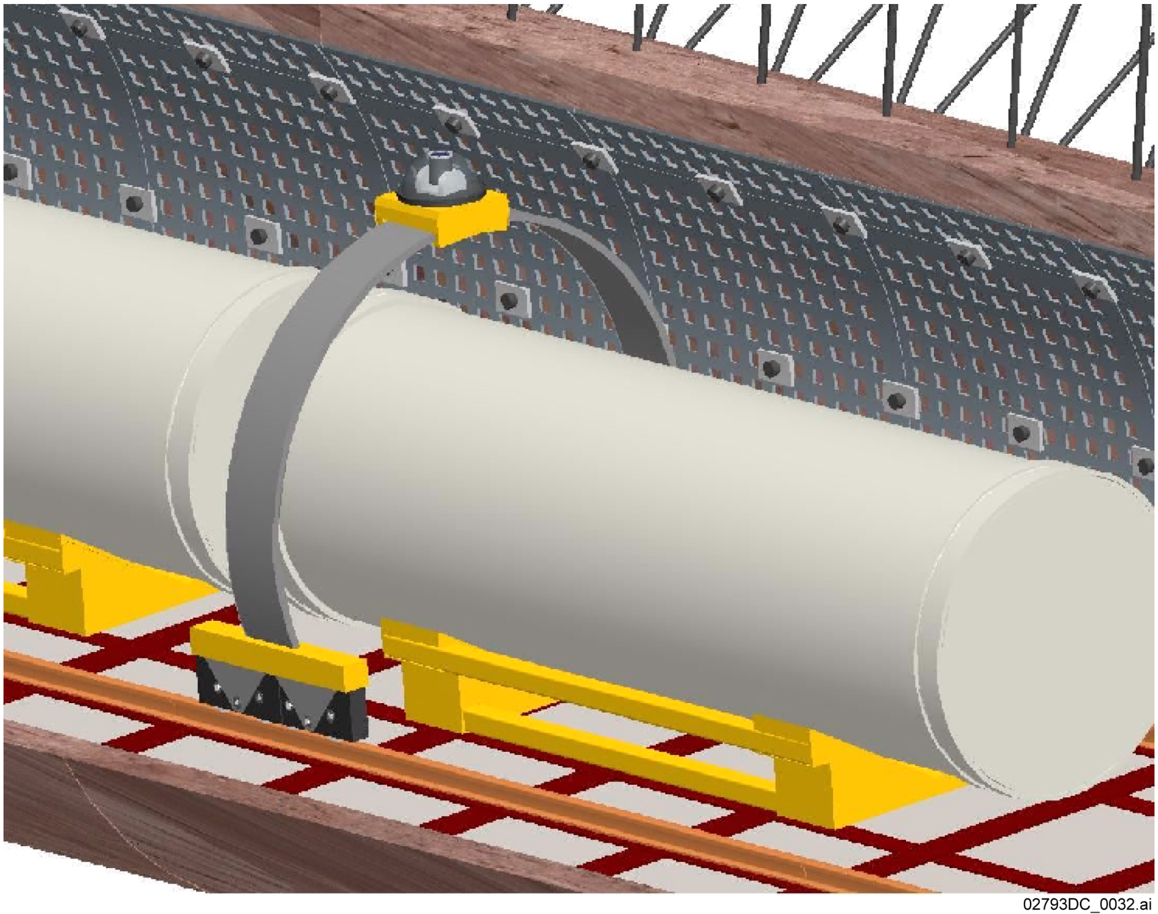

Figure 2. A Conceptual Remotely Operated Vehicle for Emplacement Drift Ground Support Inspection.

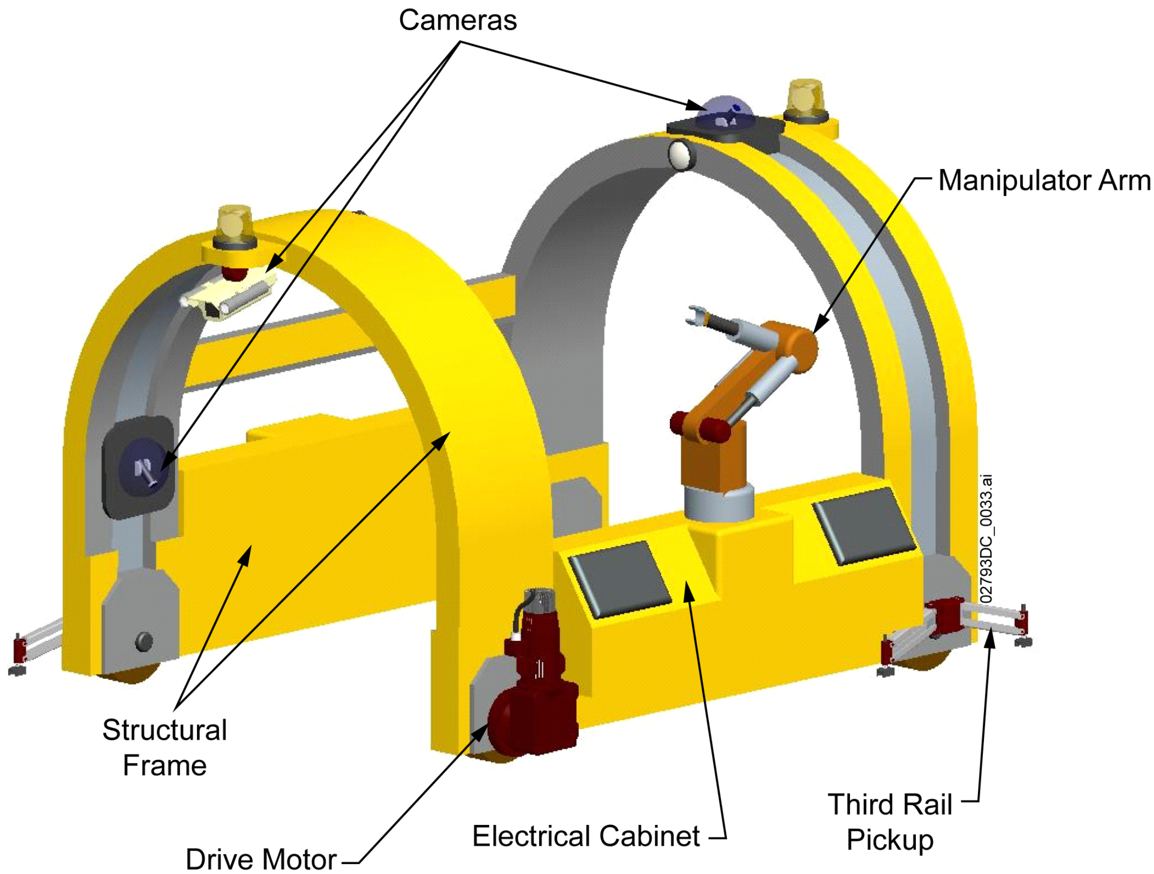

Figure 3. A Gantry-Type Remotely Operated Vehicle Concept for Inspection of Emplacement Drifts and Turnouts.

RAI Volume 2, Chapter 2.2.1.2, First Set, Number 2:

> Provide information regarding applicant's plan for potential off-normal events that may affect any waste retrieval operation.
>
> In SAR Section 1.11.1.2.1 the applicant refers to "BSC 2007b. Strategies for Recovery after an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle. 800-30R-HE00-01800-000-000. Las Vegas, Nevada: Bechtel SAIC Company" but this document has not been provided. This information is needed to verify compliance with 10 CFR 63.111(e).

1. RESPONSE

Strategies for Recovery after an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle (BSC 2007) evaluates various off-normal events related to emplacement and retrieval system operations, specifically those associated with the transport and emplacement vehicle (TEV) operations. The document identifies conceptual methods and processes for recovery from the off-normal events. The recovery strategies study (BSC 2007) is limited to those events associated with TEV emplacement and retrieval operations that are considered to have the potential to significantly impact repository operations or retrieval operations. Further, the recovery strategies study (BSC 2007) focuses on events that could impact the TEV rather than considering TEV equipment malfunctions. The following criteria have been used to identify the potential off-normal events for evaluation that may have a significant impact on emplacement or retrieval operations:

- Cessation of repository operations for extended periods
- Radiological release leading to exposure of individuals to radiation.

No off-normal events have been identified where the TEV could not be recovered. However, the study identifies and evaluates two events (derailment of the TEV and rockfall that covers the TEV). Neither TEV derailment nor rockfall on the TEV has the potential to cause a waste package breach or a radiological release and are beyond Category 2 events. The consequences of these two events bound the consequences of any other analyzed event sequences.

In addition to identifying and evaluating potential recovery concepts, the recovery strategies study (BSC 2007) describes several vehicle configurations that could be used to implement recovery actions. One such concept, the multipurpose recovery vehicle, is remotely operated and provides a capability for manipulating equipment and transporting materials and debris. The configuration of the multipurpose recovery vehicle is discussed and illustrated in the recovery strategies study (BSC 2007, Section 3.2), and conceptual use of such a vehicle is discussed in the response to RAI 2.2.1.2-003.

The recovery strategies study (BSC 2007) is provided with this response.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Strategies for Recovery After an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle*. 800-30R-HE00-01800-000 REV 000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0043.

RAI Volume 2, Chapter 2.1.2, First Set, Number 3:

> Describe how a temporary shield wall will be installed using the Multipurpose Recovery Vehicle (MRV). (Section 3.3.4 of BSC 2007b).
>
> In a document that the applicant cited in SAR section 1.11 as "BSC 2007b. Strategies for Recovery after an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle. 800-30R-HE00-01800-000-000. Las Vegas, Nevada: Bechtel SAIC Company," the applicant indicated a MRV might be used to install a temporary shield wall in a loaded emplacement drift to permit worker access for repairing a damaged rail section. The applicant, however, has not described how the shield wall will be installed using the MRV. This information is needed to verify the feasibility of the proposed operations and compliance with 10 CFR 63.111(e).

1. RESPONSE

Strategies for Recovery after an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle (BSC 2007) evaluates potential off-normal events related to emplacement and retrieval system operations, specifically for the transport and emplacement vehicle (TEV), and conceptually identifies methods and processes for recovery from these events. Additionally, the study describes several vehicle configurations that could be used to implement recovery actions. One such concept, the multipurpose recovery vehicle (MRV), provides a capability for manipulating equipment and transporting materials and debris.

1.1 MULTIPURPOSE RECOVERY VEHICLE CONFIGURATION

The configuration of the MRV, as discussed and illustrated in Section 3.2 and Figure 3.2-1 of the recovery strategies study (BSC 2007), would be based on the same design concept as the TEV. Like the TEV, the MRV would be remotely operated and use the same transportation rails and third-rail power system. The structural configuration of the MRV would be similar to the TEV except that the shielded enclosure would be removed, and a fixed base plate would be attached between the two chassis side members. The base plate would be used to carry needed tools, equipment, and material to an event location and, if needed, could carry debris away. The equipment listed below supports both the capability of the MRV to respond to a potential off-normal event and to allow for suitable operator evaluation and control of the operations.

The current design concept for the MRV includes the following equipment:

- Cameras and lights
- Communications equipment
- Telescoping boom crane
- Manipulator arms
- Winch
- Rail clamps.

1.2 CONCEPTUAL APPROACH TO SHIELD WALL INSTALLATION IN A LOADED EMPLACEMENT DRIFT

1.2.1 Event Evaluation and Preplanning

This is a highly unlikely event. However, for the purposes of responding to the RAI, it is assumed that an off-normal event has occurred that has resulted in a need to replace a segment of rail in an emplacement drift that contains waste packages. The initial step after the occurrence of such an off-normal event would be to gather information at and near the event site using radiation monitoring equipment, fixed cameras, and environmental monitoring instrumentation. Part of this information gathering process would be to perform an inspection of the emplacement drift using inspection gantries and cameras mounted on the MRV. The information collected would be used to evaluate the nature of the off-normal event, determine the extent of condition and assess the potential for related conditions, and identify conditions and operating environments. The collected event and site condition information would be used as the basis for developing a recovery strategy and an implementation plan and schedule.

1.2.2 Shield Wall Installation Process

The MRV would be equipped with tools such as cameras, lights, telescopic boom crane, and manipulator arms. The fixed base plate area (MRV deck) between the wheels would be used for transporting other handling tools and materials (e.g., shield bricks) for building the temporary shield wall. This approach demonstrates a practical way for erecting a shield wall using remote handling tools or technology that is currently available. The shield wall thickness (shield brick length) will be established to meet the necessary shielding and as low as is reasonably achievable requirements. The existing transverse and longitudinal beams in the emplacement drifts have untapped and tapped holes to be used for guide pins and remote bolting of the wall base frame for the purpose of the recovery, although clamps could provide adequate anchorage if holes are not available. The wall construction approach is similar to building a typical wall (i.e., a secure base or foundation is required), as shown in Figure 1, and includes a framework to support the wall, as shown in Figure 2.

1.2.2.1 Remote Installation of Wall Base Frame

The wall base frame would be mounted on the transverse beam of the emplacement drift and used as a base for placing shield bricks and building the shield wall layer by layer. The wall base frame is conceptualized as two pieces for ease of handling and transportation as shown in Figure 3. The wall base frame is equipped with features such as captive bolts for remotely bolting to the transverse and longitudinal beams using a remotely operated torque wrench, guide pins for alignment, and removable tubular cameras mounted on the base plate for viewing and positioning. Tubular cameras would be held onto the base plate by the spring-loaded clamps and could be demounted using a slight pull. The cameras would be tied to the handling fixture by a steel cable. The cameras would be demounted and moved away when the handling fixture is disengaged from the wall base frame.

Remote installation of the wall base frame requires preparation prior to its transfer to the shield wall erecting site. The preparation work consists of attaching the handling fixture to the crane boom, engaging handling fixture hooks with wall base frame bails, mounting cameras to the base frame, and mounting lighting fixtures. All preparation would be performed in an assembly area away from the shield wall. Equipment would be moved to the shield wall area via the MRV. The wall base frame would be hoisted over the transverse beam and lowered into position using the camera system and guide pins.

The handling frame would then be disengaged from the wall base frame lifting bail. The MRV would be moved back to the assembly area for tool change operation. The handling fixture would be removed, and the remotely operated torque wrench would be attached to the crane boom for the next operation.

The wall base frame would be secured to the transverse and longitudinal beam using the torque wrench while being monitored via the cameras. The wall base frame is shown in Figure 2. These steps would be repeated for the installation of the second half of the wall base frame. Once installation of the wall base frame has been completed, the MRV would be readied for the next operation.

1.2.2.2 Remote Installation of the Vertical Beam Framework

The vertical beam framework would be built by using two vertical telescopic beams, one center horizontal beam, and two side telescopic horizontal beams, as shown in Figure 2. The beam extension would be achieved by using a load-lifting screw jack with screw actuators mounted on the beam and operated by a torque wrench held by the MRV manipulator arm.

The two vertical beams would be installed by using the crane boom grabber, holding the beam in a vertical orientation, and inserting the bottom end into the beam support pocket located on the wall base frame and beam. The telescopic end would be extended to engage with the top of the emplacement drift for rigidity as depicted in Figures 2 and 4. The beam framework would be completed in this fashion using the MRV boom crane, manipulator arm, and camera system.

1.2.2.3 Remote Installation of Steel Plates

The steel plates would be used to add additional rigidity and strength to the erected framework and also to provide support for shield bricks as they are placed one on top of the other. The steel plates would be handled by using the MRV crane boom and a special handling tool as shown in Figure 5. A cutout on the steel plate would be provided for plate handling, and hooks on the plate would engage with the pins on vertical beams to hold the steel plates in place, as shown in Figure 2. Using this approach, the steel plates would be used to construct a steel wall that covers the beam framework.

1.2.2.4 Remote Placement of the Shield Wall

The shield bricks would be sized to provide necessary shielding for the operating personnel. The shield brick concept includes features for prevention of direct radiation from the joints. This would be achieved by offset brick placement and covering the joint with the placement of the next shield brick. As shown in Figures 6 and 7, the shield wall would consist of a base layer and top layer. The base layer shield bricks would be handled by using a grabber type tool, as shown in Figure 6. The top layers of shield bricks would be placed using a special tool that would engage with the shield brick-lifting feature, as shown in Figure 7. Any crevices or small openings between the bricks would be detected by remote instruments and covered by lead blankets to limit radiation levels.

1.3 SUMMARY

The conceptual design of the MRV allows for the installation of a shield wall in an emplacement drift. The MRV will have the capability to transport needed materials to the off-normal event site and to install and inspect the shield wall.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Strategies for Recovery After an Off-Normal Event to the Waste Package Transport and Emplacement Vehicle*. 800-30R-HE00-01800-000 REV 000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070531.0043.

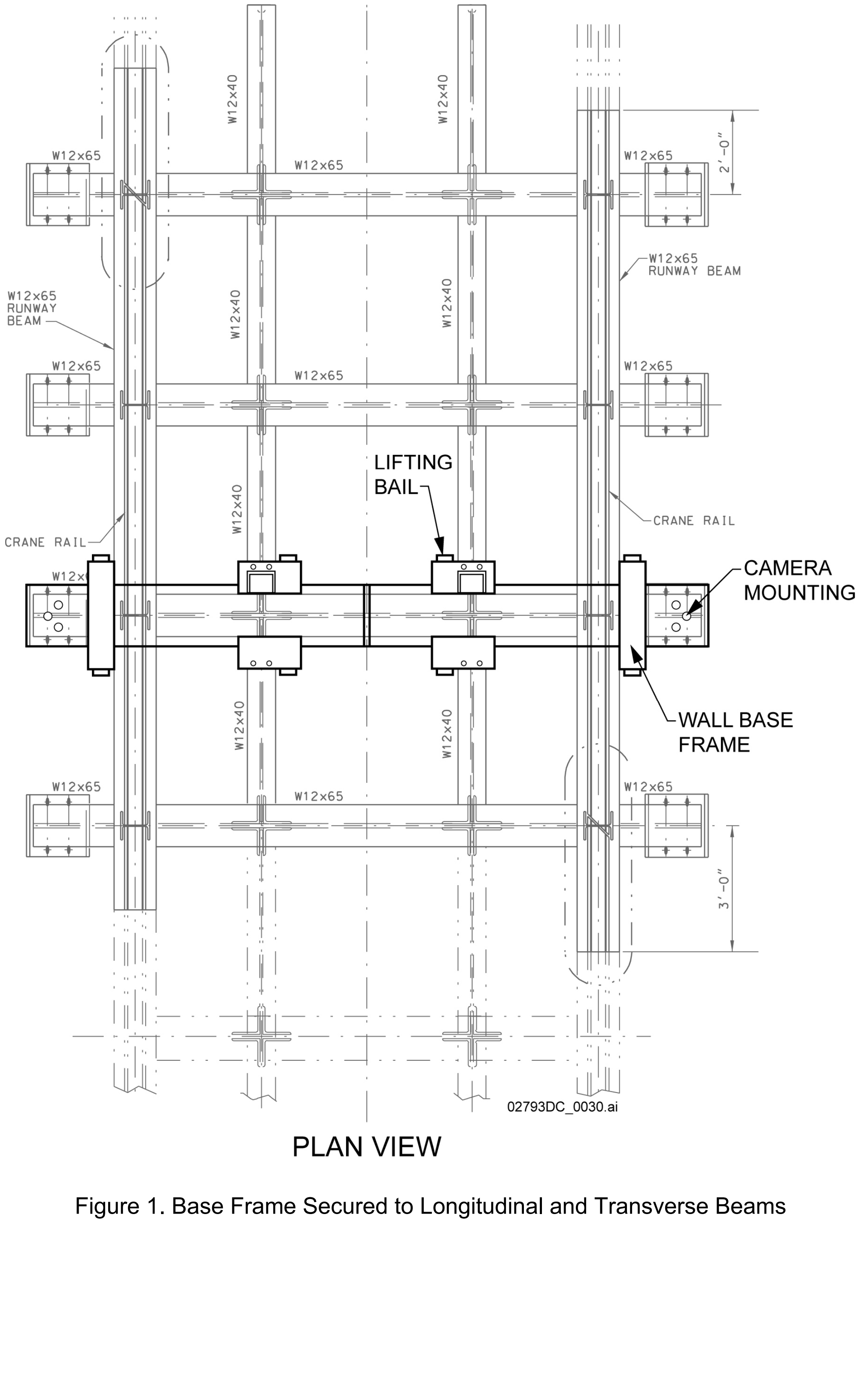

Figure 1. Base Frame Secured to Longitudinal and Transverse Beams

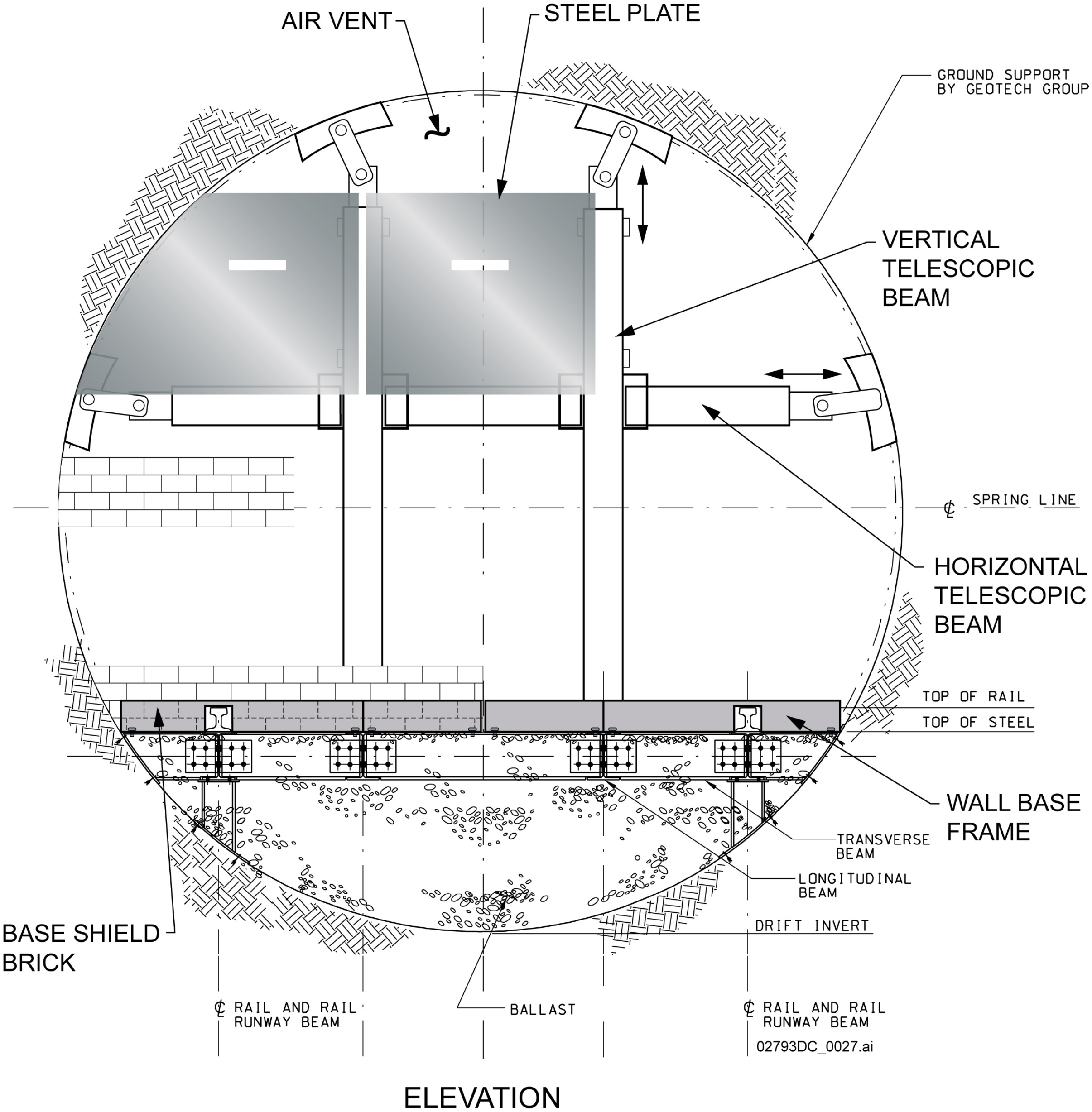

Figure 2. Framework and Wall Construction

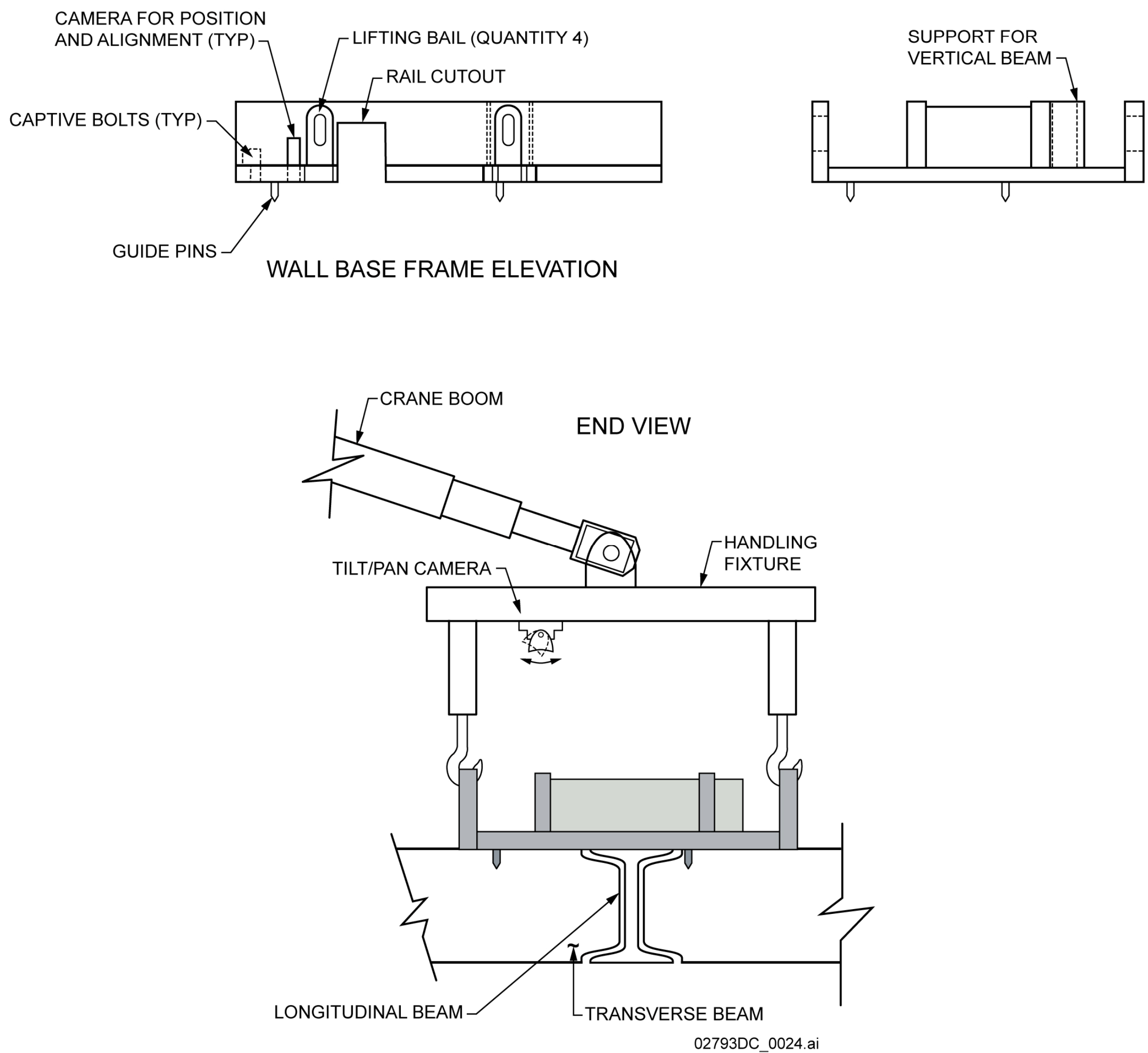

Figure 3. Step 1—Remote Placement of Wall Base Frame Using MRV

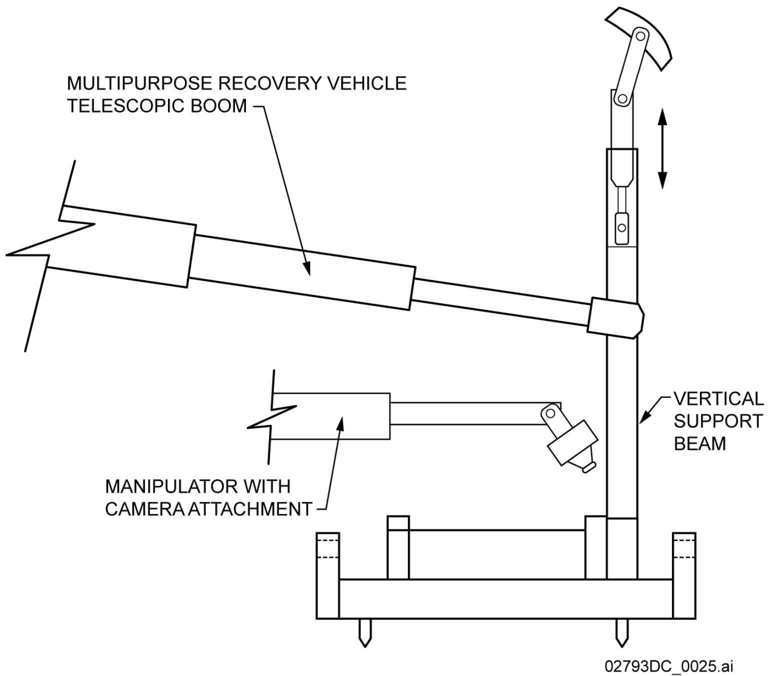

Figure 4. Step 2—Install Vertical Support Beam and Complete Vertical Beam Framework

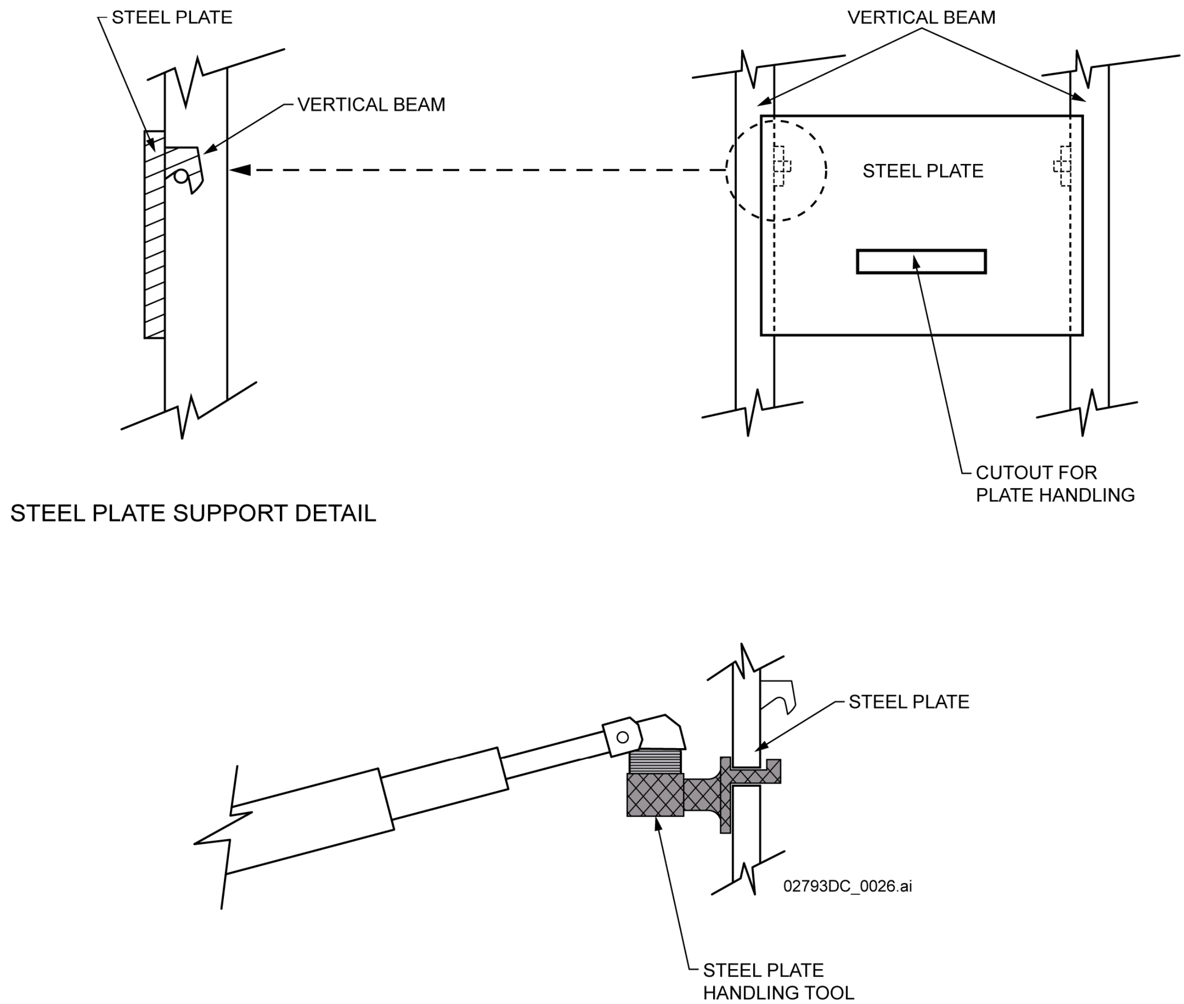

Figure 5. Step 3—Install Steel Plate Remotely Using MRV Telescopic Boom

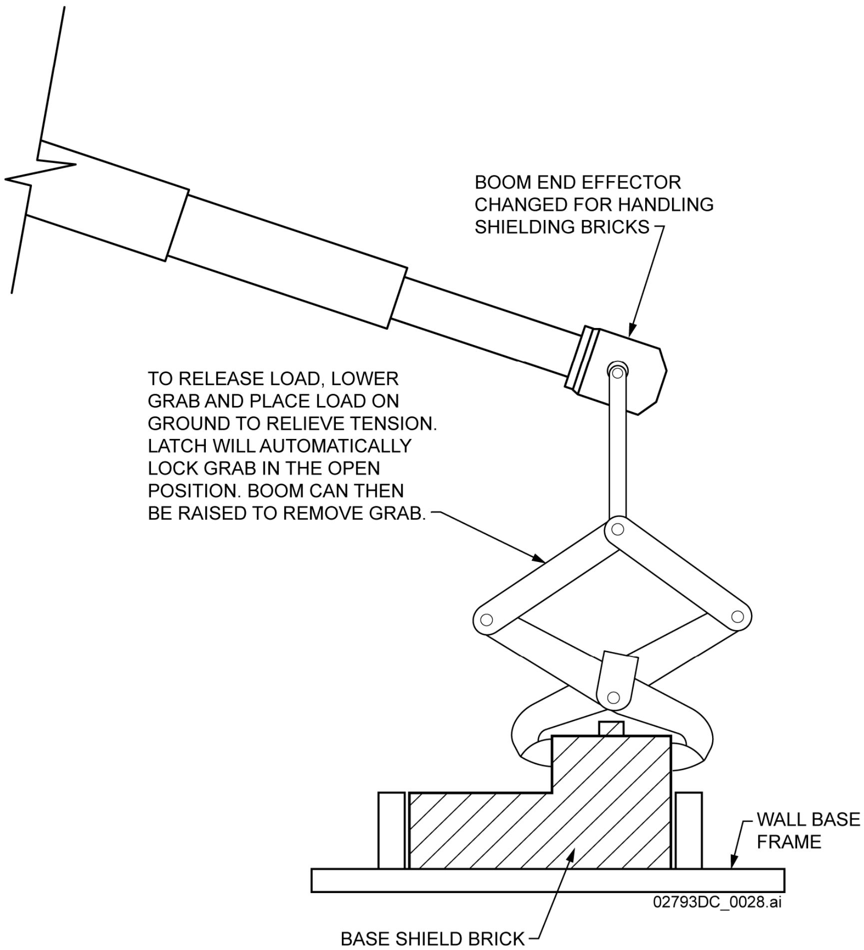

Figure 6. Step 4—Shield Brick Handling and Installation

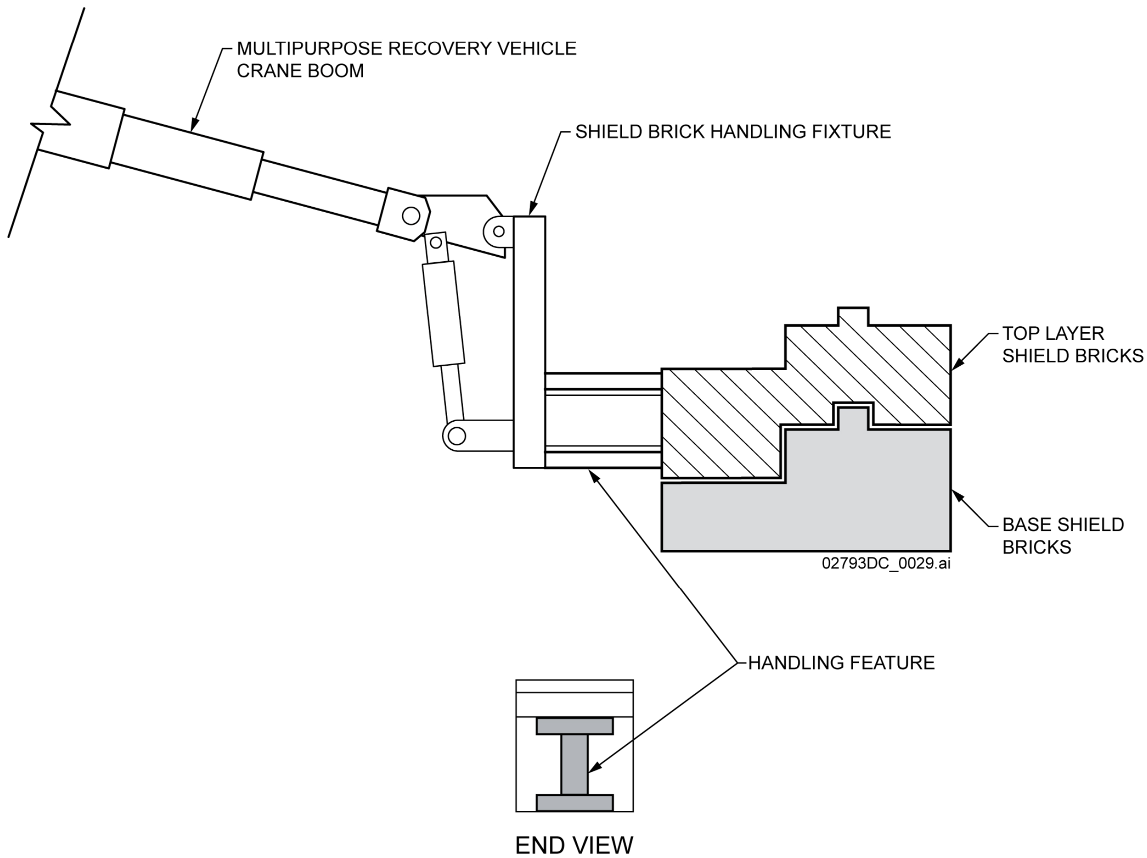

Figure 7. Step 5—Shield Brick Lifting Feature

RAI Volume 2, Chapter 2.1.2, First Set, Number 4:

> Provide information to a) define limits to waste-package temperature or physical damage that would not impair retrieval and to b) determine if off-normal conditions such as invert failure or rubble blockage of a ventilation conduit could cause the limits to be exceeded.
>
> In SAR Section 1.3.5.3.2.1, the applicant indicated that a complete loss of ventilation due to an off-normal event could cause the surface temperature of waste packages to exceed 300 °C in 162 days. The applicant has specified this temperature limit for waste emplacement but has not specified a similar limit applicable to retrieval operations. Also, the applicant has not assessed the potential physical damage to the waste package that could occur under potential off-normal scenarios and the limit of such damage without adversely affecting retrieval operations. This information is needed to verify the feasibility of the proposed operations and compliance with 10 CFR 63.111(e).

1. RESPONSE

1.1 SUMMARY OF RESPONSE

Retrieval operations are defined as the operations performed with the structures, systems, and components (SSCs) described in the SAR, in conformance with the requirements, criteria, and design bases for which those SSCs were designed to support retrieval of the emplaced waste packages from the repository, and in accordance with 10 CFR 63.111(e). This regulation stipulates that the geologic repository operations area must be designed so that any or all of the emplaced waste can be retrieved on a reasonable schedule. Retrieval operations as described in the SAR do not include retrieval under off-normal conditions that would result from occurrence of beyond Category 2 event sequences. If such beyond Category 2 event sequences occur during the preclosure period, DOE would at that time assess the conditions and the methods by which retrieval could be successfully accomplished in accordance with 10 CFR 63.111(e).

Retrieval operations are planned to be performed with a waste package resting on a pallet and the waste package-pallet unit being lifted and loaded by the transport and emplacement vehicle (TEV), as described in SAR Section 1.11. A description of the return of the waste package to the surface facilities is provided in SAR Sections 1.3.3.5 and 1.3.4.8, which describe recovery of a single waste package. While such a waste package recovery is similar, the discussion in this response is limited to retrieval.

The design bases of the repository are established to provide assurance that conditions for retrieval operations would be maintained within normal operational envelopes, that is, performed under the same conditions that apply during waste package emplacement. Only very limited off-normal occurrences would require mitigation during the retrieval process. No Category 1 or Category 2 event sequences have been identified for the preclosure period that would result in temperature-related or physical damage to the waste package and/or pallet that could interfere with retrieval as described in the SAR (Section 1.7). Low-probability beyond design bases conditions are also not likely to interfere with retrieval operations.

1.1.1 Limits to Waste Package Temperatures that Would not Impair Retrieval

The applicable waste package surface temperature limits, below which a retrieval operation would not be impaired, are listed below. The off-normal conditions that could result in those limits being approached, and the peak temperatures that have been estimated due to the occurrence of the controlling event for each limit, are discussed in the following sections.

- **Limit to Prevent Loss of Alloy-22 Structural Properties**—The Boiler and Pressure Vessel Code, Section I, Code Case 2226-2, *Ni-Cr-Mo Alloy UNS N06022 for Code Construction Temperatures up to 1250°F* (ASME 2007a) includes a note that indicates that this alloy has been observed to suffer a severe loss of impact properties after an exposure of solution annealed material to temperatures ranging from 538°C (1,000°F) to 677°C (1,250°F) (ASME 2007a, Table 2, Note (1)). The estimated peak outer corrosion barrier (OCB) surface temperature resulting from a low probability off-normal event is 451°C (844°F) (Section 1.2.1.2).

- **Limit to Prevent Creep Rupture of Weldment Material**—Preventing the waste package OCB surface temperature from exceeding a value of 501°C (934°F) assures adequate structural strength and confinement capability of the waste package. This limit is based on 100,000 hours of exposure during creep rupture tests for minimum strength weldment material (Structural Integrity Associates 2005; ASME 2007a), as described in *Evaluation of an Event Sequence for Waste Package Burial* (BSC 2008, Attachment III). The estimated peak OCB surface temperature resulting from a low probability off-normal event is 451°C (844°F) (Section 1.2.1.2).

- **Limit to Prevent Failure of the Bottom Lid of the OCB from Over-Pressurization**—Conservative calculations using closed-form stress solutions indicate that the lower bound temperature for pressure creep rupture of the bottom lid of the OCB for minimum-strength material is 400°C (750°F) (BSC 2008, Attachment V Worksheet 2 – File: "Attachment III Creep Stress Excel Workbook.xls"). Immediate pressure-induced rupture for minimum-strength material is possible if this temperature limit is reached. Because the location for a potential breach is at or near the center of the lid, which is the location most susceptible to pressure-induced rupture, the OCB surface temperature at the side of the waste package is considered to be representative of the temperature at the center of the lid and is the bounding condition. The estimated peak OCB surface temperature resulting from a low probability off-normal event for this case is 364°C (687°F) (Section 1.2.1.3.3).

The analyzed conditions for potential low probability, beyond design bases conditions are considered representative of cases that may result in the limits above being approached or exceeded. The limiting conditions will not be exceeded for these low probability, beyond design bases conditions. All of the waste packages include an Alloy-22 OCB. Conditions analyzed and described in this response relate to maintaining integrity of the Alloy-22 OCB, so they apply to all the waste packages regardless of their waste form.

1.1.2 Limits to Waste Package Physical Damage that Would not Impair Retrieval

The physical damage limit that would prevent retrieval of waste packages would be the existence of extremely damaged or deformed waste packages and associated pallets such that retrieval with the TEV would not be possible. Similar to the case of exceedence of temperature limits, no off-normal occurrences resulting from Category 1 or Category 2 event sequences or low probability, beyond design bases conditions have been identified for the preclosure period that could result in such physical damage to waste packages and pallets while emplaced.

1.2 OFF-NORMAL EVENTS POTENTIALLY AFFECTING EMPLACEMENT DRIFTS

1.2.1 Possible Events

Events capable of collapsing an emplacement drift have been determined to be beyond the design basis for the 100-year preclosure period and are therefore not considered as part of the operational planning for retrieval. SAR Section 1.3.4.4.1 indicates that the unsupported (not considering effects of ground support) emplacement drift openings are self-supporting with safety factors of two or greater against collapse modes for the rock mass quality conditions. The assessments described in SAR Section 1.3.4.4.1 are based on *in situ*, thermal, and seismic loads.

The seismic ground motion criteria for the subsurface facility are described and justified in SAR Section 1.3.2.5.1. Repetitive seismic loading was examined for applied ground motions with a mean annual probability of exceedence of 5×10^{-4} (design basis ground motion 2 or DBGM-2). A beyond design basis ground motion (BDBGM) event applicable to the subsurface facility during the 100-year preclosure period has a mean annual probability of exceedence of 1×10^{-4} and the associated ground motions were used to determine the impact of seismic shaking on emplacement drift stability. Evaluations of emplacement drift stability show that drift collapse does not occur at seismic ground motions up to and including mean annual probabilities of exceedence of 1×10^{-4} (SAR Section 2.3.4.4) Significant rockfall has been shown to occur for seismic events with mean annual probabilities of exceedence much lower than 1×10^{-4}.

The emplacement drift invert structure has been designed to withstand DBGM-1 (mean annual probability of exceedence of 1×10^{-3}) and DBGM-2 (mean annual probability of exceedence of 5×10^{-4}) ground motions from seismic events. The DBGM-1 ground motion is used to analyze the invert, runway beam, and rail designs under the loads imposed by a loaded TEV. The DBGM-2 ground motion is used for analysis of the invert structural frame design (longitudinal and transverse support beams) under normal loads (including loads associated with the presence of the heaviest waste package and pallet) without the TEV loads. These analyses demonstrate structural soundness of the emplacement drift invert for the applicable preclosure design seismic ground motions. No invert structure failures are expected to occur during the preclosure period for the structure's applicable design bases (SAR Section 1.3.4.5.9).

Accordingly, degradation of waste form containment capability of the waste packages need not be considered for retrieval of waste packages from the emplacement drifts except for one low probability intervening event that affects the integrity of the drift. Such an event would potentially be initiated by vibratory ground motion resulting from a seismic event. *Evaluation of an Event Sequence for Waste Package Burial* (BSC 2008) analyzes the thermal and structural effects of seismically induced rockfall that accumulates around a waste package. It provides the results based on: (1) horizontal and vertical peak ground velocities (PGV) for the expected ground motion exposures during the preclosure period; (2) the rockfall volume expected in an emplacement drift (m^3/m of tunnel length) based on the maximum PGV identified; (3) the maximum emplacement drift rockfall volume to determine how much a waste package will be covered; (4) the thermal response of a waste package buried in rockfall (rubble); and, (5) the structural creep of waste package materials. The calculation provides estimates of rockfall burdens for the waste packages emplaced in drifts excavated in both the nonlithophysal and lithophysal lithostratigraphic units. The case analyzed for the lithophysal rubble burial was for the hottest waste package to be emplaced (18-kW initial thermal-power commercial spent nuclear fuel), so that case is also bounding for all waste packages. The rockfall burdens have been conservatively determined based on vibratory ground motions associated with a seismic event with a mean annual probability of exceedence of 2×10^{-6}, within the realm of Category 2 event sequences analyzed in preclosure safety analysis, and considered an upper limit case for determining if the waste package temperature limits that could impair retrieval are exceeded.

The seismic probability for the burial analyses is based on examination of the period of time when burial of a waste package having the maximum allowable thermal power at emplacement (an initial thermal power of 18 kW) could occur, with rubble resulting from a drift collapse before the waste package cools to the equivalent of a 14-kW thermal power (or approximately 10 years after emplacement). This was chosen because calculations indicate that 100% burial of a 14-kW or less thermal power waste package has no thermal consequence (OCB surface temperature stays below the 501°C limit) (BSC 2008, Sections 6.1.4, 6.2.2, and Table 4). The seismic event with a mean annual probability of exceedence of 2×10^{-6} is the probability applicable to this window of time. This seismic event is beyond the design bases for the subsurface facility SSCs for the 100-year preclosure period. The SSCs in the subsurface facility have been designed for DGBM-1 or DGBM-2 and in some cases evaluated for the BDBGM; however, an event with a 2×10^{-6} return frequency is within the evaluation range of Category 2 event sequences considered in the preclosure safety analysis (BSC 2008, Section 6.1).

1.2.1.2 Thermal Consequences to the Waste Package

Rockfall of substantial key blocks might occur in the nonlithophysal units, and the thermal and structural performances of the waste package have been considered for such rock block impacts resulting from seismic events with an annual probability of exceedence of 2×10^{-6}. However, such rockfall is of insufficient volume to bury a waste package (i.e., less than 0.5 m^3 of rock rubble per meter of drift length, or 0.5 m^3/m) (BSC 2008, Section 6.1.2). This burial scenario results in a waste package OCB surface temperature distribution that is essentially unchanged from the unaffected configuration, and those temperatures are well below any of the controlling Alloy 22 preclosure temperature limits.

For rockfall in the lithophysal units, and for the same seismic conditions as analyzed for the nonlithophysal units, the accumulation of rock rubble due to rockfall is sufficient—without considering the drift geometry change caused by the rockfall—to partially cover the waste packages. The rock volume per meter of drift length for such a fall is calculated to be 5 m^3/m (BSC 2008, Section 6.1.3). The rubble volume is adjusted to 6.25 m^3/m, taking into consideration the bulking of the fallen rock. For a waste package, the depth of burial due to such a rockfall is illustrated in Figure 1. As a result of such a rockfall, the waste package would be buried up to 80% of its height (BSC 2008, Figure 7). The geometry represented in Figure 1 is conservative. If the dynamics of the rockfall are considered, the resulting drift opening becomes elliptical and little, if any, waste package burial occurs. One possible and more realistic geometric representation of the rubble is shown in Figure 2. The drift damage mechanism consists primarily of shear failure at the springlines of the opening coinciding with passage of the PGV peaks in the seismic velocity time history and the associated compressive stress increase (BSC 2004, Section 6.4.2.2).

For the more conservative waste package burial configuration illustrated in Figure 1, analyses performed with ANSYS for a drift air temperature of 100°C, based on a 6.25 m^3/m rockfall confined to the excavated emplacement drift diameter and resulting in a waste package burial height of 80%, demonstrate that a maximum OCB surface temperature of 451°C is reached. This estimated peak temperature is less than the 501°C and the 538°C limits that prevent creep rupture of the weldment material and loss of the Alloy-22 structural properties, respectively. The maximum temperature of the OCB is estimated to occur at the bottom of the waste package (BSC 2008, Section 7.2), with other portions of the OCB experiencing lower temperatures due to closer proximity to the free surface of the rubble. The OCB surface temperatures at the side (mid-point) and top of the waste package are estimated as 364°C and 180°C, respectively (BSC 2008, Figure 13).

The events leading to ventilation shutdown described in SAR Section 1.3.5.3 (i.e., mechanical equipment failure, power shutdown, airway drift collapse) and their consequences have less of an effect on the waste package OCB temperatures than the burial conditions discussed above.

1.2.1.3 Structural Consequences to the Waste Package

Calculations of the structural performance of the waste package under both nonlithophysal rockfall impact and burial under rock rubble from lithophysal rockfall have been performed. The nature of the structural challenges to the waste form containment capability of the OCB of the waste package is different for the two lithostratigraphic units.

Nonlithophysal —For design basis seismic events with a mean annual probability of exceedence much less than 1×10^{-4}, substantial size rock blocks may be anticipated to fall in the emplacement drifts located within the nonlithophysal units. The integrity of the OCB of the waste package has been demonstrated for rock block sizes and impact velocities well beyond those anticipated in the preclosure period. These analyses were documented in the calculation *Nonlithophysal Rock Fall on Waste Packages* (BSC 2007), which was transmitted to the NRC as a part of the response to RAI 2.2.1.1.7-2-002. No adverse affects on the waste package OCB integrity are anticipated, and the waste packages should remain suitable for retrieval.

Lithophysal Rockfall—The three challenges to OCB integrity listed below have been identified and analyzed for rockfall cases typical of the drift failure modes expected in emplacement drifts located in the lithophysal units (BSC 2008). The lithophysal zone rockfall event tends to develop higher thermal transients than a rockfall in the non-lithophysal zone due to the comparatively smaller size of the rubble and its effects on the burial of the waste package.

- The high temperatures experienced by the waste package during burial due to rockfall do not cause a direct failure of the OCB but might predispose the OCB to failure during an off-normal handling event while being retrieved. This is because exposure of Alloy 22 to high temperatures with subsequent cooling has been shown to reduce the inherent structural capability of that alloy.
- Failure of the OCB due to creep rupture at the locations where the OCB is supported by the support piers of the waste package emplacement pallet
- Rupture of either the top or bottom lid of the OCB due to internal pressurization, including the effect of creep

1.2.1.3.1 Loss of Structural Properties

The aforementioned Code Case for Alloy 22 includes a note that indicates that this alloy has been observed to suffer a severe loss of impact properties after an exposure of solution annealed material to temperatures ranging from 538°C (1,000°F) to 677°C (1,250°F) (ASME 2007a, Table 2, Note (1)). The analyses of various off-normal scenarios do not result in OCB surface temperatures exceeding 451°C; therefore, these conditions are not approached.

1.2.1.3.2 Creep Rupture

Average creep rupture strengths for Alloy 22 were examined in *Creep Rupture Properties of Alloy 22* (Structural Integrity Associates 2005) to determine the lower bound temperature that would result in rupture after 100,000 hours (~11.4 years) of continuous loaded exposure. This data was corroborated by the ASME Code Committee for Code Case 2226-2 (ASME 2007a), which permitted high temperature applications for Alloy 22 (material code UNS N06022). This data included a best-fit Larson-Miller Parameter for time and temperatures outside of the Code Case data set. Weld material creep rupture is typically reduced with elevated temperatures, and existing adjustment factors from the ASME Boiler and Pressure Vessel Code (ASME 2007b) are used. There is no data for creep rupture triaxiality effects for Alloy 22; however, the primary stress intensity limits from the ASME Boiler and Pressure Vessel Code (ASME 2007b) do not consider triaxiality-based adjustments and thus triaxiality was not considered in this evaluation (BSC 2008, Attachment III, pp. III-3 through III-5).

The lower bound temperature for average-strength weldment material has been determined to be 541°C (1,006°F). The lower bound temperature for the minimum strength weldment material has been determined to be 501°C (934°F) (BSC 2008, Attachment III). The lower of the two values is used as a controlling limit. For the rubble burial cases analyzed, the estimated peak temperature for the OCB surface is estimated at 451°C and it occurs at the bottom of the waste package. This estimated peak temperature is lower than the 501°C limit.

The OCB stress values, which are necessary to determine the creep rate, were calculated for the given rubble condition and self-weight loading of the waste package on the emplacement pallet support piers. The failure mode addressed in the evaluation was creep rupture of the OCB due to primary stresses having high shear and membrane components from weight and thermally induced internal pressure. This loading is sustained and not relieved by OCB deformations and is, thus, a primary load. Since the sizes of the falling rocks are small and are bounded by the nonlithophysal evaluation, residual stress due to such impacts is not considered. These stresses are secondary and will relax with deformation of the OCB at higher temperatures.

1.2.1.3.3 Pressure Failure of Waste Package Lids

Conservative calculations using closed-form stress solutions indicate that lower bound temperature for pressure creep rupture of the bottom lid of the OCB for average-strength material is 421°C (790°F). Immediate pressure-induced rupture for minimum-strength material is possible for a lower bound temperature of 400°C (750°F). The lower of the two values is used as the controlling limit.

For the rubble burial cases analyzed, it is assumed that the sealing welds on the waste package inner vessel and waste form canisters are disrupted due to the vibratory ground motion and accompanying rockfall; therefore, the total gas inventory of the waste package is assumed to be available to pressurize the OCB (BSC 2008, Attachment III, pp. III-3 through III-5). Since the location of a potential breach is at or near the center of the lid, the predicted bounding temperature is that of the side of the waste package, which has a value of 364°C (687°F) (BSC 2008, Section 6.2 and Figure 13). This estimated peak temperature is lower than the 400°C limit stated in Section 1.1.1.

1.2.2 Off-Normal Events Potentially Affecting Access or Ventilation Openings

Drift collapse scenarios that could affect access or ventilation are discussed in SAR Section 1.3.5.3. It is emphasized that events leading to such collapses are within the evaluation range of Category 2 event sequences considered in the preclosure safety analysis for the subsurface facility but not part of the 100-year preclosure period design bases of the subsurface SSCs which are designed to DGBM-1 or DGBM-2 and in some cases evaluated at BDBGM. If such a collapse were to occur prior to or during the retrieval operation, remediation work would be carried out to re-establish ventilation (if a ventilation airway is blocked) within the 30-day administrative limit defined in SAR Section 1.3.1.2.4. Damage to openings that constitute the TEV transportation route and damage to operational SSCs would be restored to support a retrieval operation.

Rockfall or rubble burial scenarios that might occur in the transportation routes while the TEV is transporting a retrieved waste package would not result in worse thermal or structural consequences than those that could occur in the emplacement drift and that are described in the previous sections of this response. During transportation to the surface, if a rockfall event were to occur, the waste package would be protected from direct rubble burial or impact from rockfall by the TEV's shielded enclosure.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ASME 2007a. Boiler and Pressure Vessel Code, Section I, Code Case 2226-2, *Ni-Cr-Mo Alloy UNS N06022 for Code Construction Temperatures up to 1250°F.* [New York City, New York]: American Society of Mechanical Engineers. TIC: 259190.

ASME 2007b. Boiler and Pressure Vessel Code, Section III, Division I, Subsection NH, *Class 1 Components in Elevated Temperature Service.* [New York City, New York]: American Society of Mechanical Engineers. TIC: 259190.

BSC (Bechtel SAIC Company) 2004. *Drift Degradation Analysis.* ANL-EBS-MD-000027 REV 03. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20040915.0010; DOC.20050419.0001; DOC.20051130.0002; DOC.20060731.0005; LLR.20080311.0066; DOC.20090226.0003; DOC.20090331.0006.

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BSC 2008. *Evaluation of an Event Sequence for Waste Package Burial*. 800-K0C-WIS0-00600-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080221.0021.

Structural Integrity Associates 2005. *Creep Rupture Properties of Alloy 22*. SIR-05-109, Rev. 1. San Jose, California: Structural Integrity Associates. ACC: MOL.20050426.0375.

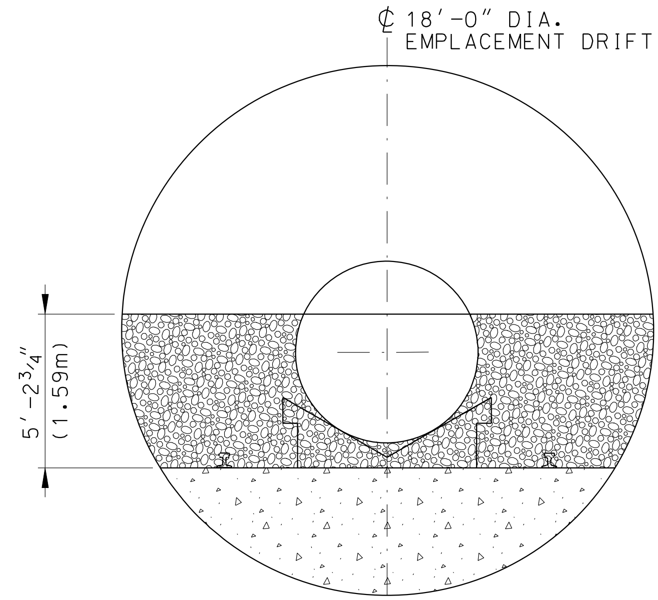

Figure 1. Rock Rubble Volume of 6.25 m^3/m with Waste Package Emplaced

Source: BSC 2008, Figure 3.

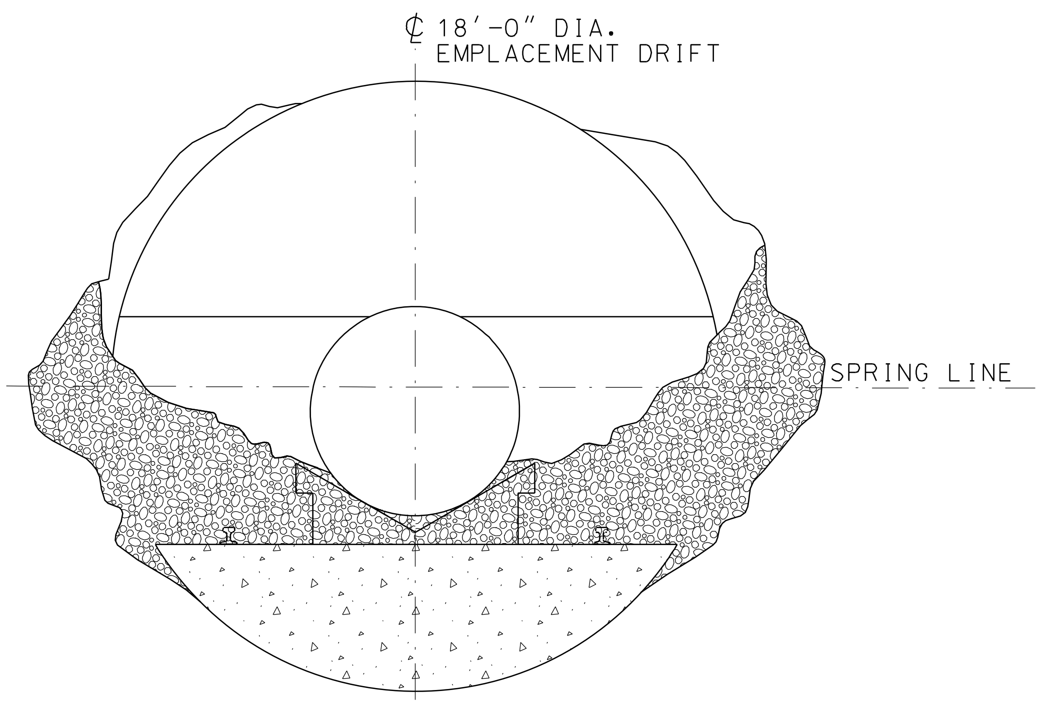

Figure 2. Possible Profile for 6.25 m^3/m Rubble Volume

Source: BSC 2008, Figure 4.