RAI Volume 2, Chapter 2.1.2, Set 1, Number 1: Supplemental Question 1

The DOE plans to monitor convergence of emplacement drifts through measurements at preselected locations using laser targets (DOE 2009bb, Enclosure 1). The plan appears different from the DOE statement during the July 8, 2009 clarification call that emplacement drift convergence will be monitored through three-dimensional scanning of the drift walls over the entire drift length.

Clarify how the DOE plan will be adequate to determine potential convergence of the entire length of an emplacement drift to preserve operating envelopes and to detect potential drift wall instability in a timely manner.

1. RESPONSE

This response provides supplemental information to the response to RAI 2.2.1.2-001, previously submitted, that identified measurement of convergence at preselected points by remote means. The supplemental information in this response identifies alternate means of obtaining convergence information and operating envelope deformation information. The alternatives discussed include monitoring of emplacement drift opening convergence by: (1) direct (conventional) measurements with convergence pins and extensometers prior to installation of ground support; (2) direct measurement of convergence at selected locations by using fixed laser targets at the heads of rock bolts as surrogates for convergence pins, as well as using laser scanning equipment to accurately measure the position of the fixed targets, as described in the original response; and (3) measurement of the steel liner configuration along the length of the drifts with laser scanning technologies as an approximate measurement of opening drift convergence. The latter method will provide checks on the integrity of the equipment operating envelope, more so than convergence, along the lengths of the drifts initially, and at selected sections of drifts in subsequent scans.

The ground support calculations establish soundness of the unsupported openings at the repository horizon during the 100-year preclosure period, including effects of potential seismic ground motions with a mean annual probability of exceedance of 10^{-4} (SAR Section 1.3.4.4.1) and thermal stresses from heating of the rock by the waste packages. Based on these assessments and on historical convergence data obtained at the Yucca Mountain Project, it is not anticipated that convergence of the emplacement drift openings will be large enough in magnitude to impact equipment operating envelopes. Furthermore, the ground support for emplacement drifts is not relied upon to prevent or mitigate event sequences; therefore, it has been classified as not important to safety (SAR Section 1.9).

Because of the robustness of the host rock and the ground support design, maintenance in the emplacement drifts is done only when needed to maintain operational capability. In the unlikely event of an isolated ground support failure in an emplacement drift (which is not expected to compromise the integrity of the waste packages), repairs will be postponed until they are necessary. In such cases, inspection and recovery of damaged waste packages in areas where rock fall has occurred are subject to the conditions stipulated in SAR Section 1.3.6, so that emplacement drift conditions will be returned to the requirements specified by postclosure performance analyses prior to closure of the repository.

The emplacement drift convergence data will provide information to assist in determining when maintenance may be required so that the subsurface facility can remain functional during the preclosure period (i.e., ensure accessibility of drifts for required activities and associated equipment). The convergence information would also be made available to the Performance Confirmation Program. From the facility operations perspective, maintaining the integrity of the equipment operating envelopes is a high priority, so alternate measurement techniques are proposed to monitor the position of the steel liner over larger distances of drift as a supplement to direct measurements of convergence in selected locations. This response, as well as previous responses associated with RAI 2.2.1.2-001, identifies monitoring of emplacement drift convergence in selected locations, using a risk-informed approach to increase or decrease the monitoring effort over time, depending on results of initial and subsequent observations. Direct measurements of rock wall convergence will be performed, and supplemental indirect measurements will be made for monitoring the deformation of the liner as an approximate indication of convergence at additional locations. These additional measurements will provide the means to ensure that the integrity of the in-drift equipment operating envelopes has not been compromised before deployment of the equipment.

1.1 OVERVIEW OF CONVERGENCE INFORMATION

During construction of the Exploratory Studies Facility (ESF), information was obtained regarding the magnitude of deformation resulting from tunnel excavation. Displacement data from 94 tape extensometer stations and 18 borehole extensometer stations along the ESF main loop (i.e., the North Ramp, main drift, and South Ramp) were evaluated and the measured convergence was generally low in the ESF main drift. Maximum observed convergences were 5.8 mm for one of the welded tuff units (with most of the welded tuff units having convergences less than 2 mm), and 15.55 mm for one of the nonwelded tuff units (with most of the nonwelded tuff units having convergences of less than 5 mm). Instrumentation was installed one to two months after the excavation, so some of the more pronounced initial deformations may not have been measured, and some of the larger readings may be part of that initial deformation. Subsequent convergence measurements have shown less pronounced deformations, in the millimeter or submillimeter range per year.

Convergence monitoring of the ESF tunnels and the Enhanced Characterization of the Repository Block Cross-Drift has continued as permitted by access and availability of support systems. Measured convergence during the 2009 fiscal year from selected monitoring locations at the ESF range from −0.069 mm to 2.418 mm. Measured convergence at one location in the Enhanced Characterization of the Repository Block Cross-Drift was reported as −0.024 mm.

The convergence measurement program will address the effects of long-term thermal stress. Heating of the rock at the repository will induce thermal stresses with predominant horizontal direction because the heat sources will be emplaced in a single rock horizon, while initial deformations after construction reflect vertical stresses from overburden loads that are predominantly in the vertical direction. Selection of convergence measuring methods will take this into consideration. Another important aspect to be considered is that most of the total deformation expected in a volcanic rock excavation, excluding thermally induced deformations, takes place shortly after excavation. Installation of the emplacement drift ground support will likely take place after most of the initial deformation has occurred. Installation of the perforated stainless steel liner plates will prevent direct measurements of conventional convergence pins anchored to the drift walls unless openings in the liner plate are located where needed, so an alternative to placing additional perforations in the steel liner is provided in this response. In addition to direct measurement of convergence at discrete locations, monitoring the deformation of the steel liner will provide the data necessary to determine the integrity of the operating envelopes for the waste package emplacement and retrieval and the drip shield emplacement gantry, independently from direct measurements of convergence of the excavated openings.

SAR Figure 1.3.4-18 illustrates the 16-ft equipment operating envelope inside an emplacement drift with an 18-ft excavated diameter. The drip shield gantry depicted in the figure represents the largest operating envelope requirements for the subsurface facility equipment. SAR Figure 1.3.4-20 illustrates the transport and emplacement vehicle within the same 16-ft operating envelope. The operating envelope allows a radial clearance of one foot for accommodating the ground support structures and allowances for construction/installation tolerances and potential future drift convergence. The DOE site characterization plan estimated a total displacement of 70 mm (2.75 inches) for 100 years. Subsequent convergence measurements indicate that this estimate is not expected to be exceeded.

Drift closure calculations in *Ground Control for Emplacement Drifts for LA* (BSC 2007, Section 6.4.2.1) estimated the maximum vertical closures to range from about 40 mm to about 55 mm for Category 1 rock mass (the lowest quality-rated rock), and from about 3 mm to about 5 mm for Category 5 rock mass (the highest quality-rated rock). The maximum horizontal closures are expected to vary from about 4 mm to about 40 mm for Category 1 rock mass, and from about 1 mm to about 5 mm for Category 5 rock mass. It appears that the rock deformation is induced primarily by *in situ* stress during excavation. Additional thermally induced deformation is anticipated to be minimal.

1.2 DIRECT CONVERGENCE MEASUREMENTS

Direct convergence measurements prior to installation of the stainless steel liners in the emplacement drifts are not addressed in the SAR but may be possible before the final ground support is installed. Based on assessment of previous convergence measurements and consistent with relaxation characteristics of the rock and the length of the time interval between excavation and ground support installation, a large percentage of the drift deformation is anticipated to take place shortly after excavation (BSC 2007, Section 6.7.2). Therefore, it would be beneficial to take some direct (conventional) convergence measurements prior to the final ground support installation, or as part of the installation process, to ensure meeting allowances prescribed by the equipment operating envelope (BSC 2008, Sections 1 and 6.1.1). The Performance Confirmation Program plans to conduct such measurements.

As described in the supplemental response to RAI 2.2.1.2-001, convergence measurements will be taken at selected locations at the emplacement drifts in the initial phase of development

(Panel 1). Results from those measurements will dictate the density and frequency of such monitoring in future emplacement drifts, on a risk-informed basis. Placement of convergence pins through the steel liner is possible and, as an alternative, the targets intended for convergence readings with a laser system would be placed at the heads of the 3-m stainless steel expandable rock bolts, because drift wall deformations will be directly reflected in the movement of the rock bolts. Laser equipment to make such measurements would be installed on a monitoring gantry as previously described in the response to RAI 2.2.1.2-001. These measurements detect displacements of a few millimeters, and repeated measurements at different times at the same locations can discern trends and rates of movement of the deformations. Commercially available equipment capable of this type of monitoring is currently being used in the construction and tunneling industries.

1.3 OTHER MEASUREMENTS TO SUPPLEMENT CONVERGENCE MEASUREMENTS

Measurement of the deformation of the steel liner will constitute a supplemental indirect measurement of drift deformation. Although not as precise as conventional convergence measurements, such measurements have the added advantage of constituting a direct check of the available equipment envelope. Laser scanning of the liner surface can be done continuously, or concentrated in areas where convergence readings indicate a potentially higher rate of opening deformation than expected. Repeated scanning passes over time from the same platform (i.e., laser scanning equipment mounted on rail-based gantry) would provide detailed mapping and detection of liner movements, and monitoring of the integrity of the equipment operating envelopes. Laser scanning equipment is less accurate than laser targeting equipment with fixed targets, but still can provide measurements with 5 mm to 15 mm accuracy, which is adequate for determining magnitude of encroachment of the operating envelope by any ground support component. Moreover, laser scanning provides continuous evaluation over great distances. Again, laser scanning equipment with these capabilities is commercially available and currently being used in the construction and tunneling industries. Laser scanning equipment is also widely used in inaccessible areas of nuclear power plants.

1.4 CRITERIA FOR SELECTING INITIAL LOCATIONS FOR CONVERGENCE MEASUREMENTS

Conventional convergence measurements performed prior to installation of the stainless steel liner will provide an opportunity for more educated selections of post-liner installation measurement locations. The conventional program will identify the locations exhibiting the most pronounced initial deformations and, therefore, improve the selection of areas that may have the largest convergence over the preclosure period. The results of the geologic mapping and observations performed immediately after the excavation of each drift, in conjunction with recommendations from geotechnical engineers familiar with the rock types and their mechanical and thermal-chemical properties, are used in the process to identify convergence measurement locations. A convergence measurement location selection criteria plan will be developed in accordance with plans and procedures guidelines described in SAR Section 5.6, or in conformance with commercially available guidelines as appropriate.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Ground Control for Emplacement Drifts for LA*. 800-K0C-SSE0-00100-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070925.0082.

BSC 2008. *Ground Support Maintenance Plan.* 800-30R-SSD0-00100-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080215.0001.