RAI Volume 2, Chapter 2.1.1.4, Third Set, Number 1, Supplemental Question 9:

Where in the SAR is (or provide information on) potential susceptibility of rock bolts to stress corrosion cracking or crevice corrosion? This could happen under varying relative humidity (10% to 80%) and aqueous chemical conditions (e.g., salt precipitation) along their longitudinal direction.

The NRC staff advised that they were aware of new literature, not reflected by DOE's SAR or correspondence, that discusses susceptibility of stainless steel to stress corrosion cracking or crevice corrosion under a range of environmental conditions and applications. The DOE advised NRC that they would review the references listed below and advise the NRC of the extent to which their contents are applicable to repository conditions. The reference citations are as follows:

> T. Mintz and D. Dunn. "Atmospheric Chamber Testing to Evaluate Chloride Induced Stress Corrosion Cracking of Type 304, 304L, and 316L Stainless Steel." NACE CORROSION 2009 CONFERENCE & EXPO, Paper No. 09295, 2009.
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> T. Prosek, A. Iversen, C. Taxén and D. Thierry. "Low-Temperature Stress Corrosion Cracking of Stainless Steels in the Atmosphere in the Presence of Chloride Deposits." Corrosion, Vol. 65, pp. 105-117, 2009.
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> S. Shoji and N. Ohnaka. "Effects of Relative Humidity and Chloride Type on Stainless-Steel Room-Temperature Atmospheric Corrosion Cracking." Corrosion Engineering, 38, pp. 111-119, 1989.
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> J.I. Tani, M. Mayuzumi and N. Hara. "Initiation and Propagation of Stress Corrosion Cracking of Stainless Steel Canister for Concrete Cask Storage of Spent Nuclear Fuel", Corrosion, Vol. 65, pp. 187-194, 2009.

1. RESPONSE

This RAI relates to stainless steel components of the ground support system, specifically rock bolts. The emplacement drifts and turnouts are the only repository openings where such components are used; therefore, the response is specific to rock bolts used in the emplacement drifts and turnouts. Environmental conditions for the emplacement drift rock bolts bound the design for the turnout rock bolts. Evaluations have determined that the repository openings are stable in an unsupported condition (BSC 2007, Section 7), and the purpose of the ground support is to provide for personnel protection and to provide additional assurance in maintaining repository openings for operations.

Although the repository environment for the rock bolts is one that would not normally lead to stress corrosion cracking, tests are planned to confirm the performance of the stainless steel bolts under representative chemical conditions. The potential susceptibility of rock bolts to stress corrosion cracking or crevice corrosion is explained in SAR Section 1.3.4.4.1.1, which describes the ground support design considerations and includes a corrosion discussion that addresses the composition of seepage water and air in the host rock as considered in the design of the system. SAR Section 1.3.4.4 also discusses the intent to perform testing associated with the corrosion of the stainless steel components during construction and repository operations.

Two ground support design documents, *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003) and *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a), describe various types of corrosion that could potentially affect the rock bolts. These documents analyzed the longevity of ground support components for the environmental conditions expected in the emplacement drifts and resulted in selection of Stainless Steel Type 316L for Swellex-type bolts in the ground support. The *Longevity of Emplacement Drift Ground Support Materials for LA* calculation (BSC 2003) was a reference provided to the NRC at the time of the initial LA submittal. This calculation contains an evaluation of stress corrosion cracking and crevice corrosion as discussed in the RAI, as well as other corrosion processes. *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a) is submitted with this response. This calculation, consistent with the LA design, evaluates the longevity of steel ground support components based on modifications to the repository layout configuration and ground support systems evaluated in the earlier document.

1.1 EMPLACEMENT DRIFT ROCK BOLT DESIGN BASES

The emplacement drift ground support is classified as not important to safety (SAR Section 1.9, Table 1.9-1). *Longevity of Emplacement Drift Ground Support Materials for LA* (BSC 2003) analyzed the longevity of ground support components for the environmental conditions expected in the emplacement drifts and resulted in selection of Stainless Steel Type 316 material for the Swellex-type bolts. This document evaluates corrosion processes which include stress corrosion cracking, dry oxidation, humid-air corrosion, aqueous corrosion, pitting and crevice corrosion, hydrogen embrittlement, and microbiologically influenced corrosion. The ground support design includes an allowance for corrosion (BSC 2003, Section 5.5; BSC 2008a, Section 3.2.3). *Input Parameters For Ground Support Design* (BSC 2008b) identifies stainless steel materials, such as Stainless Steel Type 316L or equivalent, as the ground support material of choice in emplacement drifts and turnouts (BSC 2008b, Section 6.10.1). Although ground support design documents generically identify the Swellex-type rock bolts as Stainless Steel Type 316 with no grade designation, the Stainless Steel Type 316L material is the grade that will be installed, due to its high resistance to corrosion.

The most important factor in longevity of the ground support is corrosion of steel components, which is the focus of *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a). This document is based on the ground support components described in SAR Sections 1.3.3.3 and 1.3.4.4, and on updated environmental conditions in emplacement and nonemplacement drifts. The environmental conditions considered include temperature, relative humidity, water and air chemistry, and radiation (BSC 2008a, Section 6.1). The reevaluation document also summarizes observations from the Heated Drift Scale Test and other existing subsurface excavations (BSC 2009, Section 6.7).

1.1.1 Design Bases for the Rock Bolt Environment

The engineering calculations consider the environmental conditions to evaluate the longevity of the ground support materials. As summarized in the following paragraphs, the conditions considered include temperature, relative humidity, ground water chemistry, air chemistry, and radiation (BSC 2008a, Section 6.4).

Temperature—As reported in *Preclosure Emplacement Drift Temperature Calculation for the 2.0 kW/m Thermal Load* (BSC 2008c)[1], Figures 1 and 2 show the estimated emplacement drift wall temperatures for drift lengths of 600 m and 800 m for the repository design basis 2.0 kW/m thermal line load with a continuous 15 m^3/s ventilation airflow rate. These drift wall temperature estimates are conservative because they are based on simulation of the repository's thermal response assuming that the waste package inventory (70,000 MTMH) is emplaced simultaneously at the time subsurface ventilation is initiated (year 0 in Figures 1 and 2), as opposed to the expected waste emplacement phased over a period of up to the first 50 years of operations for which the duration, timing, and peak values of drift wall temperatures would be less significant relative to stress corrosion cracking conditions. A temperature drop of about 10°C to 20°C was estimated for 1 to 3 m into the host rock (BSC 2008a, Section 6.4).

Based on the discussions below, stress corrosion cracking and crevice corrosion are unlikely to occur at temperatures below approximately 70°C in the repository environment, but cannot be excluded from occurring at temperatures above 70°C. Information presented in Figures 1 and 2 includes the estimated emplacement drift wall temperatures during preclosure for typical and maximum drift lengths. The average emplacement drift length is approximately 600 m, and the longest drift approaches 800 m in length. As shown in Figures 1 and 2, the drift wall temperatures peak immediately after emplacement and decrease steadily thereafter. For a 600 m long emplacement drift, the wall temperature drops below 70°C less than 30 years after initial emplacement; and for an 800 m long drift, the drift wall temperature drops below 70°C a little more than 40 years after initial emplacement. For the first 350 m of emplacement drift, the drift wall temperatures will not exceed 70°C during the preclosure period (BSC 2008c, Figures 3 and 4). Though stress corrosion cracking cannot be excluded from occurring at temperatures above 70°C, any stress corrosion cracking is expected to be localized and is not expected to affect the overall support characteristics of the Swellex-type rock bolts.

Relative humidity—The moisture conditions along the drifts and the hydrological conditions in the repository horizon rocks have been monitored. The results of *in situ* testing at the Exploratory Studies Facility tunnels indicate the presence of a dry-out zone of up to 3 m into the drift wall caused by ventilation. Although relative humidity in an emplacement drift will be very low due to the presence of both ventilation and heat generated by the waste packages, the relative humidity inside the rock bolt boreholes is expected to be higher, especially near the end of a borehole, where the relative humidity is expected to be greater than 90% (BSC 2008a, Section 6.4). Also, some fluctuation in temperature and relative humidity will occur due to changes in the outside air. These changes will be seasonal, and more frequently caused by

[1] The BSC 2008c reference was submitted as an attachment to RAI 2.2.1.1.4-3-001 (RTN 00409-06).

weather systems. Thus, the relative humidity along a typical rock bolt may range from a few percent at the drift wall to greater than 90% at the distal end.

Ground water chemistry (aqueous chemical conditions)—The initial pore water (water filling the fine matrix pores of the host rock) chemistry in the unsaturated zone at or above the repository horizon is used for the ground support evaluations. The most important characteristics for the initial pore water related to steel corrosion, and their updated average values and ranges (in parenthesis) are: chloride concentration of 90 (23 to 146) mg/l, sulfate concentration of 86 (16 to 126) mg/l, bicarbonate concentration of 139 (126 to 149) mg/l, and pH of 8.07 (7.7 to 8.31) (BSC 2008a, Section 6.4). The contents of chlorides and sulfates with these concentrations are generally considered moderately low and low compared to saline water (30,000 and 50,000 mg/l), and the pH range is considered near neutral. These concentrations are for *in situ* pore water, corresponding to an *in situ* relative humidity of approximately 99% or greater. For the lower relative humidity that may occur along the bolt during preclosure, evaporative concentration will occur, concentrating the initial pore water. There may be small amounts of corrosive brine present that could induce corrosion damage.

Air chemistry—Since the emplacement drift airflow draws ambient air from the surface, the chemistry of air in the emplacement drifts will be the same as the ambient surface air. Due to the repository remote location there are no airborne chemicals from industry that would be drawn into the subsurface, and there is no diesel equipment used during emplacement operations. The emplacement drift ventilation nominal airflow rate of 15 m^3/s far exceeds the air exchange rate inside the host rock.

Radiation—The parameters of importance for radiation damage are the absorbed dose and the neutron fluence, which are evaluated beyond the 100-year preclosure period to minimize future maintenance or replacement should the preclosure period be extended. The impact from neutron radiation on mechanical properties of carbon steel or Stainless Steel Type 316 is insignificant. (BSC 2008a, Sections 6.4 and 6.6.2).

1.1.2 Rock Bolt Design

The repository openings are stable in an unsupported condition, and ground support is provided for personnel safety and to provide additional assurance in maintaining the operational envelopes (BSC 2007, Section 7). Voids in the lithophysal rock (lithophysae) will create zones of stress in a section of a rock bolt; however, any stress corrosion cracking that may occur because of the interface with the voids would be localized and would not affect the full length of the bolt and, therefore, would have limited impact on the ground support since the openings are stable as unsupported. Similarly, the random locations of lithophysae would not result in a specific stress corrosion cracking zone, for example at 1 m from the drift wall, in the radial bolt pattern.

The Swellex-type rock bolts provide reinforcement and support along the whole length of the borehole, and any potential corrosion along the length of a bolt does not imply a rock bolt failure. The Swellex-type rock bolts specified for the emplacement drifts located in lithophysal rock have a factor of safety estimated to be greater than 2, and greater than 10 for the rock bolts to be installed in nonlithophysal rock (BSC 2007 Section 6.7.2).

1.1.3 Ground Support Component Testing

The DOE recognizes that new research will continue to be performed that needs to be evaluated against the Yucca Mountain baseline design. For example, as part of the U.S. DOE/University and Community College System in Nevada Cooperative Agreement, the University of Nevada, Reno, conducted studies over an extended period as published in *Corrosion Research on Rock Bolts and Steel Sets for Sub-surface Reinforcement of the Yucca Mountain Repository* (UNR 2009). These studies were performed to understand environmental effects such as corrosion/oxidation of the ground support design components of Yucca Mountain. In broad terms, the University of Nevada, Reno, conducted research on two classes of materials: (1) rock bolts used for tunnel support (Split Set Friction Rock Stabilizers (SS46), Swellex Mn-24, and AISI 4340 Steel), and (2) super alloys, such as, Alloy 22 (UNS N06022), Alloy 282, and Alloy 263 (UNS N07263), for containers and other components for the underground repository.

Testing included electrochemical and conventional corrosion tests on rock bolts obtained from industry and also on other steels with desirable properties for rock bolts. Oxidation kinetic studies were performed using thermogravimetric measurements on these rock bolt steels and super alloys at elevated temperatures to obtain the oxidation mechanisms. The final report summarizing the complete results from the task (UCCSN Document ID: TR-06-001) was issued on February 28, 2009 (UNR 2009).

While these studies were not specifically designed to investigate stress corrosion cracking, useful information was obtained including certain scenarios where pitting corrosion in dry salt conditions at elevated temperatures, corrosion due to deliquescent salts, and no passivation in the presence of chlorides were observed with some types of Swellex bolts. Earlier progress reports as well as draft final reports were used in design selection since they presented important findings for Yucca Mountain that facilitated development of the licensing design basis.

SAR Section 1.3.4.4 identifies the plan to test corrosion of the stainless steel components during construction and early repository operations. The preliminary corrosion test parameters are documented in *Evaluation of Repository Ground Support Test Needs* (BSC 2009), which is submitted with this response. Significant stress corrosion cracking damage is not expected to occur because: 1) the chloride and sulfate concentrations are considered moderately low; 2) the tensile stress level induced in the bolts due to the combined *in situ*, thermal, and seismic loads is generally too low to initiate the cracks; and 3) Swellex-type rock bolts have performed in many applications without indication of damage from stress corrosion cracking. However, confirmatory studies and tests are planned to verify that stress corrosion cracking will not occur in stainless steel Swellex-type rock bolts as they are intended for use in the repository. *Evaluation of Repository Ground Support Test Needs* (BSC 2009) identifies rock bolt testing that includes intelligent (computer monitored) borehole drilling data collection, pull tests, nondestructive pull tests, over-coring, applied stress levels for testing of the potential for stress corrosion cracking, and sample rock bolts that will include variations on steel composition and environmental conditions (BSC 2009, Section 5.6.3).

1.2 REVIEW OF RECENT PUBLICATIONS ON STAINLESS STEEL CORROSION MECHANISMS

In response to NRC's questions at the supplemental clarification call, this section summarizes recent professional papers dealing with general corrosion, localized corrosion, and stress corrosion cracking of Stainless Steel Type 316L, and discusses the relevance of the contents of those papers to the repository ground support design components, specifically the emplacement drift Swellex-type rock bolts.

With the exception of the Shoji and Ohnaka (1989) paper, these papers were not available when *Longevity of Emplacement Drift Ground Support Materials* (BSC 2003) or *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a) were prepared. The two reports analyze the longevity of Stainless Steel Type 316L material that is specified for the emplacement drift Swellex-type rock bolts, bearing plates, and perforated (Bernold-type) sheets.

As discussed in *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a, Assumption 3.2.2), the initial water chemistry at or above the repository host horizon is based on measured pore water compositions found in *Drift-Scale THC Seepage Model* (SNL 2007, Table 6.2-1). These waters are very dilute and contain a maximum of 17.4 mg/L (0.0007 M) Mg^{2+}, 97 mg/L (0.0024 M) Ca^{2+}, and 146 mg/L (0.004 M) Cl^{-}. The pore water composition is not corrosive to Stainless Steel Type 316L material. As illustrated in Figures 1 and 2, the preclosure drift wall temperature will vary from about 40°C to 110°C with a range of relative humidity. For comparison, the exposure environments used in the four recent papers, which resulted in stress corrosion cracking, are more severe than those expected in the repository during the preclosure period.

Below are summary assessments of the exposure environments used in the papers, and other relevant information, as related to the expected repository chemical conditions listed above.

1.2.1 "Effects of Relative Humidity and Chloride Type on Stainless-Steel Room-Temperature Atmospheric Corrosion Cracking" (Shoji and Ohnaka, 1989).

This paper evaluated the stress corrosion cracking susceptibility of Stainless Steel Type 304 and Stainless Steel Type 316L U-bend specimens exposed under controlled relative humidity to 0.5 M solutions (NaCl, $MgCl_2$, $CaCl_2$, or $ZnCl_2$) or to synthetic sea water. Six 5-µL droplets were applied to each U-bend followed by drying in open air at room temperature. The specimens were then exposed at about 23°C for times up to 24 months over a range of relative humidity values from about 3% to 90%. With NaCl exposure, minute pits were observed for Stainless Steel Type 304 but not for Stainless Steel Type 316L at 40% relative humidity, and no stress corrosion cracking occurred for either alloy. In contrast, with synthetic seawater (in which $MgCl_2$ accounted for 10% of the total chloride) and with pure $MgCl_2$, stress corrosion cracking initiation and propagation occurred in both alloys at about 30% relative humidity. For $CaCl_2$, stress corrosion cracking was observed for Stainless Steel Type 316L between about 20% and 30% relative humidity. $ZnCl_2$ produced stress corrosion cracking at 5% relative humidity. The paper (Shoji and Ohnaka 1989, Table 4 and Figure 5) compared the equilibrium humidity of a saturated solution of each salt at room temperature, at 50°C, and at 70°C with the relative humidity for maximum stress corrosion cracking susceptibility (RH_{max}) obtained from this and previous studies at 50°C and 70°C. Shoji and Ohnaka (1989) found that, for saturated NaCl containing about 16% chloride (about 4.5 M), no stress corrosion cracking occurred at 25°C or 50°C, but did occur at 70°C with a RH_{max} of 60%. Although conditions of 70°C and 60% relative humidity may occur part way back into rock bolt holes, when the drift wall temperature is greater than 70°C, chloride concentrations as high as 16% are not expected to contact the emplacement drift rock bolts to any significant extent during the preclosure period.

1.2.2 "Atmospheric Chamber Testing to Evaluate Chloride Induced Stress Corrosion Cracking of Type 304, 304L, and 316L Stainless Steel" (Mintz and Dunn 2009)

This paper evaluated Stainless Steel Type 304, Stainless Steel Type 304L, and Stainless Steel Type 316L. Single and double U-bend specimens of these alloys were exposed to alternate wetting (15 seconds) and drying cycles in simulated sea salt solution at 25°C, 93°C, or 176°C. The sea salt solution used in these tests was much more concentrated, 24.53 g/L NaCl, 5.20 g/L $MgCl_2$, 1.16 g/L $CaCl_2$, among other components, than the initial water chemistries at or above the repository host horizon. Furthermore, the specimen temperature was observed to drop significantly during wetting cycles, resulting in a significant cyclic loading component to the stress state. Although stress corrosion cracking was observed on specimens held at 93°C and 176°C, no cracking was observed on specimens exposed at about 25°C. In a second set of experiments, U-bend specimens were individually heated to 60°C, 70°C, 80°C, and 94°C in an environmental chamber held at a relative humidity of 95% and a temperature of 35°C. Significant temperature gradients existed along the length of the U-bends with the maximum temperature near the heated apex region and the minimum temperature along the specimen leg region. Steep relative humidity drops were observed near the specimen surfaces with the drop being most severe at the higher temperatures. The authors concluded that for stress corrosion cracking to occur, the exposure temperature must exceed about 50°C and the relative humidity must be above the level necessary for deliquescence of $MgCl_2$ (roughly 30% relative humidity). Overall, the use of significantly more concentrated test solutions (containing high magnesium, calcium, and chloride ion concentrations) than those expected in the repository as well as cyclic temperature/stress not expected in the repository environment indicate that the results of Mintz and Dunn (2009) are not appropriate for use in the emplacement drift rock bolt performance evaluations.

1.2.3 "Low-Temperature Stress Corrosion Cracking of Stainless Steels in the Atmosphere in the Presence of Chloride Deposits" (Prosek et al. 2009).

Prosek et al. (2009) evaluated the low-temperature atmospheric stress corrosion cracking of several stainless steels, including Stainless Steel Type 316L, in the presence of chloride deposits. The study evaluated the tendency for stress corrosion cracking on U-bend specimens exposed in atmospheric chambers as a function of the type of deposit ($CaCl_2$, $MgCl_2$, or NaCl), temperature (20°C, 30°C, and 40°C), and relative humidity (30%, 50%, and 70%). Prosek et al. (2009, Table 3) indicates that stress corrosion cracking occurred in Stainless Steel Type 316L with $MgCl_2$ and $CaCl_2$ deposits at temperatures down to 30°C.

Prosek et al. (2009) calculated the equilibrium chloride ion concentration present in the various salt deposits tested and determined the approximate range of relative humidity and chloride concentrations leading to stress corrosion cracking of Stainless Steel Type 316L at 20°C, 30°C, and 40°C. The calculated chloride concentrations needed were quite high, varying from greater than 12 molal at 40°C to greater than 14 molal at 20°C, with the critical relative humidity ranging from 12% to 40% for $CaCl_2$, and no stress corrosion cracking tendency for magnesium chloride over this temperature range (Prosek et al. 2009, Table 6). The calculated equilibrium chloride concentration for NaCl deposits, 5.2 molal at 50°C and 80% relative humidity (Prosek et al. 2009, Table 4), is well below the critical concentrations needed for stress corrosion cracking at this temperature and below, and is consistent with the lack of relevance of these results to the emplacement drift rock bolt assessment case. These results are in agreement with those of Mintz and Dunn (2009) and indicate that, in environments without significant concentrations of magnesium or calcium ions such as the repository exposure environment, stress corrosion cracking of Stainless Steel Type 316L is not expected at these temperatures.

1.2.4 "Initiation and Propagation of Stress Corrosion Cracking of Stainless Steel Canister for Concrete Cask Storage of Spent Nuclear Fuel" (Tani et al. 2009)

The authors investigated the stress corrosion cracking failure time of candidate canister materials (including Stainless Steel Type 316L) at 353ºK (80ºC), at a relative humidity of 35%, using a constant load test in a synthetic seawater solution containing NaCl, $MgCl_2$, and Na_2SO_4. As indicated by Mintz and Dunn (2009, Figure 15), at 35% relative humidity, only $MgCl_2$ is expected to deliquesce. Although the compositions of the solutions used are not readily apparent (five 10-µL drops were allowed to dry on the specimen surface and rewet leading to a chloride ion concentration greater than 10 g/m^2), it is reasonable to expect that the test solutions had higher magnesium chloride concentrations than would be expected in the repository. Specimens were stressed over a range of applied stresses from 0.25 YS to 1.75 YS, where YS is the yield stress. Stainless Steel Type 316L was found to be more resistant than Stainless Steel Type 304L and failed only at the highest applied stress (1.75 YS) after about 700 hours. The maximum time on test for Stainless Steel Type 316L at lower applied stresses was about 4,000 hours with no stress corrosion cracking observed. Consistent with the previous studies discussed, the results of Tani et al. (2009) indicate that in environments without significant concentrations of $MgCl_2$, like the environment expected in the repository, Stainless Steel Type 316L is not susceptible to stress corrosion cracking.

Tani et al. (2009) also performed crevice repassivation potential tests on Stainless Steel Type 316L in synthetic seawater because the authors assumed that the occurrence of crevice corrosion is necessary to initiate stress corrosion cracking on surfaces beneath sea salt particles. The authors concluded that crevice corrosion (and hence stress corrosion cracking initiation) was possible for this alloy in the concentrated electrolyte even at 283 K (10°C), although no incipient cracking was observed below 313 K (40°C). As discussed previously, the concentrated electrolyte used for these tests is not similar to the expected exposure conditions in the repository.

1.3 CONCLUSIONS

In summary, stress corrosion cracking and crevice corrosion of emplacement drift rock bolts, under more relevant exposure conditions, is considered in *Longevity Reevaluation of Repository Opening Steel Ground Support Components* (BSC 2008a, Section 6.6.3.4). The detailed design will consider applicable technical information and evaluate/test the ground support stainless steel components appropriately.

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.

BSC 2007. *Ground Control for Non-Emplacement Drifts for LA*. 800-K0C-SSD0-00400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071001.0042.

BSC 2008a. *Longevity Reevaluation of Repository Opening Steel Ground Support Components*. 800-K0C-SS00-01100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080527.0001.

BSC 2008b. *Input Parameters for Ground Support Design*. 800-K0C-SSD0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080905.0002.

BSC 2008c. *Preclosure Emplacement Drift Temperature Calculation for the 2.0 kW/m Thermal Load*. 800-KVC-VUE0-00700-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080110.0001.

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UNR (University of Nevada, Reno) 2009. *Corrosion Research on Rock Bolts and Steel Sets for Sub-surface Reinforcement of the Yucca Mountain Repository*. Task 19 YM Project, Document ID: TR-06-001. Copy of the UNR document is available at http:// hrc.nevada.edu/data/tda/

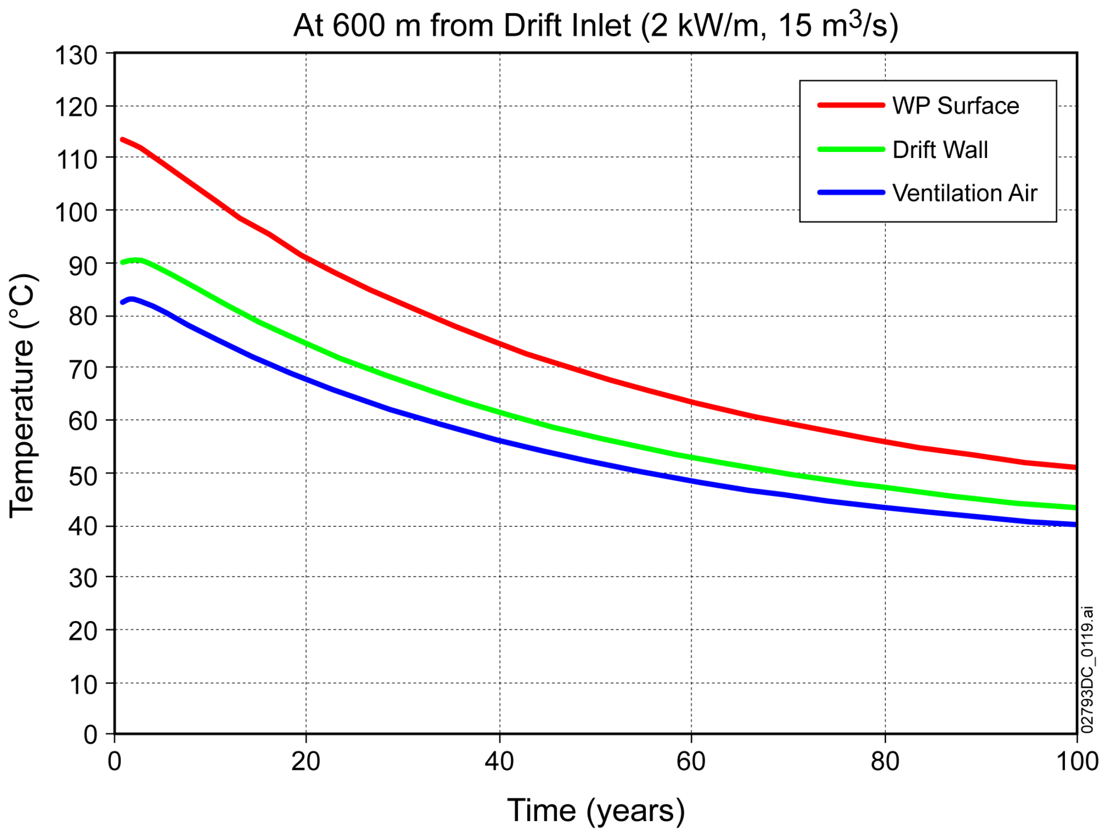

Figure 1. Temperatures at 600 m from Emplacement Drift Inlet

NOTE: WP = waste package.

Source: BSC 2008c, Figure 6.

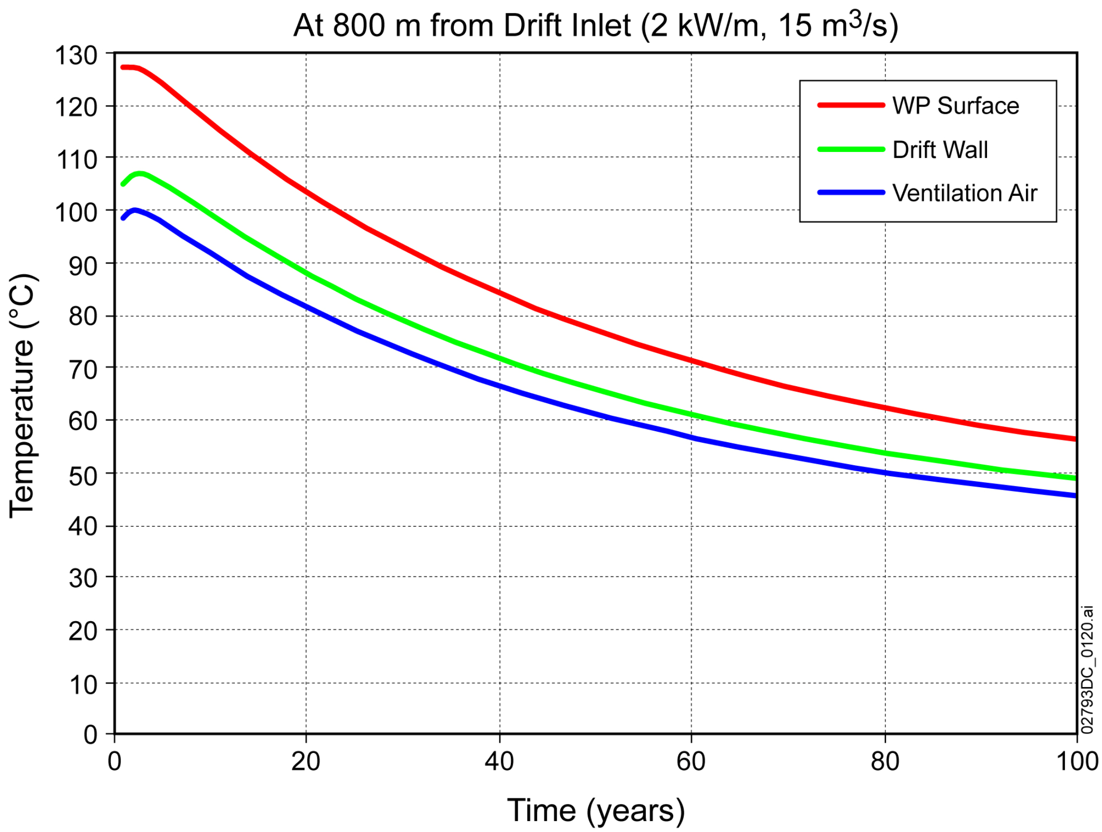

Figure 2. Temperatures at 800 m from Emplacement Drift Inlet

NOTE: WP = waste package.

Source: BSC 2008c, Figure 8.