**From:** Doug Gute [dgute@cnwra.swri.edu]
**Sent:** Wednesday, July 14, 2004 11:56 AM
**To:** Aladar Csontos; 'DDUNN@cnwra.swri.edu'; 'gcragno@cnwra.swri.edu'; Ken Chiang; Lietai Yang; Osvaldo Pensado; 'VJAIN@cnwra.swri.edu'; Xihua He; Yi-Ming Pan; Dennis Galvin; Tae Ahn
**Cc:** Asadul Chowdhury; Sitakanta Mohanty; Andy Campbell; 'Abou-Bakr Ibrahim'; Bret Leslie; 'Dan Rom'; Gregory Hatchett; Marissa Bailey; Mysore Nataraja; Richard Codell; Timothy Kobetz
**Subject:** RE: TBD-6 Agreements Path Forward
**Attachments:** TBD 6 Review Input Rev01 (Gute).wpd

All,

I am at a loss as to why there is not ample justification for the requested documents needed to complete the review for CLST.01.14. As noted in the attached file (dated 2/5/2004), Appendix C has not provided (i) a basis for the rockfall loads used in the analysis, (ii) sufficient documentation of the finite element modeling methodology used to assess the response of the drip shields to the assumed rockfall loads, and (iii) a reasonable explanation of how the results obtained from the analysis are used to justify their conclusions.

I would appreciate it if someone could explain to me how this information is not relevant to closing the agreement.

Doug

-----Original Message-----
From: Aladar Csontos [mailto:aac@nrc.gov]
Sent: Tuesday, July 13, 2004 7:47 PM
To: DDUNN@cnwra.swri.edu; DGUTE@cnwra.swri.edu; gcragno@cnwra.swri.edu; KCHIANG@cnwra.swri.edu; LTYANG@cnwra.swri.edu; OPENSADO@cnwra.swri.edu; VJAIN@cnwra.swri.edu; xhe@cnwra.swri.edu; YPAN@cnwra.swri.edu; Dennis Galvin; Tae Ahn
Cc: ACHOWDHURY@cnwra.swri.edu; SMOHANTY@cnwra.swri.edu; Andy Campbell; Abou-Bakr Ibrahim; Bret Leslie; Dan Rom; Gregory Hatchett; Marissa Bailey; Mysore Nataraja; Richard Codell; Timothy Kobetz
Subject: Re: TBD-6 Agreements Path Forward

First, we never said that the appendices do not provide a sufficient basis for closing agreements. Greg has a high threshold for justifying the examination of supporting documents, however, it's with good reason.

For this case, there are two documents that we need to examine that are the basis for Appendix C, D, F, H, and K to complete our examination of CLST 1.14 and 1.15 which are both medium risk. Even though these are medium risk, the results directly feed into CLST 2.08 which is of high risk significance. We need to first clarify the 1.14 and 1.15 issues to appropriately work on 2.08. Furthermore, Yiming Pan from the Center is to arrive next week for a 2-week staff exchange to conduct an analysis specifically looking at CLST 1.14 and 1.15. Hence, to facilitate his staff exchange and the possible resolution of other similar agreements, the 2 AMRs that Dennis asked for are requested.

To quell Greg's fears, the purpose of the SHORT 1-2 day examination is to focus on specific sections to ensure tractability to the TBD6 appendices and relate similar technical arguments across medium and high agreements. The latter point is of concern to us since DOE has had conflicting technical arguments to close separte agreements in the past. For example, TBD8 says that seepage waters will be concentrated to precipitate out colloids that could accelerate radionuclide transport, however, their NWTRB presentations argued that the waters will be dilute and not cause corrosion. These points are obviously opposed to each other and are used to support their arguments against colloid-aided transport and corrosion resistance. We are asking which one is it?

If you need any additional information, please call or see me.

Al

>>> Dennis Galvin 07/13/04 18:32 PM >>>
CLST and Associates

The meeting on TBD 6 agreements was successful. Teams have been identified to read the TBD 6 Appendices and perform an initial assessment by 7/22/04. At that point we can plan a preliminary path forward on the agreements and schedule. I have updated the information in the table (See Attached) and have provided some additional information.

There have been two changes since the meeting:

1. Appendix Q (ML041940417) Waste Package: Fabrication, Aging, and Phase Stability Effects, has arrived. It covers CLST 2.04 (High) and 2.05 (High) and GEN 1.01 Comment 7. Since the CLST agreements are high and the Appendix is fairly involved (30 pages), it may displace the initial review of medium or low agreements on the Table. For the initial review I have identified Al Csontos, Yi-Ming Pan, Darrell Dunn, and Dick Codell.

2. I ran into Greg after the meeting and he believes we need a better justification for the references for Appendix C, CLST 1.14 (Medium) and Appendix D, CLST 1.15 (Medium). I will prepare an initial argument tomorrow, but will probably need support from Doug Gute, Al Csontos, Tae Ahn, and Darrell Dunn. The current position of the CLST team is that these appendices do not provide a sufficient bases for closing these agreements.

Thanks,

Dennis Galvin
Acting CLST Team Lead

**Hearing Identifier:** HLW_YuccaMountain_Hold_EX
**Email Number:** 1676

**Mail Envelope Properties** (000901c469bb$1e2f3e70$c0c8a281)

**Subject:** RE: TBD-6 Agreements Path Forward
**Sent Date:** 7/14/2004 11:56:25 AM
**Received Date:** 7/14/2004 11:50:43 AM
**From:** Doug Gute

**Created By:** dgute@cnwra.swri.edu

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**Post Office:** GALIT

| **Files** | **Size** | **Date & Time** |
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| MESSAGE | 4421 | 7/14/2004 11:50:43 AM |
| TBD 6 Review Input Rev01 (Gute).wpd | 25565 | |

**Options**

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|---|---|
| **Priority:** | Standard |
| **Return Notification:** | No |
| **Reply Requested:** | No |
| **Sensitivity:** | Normal |
| **Expiration Date:** | |
| **Recipients Received:** | |

**CLST.1.14 (Appendix C)**

**Although the potential occurrence of drift degradation is acknowledged within TBD 6, the effects of increased EBS component temperatures and mechanical loading conditions consistent with the drift degradation scenario were not adequately addressed in the response to DOE/NRC KTI Agreement CLST.1.14 (Bechtel SAIC Company, LLC; 2003a, Appendix C).**

DOE Approach:

Table C-1 (Bechtel SAIC Company, LLC; 2003a, Appendix C) indicates that the maximum accumulated rock rubble load considered by DOE in their assessment of the drip shield was consistent with “backfill heights” of 0.9 and 1.1 m [3.0 and 3.6 ft]. To consider the potential effects of decreasing material thickness caused by corrosion, the DOE also performed additional analyses of the drip shield subjected to these rock rubble loads with the thickness of the exposed drip shield component surfaces reduced by 1.0 and 1.5 mm [0.04 and 0.06 in] [see Table C-2 (Bechtel SAIC Company, LLC; 2003a, Appendix C)]. Moreover, as stated in Section C.4, “To assess the potential for SCC initiation at various locations, the calculated stresses indicated in Tables C-1 and C-2 are compared with the SCC initiation threshold stresses (50 percent of the at-temperature yield strength) for either room temperature or 150 °C. (Corresponding yield strength values are 362.5 MPa at room temperature and 210.4 MPa at 150 °C for Titanium Grade 7).”

Staff Position and Request Justification:

First, the accumulated rockfall rubble loads that were used to assess the potential for stress corrosion cracking of the drip shield have not been adequately described. Specifically, Table C-1 (Bechtel SAIC Company, LLC; 2003a, Appendix C) simply indicates that the calculated drip shield stresses correspond to “backfill heights” of 0.9 and 1.1 m [3.0 and 3.6 ft]. This description of the accumulated rockfall rubble loads is ambiguous in that it does not clearly define either the net loads or pressure distributions that were applied to the drip shield. In addition, it appears that the net loads or pressure distributions acting on the drip shield caused by “backfill heights” of 0.9 and 1.1 m [3.0 and 3.6 ft] are significantly smaller than those loads derived in the Drift Degradation Analysis and Model Report (AMR) (OCRWM M&O, 2003, Attachment XVI). As a result, additional documentation that (i) provides more definitive descriptions of the drip shield dead-weight loads that have been evaluated by DOE and (ii) demonstrates the consistency of these loads with those presented in OCRWM M&O (2003) is needed to complete the review. Based on the references cited in support of the response to DOE/NRC KTI Agreement CLST.1.14 (Bechtel SAIC Company, LLC; 2003a, Appendix C), the requested information should be documented in Bechtel SAIC Company, LLC (2003b,c). Furthermore, the potential drip shield residual stresses created by dynamic rock block impacts and seismic excitation (including the presence of rockfall rubble) and their influence on potential SCC were not discussed. This information should be documented in Bechtel SAIC Company, LLC (2003b,c,d,e).

Second, insufficient information regarding the finite element models used to assess the behavior of the drip shield when subjected to accumulated rockfall rubble loads was provided in the response to DOE/NRC KTI Agreement CLST.1.14 (Bechtel SAIC

Company, LLC; 2003a, Appendix C). The following information is needed to evaluate the adequacy of these models to estimate the stresses that may be incurred by the drip shield under accumulated rockfall rubble loads: (i) detailed drip shield design dimensions, (ii) complete bill of materials, (iii) description of the load and displacement boundary conditions, (iv) demonstration of the adequacy of the finite element mesh discretization, (v) drip shield material constitutive models, and (vi) justification for the assumed material temperatures given the expected insulating effects of the accumulated rockfall rubble. In addition, a summary of the results derived from the models {including the first principal and hydrostatic stresses along with von Mises and/or stress intensities [as defined by the ASME International Boiler & Pressure Vessel Code (2001)]} are also required. Based on the references cited in support of the response to DOE/NRC KTI Agreement CLST.1.14 (Bechtel SAIC Company, LLC; 2003a, Appendix C), the requested information should be documented in Bechtel SAIC Company, LLC (2003b,c,e,f).

Third, the calculated stresses presented in Tables C-1 and C-2 are not sufficient to calculate the potential for SCC or plastic collapse as it is not clear whether they are the first principal stresses or simply individual components of a multiaxial stress state. It needs to be recognized that the locations where cracking is likely to be initiated correspond to the locations where the first principal stress is tensile. Moreover, the orientation of these potential cracks is likely to be governed by the orientation of these tensile first principal stresses. Specifically, the fracture surface normal is typically parallel to the direction of the tensile first principal stress. As discussed in more detail in the response to DOE/NRC KTI Agreement RDTME.3.18 (Bechtel SAIC Company, LLC; 2003a, Appendix F), the propagation of SCC cracks is not necessarily controlled solely by the magnitude of the first principal stress. For ductile materials the potential for mixed mode failure is increased by the presence of compressive principal stresses (which are perpendicular to the tensile first principal stress) because they contribute to the potential for slip dislocations, oftentimes referred to as shear-lips, to occur at the leading edge of the crack tip.

Required References:

Bechtel SAIC Company, LLC. Drip Shield Structural Response to Rock Fall. 000-00C-TED0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: ENG.20030327.0001. 2003b.

Bechtel SAIC Company, LLC. Drip Shield Statically Loaded by Backfill and Loose Rock Mass. 000-00C-TED0-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: ENG.20030224.0004. 2003c.

Bechtel SAIC Company, LLC. Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material. ANL-EBS-MD-000005 REV 01 ICN 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: DOC.20030717.0001. 2003d.

Bechtel SAIC Company, LLC. Seismic Consequence Abstraction. MDL-WIS-PA-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: DOC.20030818.0006. 2003e.

Bechtel SAIC Company, LLC. Repository/PA IED Interlocking Drip Shield and

Emplacement Pallet. 800-IEDWIS0-00401-000-00Ba. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: MOL.20030929.0051. 2003f.

References:

ASME International. *ASME International Boiler and Pressure Vessel Code*. New York City, New York: ASME International. 2001.

Bechtel SAIC Company, LLC. "Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion." Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003a.

Fedors, R.W., G.R. Adams, C. Manepally, and S.T. Green. "Thermal Conductivity, Edge Cooling, and Drift Degradation - Abstracted Model Sensitivity Analyses for Yucca Mountain." San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 2003.

OCRWM M&O. "Drift Degradation Analysis." ANL-EBS-MD-000027 REV 02. North Las Vegas, Nevada: Office of Civilian Radioactive Waste Management. 2003.

**RDTME.3.18 (Appendix F)**

**It was not clear in the response to DOE/NRC KTI Agreement RDTME.3.18 (Bechtel SAIC Company, LLC; 2003a, Appendix F) whether the stress measure that will be used as the equivalent uniaxial stress measure for assessing the susceptibility of the various EBS materials to stress corrosion cracking when subjected to a multiaxial stress state is the von Mises stress, first principal stress, or stress intensity [as defined by the ASME International Boiler and Pressure Vessel Code (2001)].**

DOE Approach:

The DOE response to DOE/NRC KTI Agreement RDTME.3.18 (Bechtel SAIC Company, LLC; 2003a, Appendix F) did not specifically identify what stress measure would be used as the equivalent uniaxial stress to assess the potential for SCC when a multiaxial stress state exists.

Only one component of stress (calculated using the finite element method) appeared to be used for assessing the potential of SCC of the waste package and drip shield in Technical Basis Document No. 6 (Bechtel SAIC Company, LLC; 2003a, Appendices B.3 and C.4),.

Specifically, with regard to the waste package, it was stated in Technical Basis Document No. 6 (Bechtel SAIC Company, LLC; 2003a, Appendix B.3) that "… the hoop stress, which promotes radially oriented crack growth, is the dominant component of stress in the waste package outer shell closure lid weld regions and, therefore, only the hoop stress profiles were considered in the integrated waste package degradation model …." It was not clear whether this conclusion is limited to the as-welded condition or is also true after stress mitigation by way of laser peening or plasticity burnishing. In either case, it does not appear that DOE is using any equivalent uniaxial stress measures to assess the potential for SCC of the waste package.

Similarly, based on the information provided in Tables C-1 and C-2 (Bechtel SAIC Company, LLC; 2003a, Appendix C), it appears that DOE is simply using the maximum calculated normal stress to assess the potential for SCC of the drip shield.

Staff Position and Request Justification:

There are basically two methods for using the finite element method to assess the potential for SCC. The first is to explicitly include the presence of a defect or crack in the finite element model. Using this approach allows the model to explicitly calculate the stresses generated at the crack tip when subjected to the design basis loads and, in some cases, calculate the stress intensity directly from the results of the analysis (i.e., from a fracture mechanics perspective). The second approach, which appears to be the method of choice of the DOE, is to model the drip shield and waste package without any defects and then assess the potential for SCC based solely on the calculated stresses. This may, or may not, be adequate, depending on the magnitudes and nature of the principal stresses (i.e., tensile or compressive).

As noted by Felbeck and Atkins (1996, p. 337)

"A criterion for fracture based on the attainment of some characteristic maximum tensile stress has been used with a certain degree of success, particularly in very brittle solids. It should be clear, however, that quantitative criteria for fracture based merely on some maximum tensile stress (or combination of stresses) address only part of the necessary and sufficient conditions for fracture. No consideration is given to the energetics of crack propagation. Although maximum stress theories may be intuitively appealing and *may* work reasonably well under the circumstances, they should not be expected to apply to large structures containing critical flaws."

In addition, from Felbeck and Atkins (1996, p. 311),

"The sort of fracture produced in a solid depends very much on conditions. …. The state of stress is important, and although in-service situations may be complex, the mean hydrostatic stress component [i.e., $\sigma_m = (\sigma_1 + \sigma_1 + \sigma_1)/3$], sometimes called *triaxiality*, is a good indicator to the type of fracture obtained. *Tensile* values for $\sigma_m$ encourages brittle fracture. …. The effects of residual stresses (e.g., resulting from manufacturing processes or nonuniform heating and cooling) and prestrain on fracture can also be thought of in terms of their influence on promoting triaxiality."

Based on the foregoing observations, DOE has not adequately justified using a single component of stress to assess the potential for SCC occurring in the Engineered Barrier System component materials. Note that, based on the information provided in Tables C-1 and C-2 (Bechtel SAIC Company, LLC; 2003a, Appendix C) and the response to CLST.1.13 (Bechtel SAIC Company, LLC; 2003a, Appendix B), it appears that DOE is simply using the maximum calculated normal stress to assess the potential for SCC. It needs to be emphasized that an assessment of the potential for SCC or plastic collapse cannot be accomplished without appropriate consideration and interpretation of all of the stress components acting at a given location. Moreover, it needs to be recognized that the components of a multiaxial stress state calculated within a solid body is dependent on the orientation of the coordinate system used to formulate the analysis. To circumvent this limitation principal stresses and other stress invariants {e.g., von Mises stress, first principal stress, or stress intensity [as defined by the ASME International Boiler and Pressure Vessel Code (2001)]} are used to assess the response of a material to the applied loading conditions. Note that stress invariants are not affected by the arbitrary choice of the coordinate system used to formulate the analysis, which is the basis for referring to these stress measures as invariant. As a result, the statement that "… the use of all stress components to determine principal stress for comparison against allowable stresses (from a uniaxial test) may be conservative, because it appears that initiation and failure is a function of the maximum stress only in a specific direction." (Bechtel SAIC Company, LLC; 2003a, Appendix F) must be justified. This justification may be provided in Bechtel SAIC Company, LLC (2003b,c).

The locations where SCC is likely to be initiated correspond to the locations where the first principal stress is tensile, but the propagation of these SCC cracks is not necessarily controlled solely by the magnitude of the first principal stress. As was pointed out earlier, the applicability of using simple linear elastic fracture mechanics (LEFM) theory to assess the potential initiation and propagation of a crack is also dependent on the triaxiality (i.e., tensile or compressive hydrostatic stress) of the stress state and the ductility of the material. For ductile materials, such as the Titanium Grade 7 drip shield plate and Alloy 22 waste package outer shell, the potential for mixed mode failure is increased by having a compressive hydrostatic stress. That is to say, if the first principal stress is tensile and the hydrostatic stress is compressive, the compressive principal stresses (which are perpendicular to the tensile first principal stress) contribute to the potential for slip dislocations, oftentimes referred to as shear-lips, to manifest at the leading edge of the crack tip. Therefore, the size of the plastic zone at the crack tip is larger under these conditions than it would be when subjected to a simple uniaxial stress state. As a result, the potential occurrence of SCC cannot be based solely on an assessment of the first principal stress. Based on the references cited in support of the responses to DOE/NRC KTI Agreements CLST.1.14 and RDTME.3.18 (Bechtel SAIC Company, LLC; 2003a, Appendices C and F), these issues should be addressed in Bechtel SAIC Company, LLC (2003c).

The staff recognizes that after stress mitigation the residual waste package closure weld stresses are predominantly hydrostatic in nature (i.e., $\sigma_1 \approx \sigma_2 \approx \sigma_3$, where $\sigma_i$ are the principal stresses) and compressive. As a result, the occurrence of SCC is unlikely in this region of the waste package. It still needs to be demonstrated, however, that this stress state is not adversely affected by various mechanical loading scenarios after being placed into service (e.g., drops during emplacement, seismic and/or rockfall loads). Based on the references cited in support of the response to DOE/NRC KTI Agreement CLST.1.14 (Bechtel SAIC Company, LLC; 2003a, Appendix C), the requested information should be documented in Bechtel SAIC Company, LLC (2003c,d). In addition, the drip shield will potentially be subjected to significant rockfall dead loads. Based on the foregoing, a more thorough and rigorous assessment of the stresses incurred by the drip shield when subjected to static rockfall rubble loads is required to assess the potential occurrence of SCC.

Required References:

Bechtel SAIC Company, LLC. WAPDEG Analysis of Waste Package and Drip Shield Degradation. ANL-EBS-PA-000001 REV 01D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20031009.0225. 2003b.

Bechtel SAIC Company, LLC. Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material. ANL-EBS-MD-000005 REV 01 ICN 00. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC:

DOC.20030717.0001. 2003c.

Bechtel SAIC Company, LLC. Structural Calculations of Waste Package Exposed to Vibratory Ground Motion.000-00C-EBS0-00300-000-00B. Las Vegas, Nevada: Bechtel SAIC Company, LLC. ACC: ENG.20030520.0003. 2003d.

References:

ASME International. *ASME International Boiler and Pressure Vessel Code*. New York City, New York: ASME International. 2001.

Bechtel SAIC Company, LLC. "Technical Basis Document No. 6: Waste Package and Drip Shield Corrosion." Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2003a.

Felbeck, D.K. and A.G. Atkins. Strength and Fracture of Engineering Solids, 2nd edition. Upper Saddle River, New Jersey: Prentice Hall, Inc. 1996.