

December 21, 2001

Dr. Stephan Brocoum, Assistant Manager  
Office of Licensing and Regulatory Compliance  
U.S. Department of Energy  
Yucca Mountain Site Characterization Office  
P.O. Box 364629  
North Las Vegas, NV 89036-8629

SUBJECT: CONTAINER LIFE AND SOURCE TERM KEY TECHNICAL ISSUE  
AGREEMENTS

Dear Dr. Brocoum:

During a Technical Exchange and Management Meeting held on September 12-13, 2000, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) reached agreement on issues pertaining to the Container Life and Source Term (CLST) Key Technical Issue (KTI). By letters dated February 2, March 2, and March 30, 2001, DOE provided documents pertaining to NRC/DOE agreements, including a number of documents pertaining to CLST agreements. The NRC staff has reviewed these documents as they relate to the CLST KTI and the results of the staff's review are enclosed.

If you have any questions regarding this letter, please contact Mr. James Andersen of my staff. He can be reached at (301) 415-5717.

Sincerely,

/RA/

C. William Reamer, Chief  
High-Level Waste Branch  
Division of Waste Management  
Office of Nuclear Material Safety  
and Safeguards

Enclosure: As stated  
cc: See attached distribution list

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Letter to S. Brocoum from C.W. Reamer dated December 21, 2001

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D. Eddy, Jr. Colorado River Indian Tribes  
J. Leeds, Las Vegas Indian Center  
W. Briggs, Ross, Dixon & Bell

**NRC Review of DOE Documents Pertaining to  
Container Life and Source Term Key Technical Issue Agreements**

The U.S. Nuclear Regulatory Commission's (NRC's) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a license application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during the licensing proceedings. Also, and just as importantly, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after it's licensing review. Issues are resolved by the NRC staff during pre-licensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This enclosure addresses several NRC/DOE agreements made during the Container Life and Source Term (CLST) Technical Exchange and Management Meeting on September 12-13, 2000, (see NRC letter dated October 4, 2000, which summarized the meeting). By letters dated February 2, March 2, and March 30, 2001, DOE submitted a number of documents to address some of the CLST agreements. The documents submitted and associated Key Technical Issue (KTI) agreements are discussed below:

**1) Container Life and Source Term Agreement 2.07**

Wording of the Agreement: Provide documentation for the fabrication process, controls, and implementation of the phases which affect the TSPA [total system performance assessment] model assumptions for the waste package (e.g., filler metal, composition range). DOE stated that updates of the documentation on the fabrication processes and controls (TDR-EBS-ND-000003, Waste Package Operations Fabrication Process Report and TDP-EBS-ND-000005, Waste Package Operations FY-00 Closure Weld Technical Guidelines Document) will be available to the NRC in January 2001.

NRC Review: DOE provided, and the NRC reviewed the following documents pertaining to this agreement: Waste Package Operations Fabrication Process Report (TDR-EBS-ND-000003, Rev 01, ICN 00), Waste Package FY-00 Closure Methods Report (TDP-EBS-ND-000005, Rev 00, ICN 00), and Waste Package Operations FY01 Closure Weld Technical Guidelines Document TER-EBS-ND-000001, Rev 00, ICN 00). These documents indicate that the fabrication methods and materials used in the construction and closure of the type 316 NG inner disposal container and the Alloy 22 outer disposal container will be consistent with the guidelines of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) code Division 1 (nuclear power plant components). The subject documents do not provide documentation that supports the DOE assumption that allowable variations in the composition of the waste package materials and filler metals used in the fabrication and closure welds will not affect the assumptions used in the TSPA model.

In addition, the phase stability of Alloy 22 may affect postclosure waste package performance. Precipitation of secondary phases, which are known to occur during welding and exposure to

Enclosure

elevated temperatures, reduce the mechanical ductility and the localized corrosion resistance. The kinetics of secondary phase precipitation may be influenced by compositional variations within the allowable specifications for the plate and filler materials. DOE needs to provide documentation that addresses the effect of compositional variation on the phase stability of alloy 22, considering the complete sequence of fabrication processes used in the construction, closure welding, and closure weld stress mitigation.

Additional Information Needed:

- 1) Provide documentation that supports the DOE assumption that allowable variations in the composition of the waste package materials and filler metals used in the fabrication and closure welds will not affect the assumptions used in the TSPA model.
- 2) Provide documentation that addresses the effect of compositional variation on the phase stability of alloy 22, considering the complete sequence of fabrication processes used in the construction, closure welding, and closure weld stress mitigation.
- 3) Total System Performance Assessment and Integration (TSPAI) Agreement 2.02 (Item 35) stated that DOE would address manufacturing defects associated with the drip shield during the resolution of this agreement. This issue was not addressed in the subject documents and needs to be addressed. Provide the documentation source and schedule for addressing this issue.

Status of Agreement: CLST Agreement 2.07 needs additional information to support a potential licensing review.

**2) Container Life and Source Term Agreement 3.01  
Container Life and Source Term Agreement 4.01**

Wording of the Agreement: In the revision to the "Summary of In-Package Chemistry for Waste Forms," AMR, the NRC needs to know whether and how initial failures are included in the in-package chemistry modeling, taking into account the multiple barrier analysis. DOE stated that the Summary of In-Package Chemistry for Waste Forms ANL-EBS-MD-000050 deals with time since waste package breach, instead of time of waste package failures. The model is appropriate for the current implementation in the TSPA scenarios because breaches do not occur until after aqueous films may be sustained. Multiple barrier analyses are discussed in the TSPAI IRSR, and therefore will be discussed in the TSPA KTI Technical Exchange.

NRC Review: During the August 6-10, 2001, TSPAI Technical Exchange and Management Meeting, NRC and DOE discussed this issue. As a result of those discussions, NRC and DOE reached two separate agreements (TSPAI Agreements 3.08 and 3.14). Therefore, these agreements have been superceded and can be listed as complete.

Additional Information Needed: None

Status of Agreement: CLST Agreements 3.01 and 4.01 have been superceded by TSPAI agreements 3.08 and 3.14. Therefore CLST Agreements 3.01 and 4.01 can be listed as "Complete."

### **3) Container Life and Source Term Agreement 3.02 Container Life and Source Term Agreement 4.02**

Wording of the Agreement: In the revision to the “Summary of In-Package Chemistry for Waste Forms,” AMR, address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rates of components. DOE stated that these specific questions are currently being addressed in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and related AMRs and calculations. To be available in January 2001.

NRC Review: The NRC reviewed In-Package Chemistry for Waste Forms (ANL-EBS-MD-000056, Rev 00, ICN 00) and determined that the document does not satisfy the intent of the agreement. The NRC staff notes that the information needed for this agreement is also needed to the DOE response to CLST Agreement 3.05, Evolution of the Near-Field Environment (ENFE) Agreement 3.04, and TSPAI 3.14. DOE needs to provide information as described below.

DOE did not provide sufficient technical basis for the corrosion rates and the likely corrosion mechanisms of internal waste package components. For example, DOE has assumed that Cr(VI) species are the major corrosion products from stainless steel. However, the corrosion potential is likely to be well below the potential for transpassive dissolution of Cr containing alloys such as Alloy 22 and type 316 stainless steel when the Alloy 22 outer container is corroded under passive dissolution conditions. Therefore, Cr(III) species are the most likely corrosion products. The pronounced increase in the corrosion potential implicitly assumed by the DOE to occur inside the waste package as compared to that prevailing in the outer surface of the waste package should be explained and verified experimentally.

DOE assumes that the glass/spent nuclear fuel is dissolved at its maximum rate which is bounding. However, this high rate of dissolution results in a high pH which could neutralize the effect of the protons produced during stainless steel corrosion. In addition, DOE has assumed in the analysis that the waste package void volume of approximately 4,500 liters is completely filled with water. This assumption is questionable and lacks scientific justification because it would take approximately 30,000 years to fill a waste package at the assumed influx rate of 0.15 liters/year. Even at the maximum influx rate, assumed to be 15 liters/year, the conditions inside the waste package could be significantly different than those in which it is assumed that 4,500 liters water are already present inside the waste package. DOE should provide a better technical justification and appropriate ranges for the model abstraction parameters for each internal component of the waste package.

Sensitivity studies focused on the dissolution rates of various waste package components are incomplete. Since the issuance of the report, DOE has conducted additional sensitivity studies cited in the in-package chemistry section of the Supplemental Science and Performance Analyses (SSPA) report. The SSPA uses a significantly low glass dissolution rate as noted in Comment #100 in the Range of Thermal Operating Temperature technical exchange. Hence, DOE should provide the results of sensitivity analysis using current values of the parameters included in the model abstractions.

DOE has not provided an adequate technical basis for the in-package water chemistry since it neglected the formation of locally aggressive environments in crevices and tight spaces inside

the waste package that can enhance the degradation of waste forms and the solubility of radionuclides. Localized corrosion and corrosion products can affect the mechanisms and enhance the dissolution rates for both glass and spent nuclear fuel.

DOE has used EQ3/6 to predict the formation of secondary phases resulting from high level waste glass dissolution but the formation of these phases should be substantiated through experimental studies. Validation of this assumption is important because it will affect the groundwater composition and the in-package water chemistry.

The studies presented by the DOE to date ignores the role of halides in the dissolution process. Soluble and aggressive species such as  $\text{FeCl}_3$  formed in the crevices can significantly decrease the pH of the water inside the waste package.

Additional Information Needed:

- 1) Provide the technical basis for the corrosion rates and the likely corrosion mechanisms of internal waste package components.
- 2) Provide the technical justification and appropriate ranges for the model abstraction parameters for each internal component of the waste package.
- 3) Provide the results of sensitivity analysis using current values of the parameters included in the model abstractions.
- 4) Provide the technical basis for the in-package water chemistry, taking into account the formation of locally aggressive environments in crevices and tight spaces inside the waste package that can enhance the degradation of waste forms and the solubility of radionuclides.
- 5) Provide documentation which validates the use of EQ3/6 to predict the formation of secondary phases resulting from high level waste glass dissolution.
- 6) Provide the technical bases for ignoring the role of halides in the dissolution process.

Status of Agreement: CLST Agreements 3.02 and 4.02 need additional information to support a potential licensing review.

**4) Container Life and Source Term Agreement 3.03**  
**Container Life and Source Term Agreement 4.03**

Wording of the Agreement: Provide a more detailed calculation on the in-package chemistry effects of radiolysis. DOE stated that the calculations recently performed as discussed at the 9/12/00 Technical Exchange and preceding teleconferences are being documented. These calculations will be referenced and justified in the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 and will be available in January 2001.

NRC Review: The NRC reviewed In-Package Chemistry for Waste Forms (ANL-EBS-MD-000056, Rev 00, ICN 00) and determined that in the DOE's analysis, the effect of radiolysis on cladding corrosion is excluded based on the following arguments.

Extremely high concentrations of nitric acid (14.2 mol/L) are required to promote the corrosion of zirconium alloy cladding. As the dose rate after the waste package breaching time is low, the build up of a high concentration of nitric acid is not likely. At a dose rate of 50 R/hr, it takes  $8.29 \times 10^4$  years to reach  $2C_0R(1-1/e) = 1.26C_0R$  in a closed system, where  $C_0$  is the concentration of nitrogen in air,  $R$  is the ratio of the air volume to water volume inside the waste package. As the waste package is not closed after the breach, some of the nitric oxide may escape, thus producing less nitric acid. Furthermore, the water would constantly drip onto the cladding surface and flush away the  $\text{HNO}_3$  absorbed in the water film during this long period of time.

Although the co-existence of nitric acid and halides can promote corrosion because of the formation of metal-halide complex, the conditions for the two species to accumulate at the same time are unlikely to occur. The accumulation of the nitric acid only requires small amounts of water to enter the waste package. Any excessive amount of water influx would dilute the nitric acid. However, the accumulation of halides requires large amount of water, as the source of the halides, entering the waste package.

The first argument is acceptable. However, the calculation for the nitric acid concentration is based on a dose rate of 50 R/hr. This value is not documented in DOE's report. Furthermore, the analysis ignores the effect of  $\alpha$  particles that may escape from cladding-perforated fuels. As  $\alpha$  emitters have much longer lives than the  $\gamma$  emitters,  $\alpha$  particles may have a stronger effect than  $\gamma$ , DOE should provide additional information on the dose rate calculation as a function time for typical fuels in the waste package. This information may also be useful for the assessment of the radiolytic effect on the dissolution of waste forms.

Additional Information Needed:

1) Provide additional information on the dose rate calculation as a function of time for typical fuels in the waste package and the technical basis for 50 R/hr dose rate.

Status of Agreement: CLST Agreements 3.03 and 4.03 need additional information to support a potential licensing review.

**5) Container Life and Source Term Agreement 3.04  
Container Life and Source Term Agreement 4.04**

Wording of the Agreement: Need consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of engineered materials on the chemistry of water used for input to in-package abstractions. DOE stated that the revision of the Summary of In-Package Chemistry for Waste Forms AMR, ANL-EBS-MD-000050 will discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR. The revision will be available in January 2001.

NRC Review: The NRC reviewed In-Package Chemistry for Waste Forms (ANL-EBS-MD-000056, Rev 00, ICN 00) and determined that the document does not satisfy the agreement. DOE needs to be consistent between abstractions for incoming water and sensitivity studies conducted for in-package calculations, in particular, taking into account the interaction of

engineered materials on the chemistry of water used for input to in-package abstractions. The subject report does not discuss the applicability of abstractions for incoming water, taking into account the revised Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier AMR.

Additional Information Needed:

1) Provide documentation which shows consistency between abstractions for incoming water and sensitivity studies conducted for in-package calculations.

Status of Agreement: CLST Agreements 3.04 and 4.04 need additional information to support a potential licensing review.

**6) Container Life and Source Term Agreement 3.06**  
**Container Life and Source Term Agreement 4.06**

Wording of the Agreement: Provide additional technical basis for the failure rate and how the rate is affected by localized corrosion. DOE stated that the technical basis for local corrosion conditions will be added to by additional discussion of local chemistry in the Summary of In-package Chemistry for Waste Forms revision ANL-EBS-MD-000050 which will be available in January 2001. Current Clad Degradation Summary Abstraction AMR Section 6.3, ANL-WIS-MD-000007 and Clad Degradation - Local Corrosion of Zirconium and its Alloys Under Repository Conditions AMR, ANL-EBS-MD-000012 contain the overall technical basis.

NRC Review: DOE provided, and the NRC reviewed In-Package Chemistry for Waste Forms (ANL-EBS-MD-000056, Rev 00, ICN 00) and determined that the document does not satisfy this agreement (see also CLST Agreement 3.02). Per this agreement, NRC also reviewed Clad Degradation - Summary and Abstraction (ANL-WIS-MD-000007, Rev 00, ICN 01) and Clad Degradation - Local Corrosion of Zirconium and its Alloys (ANL-EBS-MD-000012, Rev 00, ICN 00) and determined that both documents do not contain a complete description of the necessary technical basis. DOE should provide additional information regarding the cladding failure rate and how this rate is affected by localized corrosion. The specific information needed is described in more detail below.

DOE has not provided in the In-Package Chemistry for Waste Forms (ANL-EBS-MD-000056, Rev 00, ICN 00) sufficient technical basis to define the chemical composition of the in-package water and its evolution with time. The information needed is related to the concentration of anionic species such as chloride and fluoride that can promote localized corrosion of Zircaloy cladding and other species that may inhibit the initiation of localized corrosion such as nitrate. Additional information needed includes the evolution of pH because the concentration of potential oxidizing species such as  $\text{Fe}^{3+}$  cations, produced as a result of aqueous corrosion of internal waste package structural components, is pH dependent. A better evaluation of the spatial heterogeneity inside the waste packages (per Agreement GEN 1.01 (Issue 126)) and the redox conditions is also needed because DOE should demonstrate that sufficiently high corrosion potentials cannot be reached to promote localized corrosion regardless of the presence of  $\text{Fe}^{3+}$  cations.

Localized corrosion in the form of pitting promoted by chloride, although a possible failure process, is excluded by the DOE by assuming that (i) the chloride concentration is lower than the minimum concentration required for pit initiation; (ii) the concentrations of inhibiting anions such as nitrate, sulfate, and bicarbonate are sufficient to overcome the detrimental effect of chloride; and (iii) the concentration of dissolved  $\text{Fe}^{3+}$  ions, considered to be the single species that may increase the corrosion potential of the cladding above the pitting potential, is assumed to be insufficient for the range of expected pH of the in-package water. Instead, DOE has proposed in Clad Degradation - Summary and Abstraction (ANL-WIS-MD-000007, Rev 00, ICN 01) accelerated corrosion by fluoride ions as the most plausible degradation process through a chemical reaction controlled by the volume of water entering the waste package in a flow-through scenario, the flow rate, and the concentration of fluoride in the water. However, the chloride concentration inside breached waste packages has not been properly bounded in the DOE analyses, and the presence of  $\text{Fe}^{3+}$  ions cannot be considered an absolute requirement because corrosion potentials higher than the pitting potential can be attained in the presence of other oxidizing species, including radiolytic products such as  $\text{H}_2\text{O}_2$ . Information is needed to support DOE arguments.

A detailed discussion, based mostly on data on commercial purity zirconium relevant to chemical processes and industry applications, has been provided in Clad Degradation - Local Corrosion of Zirconium and its Alloys (ANL-EBS-MD-000012, Rev 00, ICN 00) questioning the occurrence of pitting corrosion induced by chloride under repository conditions. It is claimed in the discussion that acidic pHs are not attained to maintain sufficient concentration of  $\text{Fe}^{3+}$  ions in solution. This analysis, however, contradicts screening arguments in several features, events, and processes in which the existence of acidic conditions inside the waste packages is assumed.

Additional information for the environmental conditions prevailing inside breached waste packages should be provided, in particular the evolution of pH and the concentration of detrimental species, as well as specific information for oxidized Zircaloy cladding in the initial conditions expected just prior to disposal.

Additional Information Needed:

- 1) Provide the technical basis to define the chemical composition of the in-package water and its evolution with time.
- 2) Provide the technical basis for excluding the effect of localized corrosion in the form of pitting promoted by chloride.
- 3) Provide clarification on whether or not DOE assumes that acidic conditions will be present inside the waste packages and the pH range expected if acidic conditions prevail.
- 4) Provide additional information on the environmental conditions, in terms of chemical composition, prevailing inside breached waste packages.

Status of Agreement: CLST Agreement 3.06 needs additional information to support a potential licensing review. During the CLST Technical Exchange and Management Meeting on September 12-13, 2000, NRC and DOE discussed CLST Subissues 3 and 4 together and the meeting summary stated that 10 agreements reached were applicable to both subissues.

However, the information needed in CLST Agreement 3.06 is not applicable to CLST Subissue 4 and, therefore, CLST Agreement 4.06 can be listed as "Complete."

## **7) Container Life and Source Term Agreement 4.07**

Wording of the Agreement: Provide data to address chloride induced localized corrosion and SCC under the environment predicted by in-package chemistry modeling. DOE stated that the technical basis for the models used for localized corrosion and SCC will be expanded in future revisions of the Clad Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, available by LA.

NRC Review: During the CLST Technical Exchange and Management Meeting on September 12-13, 2000, NRC and DOE discussed CLST Subissues 3 and 4 together and the meeting summary stated that 10 agreements reached were applicable to both subissues. However, the information in this agreement is not applicable to CLST Subissue 4 and therefore, CLST Agreement 4.07 can be listed as "Complete."

Additional Information Needed: None

Status of Agreement: The information needed in CLST Agreement 3.07 is not applicable to CLST Subissue 4 and, therefore, CLST Agreement 4.07 can be listed as "Complete."

## **8) Container Life and Source Term Agreement 3.08 Container Life and Source Term Agreement 4.08**

Wording of the Agreement: Provide the documentation on the distribution for cladding temperature and stress used for hydride embrittlement. DOE stated that the stresses are documented in the Initial Cladding Conditions AMR, ANL-EBS-MD-000048. CAL-UDC-ME-000001 contains the waste package internal temperatures. Waste package surface temperatures were provided within the TSPA model (ANL-EBS-HS-000003, Rev 00, ICN 01 and ANL-EBS-MD-000049). The updated versions of these documents will be available in January 2001.

NRC Review: DOE provided, and the NRC reviewed the following documents pertaining to this agreement: Initial Cladding Conditions (ANL-EBS-MD-000048, Rev 00, ICN 01) and Thermal History of Cladding in PWR SNF WP (CAL-UDC-ME-000001, Rev 00, ICN 00). The NRC has determined that the documents do not satisfy the agreement. The NRC staff has also reviewed Abstraction of Near-Field Environment Thermodynamic Environment and Percolation Flux (ANL-EBS-HS-000003, Rev 00, ICN 01) and Multiscale Thermohydrologic Model (ANL-EBS-MD-000049, Rev 00, ICN 01) as they pertain to CLST.

DOE consider that stresses and temperatures of the cladding are too low for hydride reorientation to occur. In addition, DOE assumed the cladding material would maintain sufficient strength, even if hydride reorientation did occur such that cladding failure would be unlikely. DOE's arguments are not consistent with the cladding temperatures documented in Thermal History of Cladding in PWR SNF WP (CAL-UDC-ME-000001, Rev 00, ICN 00). For the case 2 analyses, corresponding to the site recommendation waste package design, the

center rod in an average waste package after 60 years of emplacement will reach 326°C over most of its axial extension and the outer rods will peak at 305°C. These values are even higher than those reported in Clad Degradation - Summary and Abstraction (ANL-WIS-MD-000007, Rev 00, ICN 01). According to this report the center rod in an average waste package will reach 308°C and the outer rods will peak at 291°C. The temperature uncertainty is assumed to be uniformly distributed over a range of  $\pm 13.5\%$ . Thus, the hottest center rod in an average waste package could peak at 350°C while the hottest outer rod could peak at 314°C. These values are significantly higher than the value of 204°C quoted during the CLST Technical Exchange (see Subissue 3, slide 23). Therefore additional information is needed from the DOE to justify that the temperature is not sufficiently high for dissolution of some of the precipitated hydrides.

In the Initial Cladding Conditions AMR, ANL-EBS-MD-000048, the stress distribution reported for cladding is that corresponding to 27°C, which appeared to be the basis that led to the conclusion that the stress was too low to cause hydride reorientation. However, in a different document Hydride Related Degradation of SNF Cladding Under Repository Conditions, ANL-EBS-MD-000011, Revision 00, the tensile stress for hydride reorientation is estimated to be between 69 to 208 MPa, and DOE's calculations of the cladding stresses over the temperature range of 250° - 385°C result in values ranging between 55 and 120 MPa. This range of stresses is well within the minimum tensile stress for hydride reorientation to occur when the cladding cool slowly below the solvus temperature in the repository. DOE need to provide additional information regarding the accuracy and validity of the stress and temperature data because this information will determine whether hydride embrittlement should be screened out or not as a potential failure processes for SNF cladding .

Additional Information Needed:

- 1) Provide additional information to justify that the temperature is not sufficiently high for dissolution of some of the precipitated hydrides.
- 2) Provide additional information regarding the accuracy and validity of the stress and temperature data.

Status of Agreement: CLST Agreement 3.08 needs additional information to support a potential licensing review. During the CLST Technical Exchange and Management Meeting on September 12-13, 2000, NRC and DOE discussed CLST Subissues 3 and 4 together and the meeting summary stated that 10 agreements reached were applicable to both subissues. However, the information needed in CLST Agreement 3.08 is not applicable to CLST Subissue 4 and, therefore, CLST Agreement 4.08 can be listed as "Complete."

**9) Container Life and Source Term Agreement 3.09  
Container Life and Source Term Agreement 4.09**

Wording of the Agreement: Provide a technical basis for critical stress that is relevant for the environment in which external SCC takes place. DOE stated that critical stress from SCC experiments under more aggressive conditions will be cited in the Revision of the Cladding Degradation Summary Abstraction AMR, ANL-WIS-MD-000007, which will be available in January 2001.

NRC Review: The NRC reviewed Clad Degradation - Summary and Abstraction (ANL-WIS-MD-000007, Rev 00, ICN 01) and determined that the document does not satisfy the agreement. In the document, a review of information available in the open literature is presented where the possibility of stress corrosion cracking initiated from the cladding external surface is considered. This is an attempt to consider this potential failure mode that was screened out and not included in Revision 00 of the same document.

The information provided, however, is questionable because most of the observations are not applicable to the environmental conditions expected inside breached waste packages. These observations can be summarized as follows: 1) the discussion of the possible beneficial effect of thick oxide layers on SCC in chloride containing solutions (increase in the crack initiation time) is mixed with no relevant observations only applicable to iodine SCC from the internal surface; 2) the effects of galvanic coupling to carbon steel are misinterpreted although it is recognized that SCC occurs under the same conditions that promote pitting corrosion; 3) the data on the threshold stress intensity for SCC is not applicable to the in-package environment (moist chlorine is not the same as chloride anion); 4) despite the lack of validity of the data it should be noted that the values of the threshold stress intensity available are significantly lower for aqueous solutions of the halides (bromide and iodide) than for moist chlorine; 5) values of threshold stress intensity determined with precracked double cantilever beams specimens are not relevant to crack propagation in thin wall cladding under hoop stresses which may be locally close to the yield point.

DOE needs to provide specific information on the critical stress required for the occurrence of stress corrosion cracking initiated from the external surface of the fuel cladding in the presence of the possible in-package environments. The values should be compared with the estimated values of the hoop stress calculated with the same methodology used for evaluating creep failure. The information should be provided in a consistent and clear manner to fulfill the terms of the agreement.

Additional Information Needed:

1) Provide specific information on the critical stress required for the occurrence of stress corrosion cracking initiated from the external surface of the fuel cladding in the presence of the possible in-package environments.

Status of Agreement: CLST Agreement 3.09 needs additional information to support a potential licensing review. During the CLST Technical Exchange and Management Meeting on September 12-13, 2000, NRC and DOE discussed CLST Subissues 3 and 4 together and the meeting summary stated that 10 agreements reached were applicable to both subissues. However, the information needed in CLST Agreement 3.09 is not applicable to CLST Subissue 4 and, therefore, CLST Agreement 4.09 can be listed as "Complete."

## **10) Container Life and Source Term Agreement 4.10**

Wording of the Agreement: Provide analysis of the rockfall and vibratory loading effects on the mechanical failure of cladding, as appropriate. DOE stated that the vibratory effects are documented in Sanders et. al. 1992 SAND90-2406, A Method For Determining The Spent-Fuel Contribution To Transport Cask Containment Requirements. This will be discussed in the SDS

KTI meeting. The analysis of the rockfall effects on the mechanical failure of cladding will be addressed if the agreed to updated rockfall analysis in Subissue #2, Item 8 and Subissue #1, Item 14 demonstrate that the rock will penetrate the drip shield and damage the waste package.

NRC Review: During the CLST Technical Exchange and Management Meeting on September 12-13, 2000, NRC and DOE discussed CLST Subissues 3 and 4 together and the meeting summary stated that 10 agreements reached were applicable to both subissues. However, the information in this agreement is not applicable to CLST Subissue 4 and therefore, CLST Agreement 4.10 can be listed as "Complete."

Additional Information Needed: None

Status of Agreement: The information needed in CLST Agreement 3.10 is not applicable to CLST Subissue 4 and, therefore, CLST Agreement 4.10 can be listed as "Complete."

#### **11) Container Life and Source Term Agreement 4.11**

Wording of the Agreement: In the revision to the "Defense High Level Waste Glass Degradation," AMR, address specific NRC questions regarding (a) the inconsistency of the rates in acid leg for glasses, (b) the technical basis for use of boron versus silica in the radionuclide release from glass, and (c) clarification of the definition of long term rates of glass dissolution. DOE stated that these questions will be addressed in the Defense High Level Waste AMR revision and will be available in January 2001.

NRC Review: NRC reviewed Defense High Level Waste Glass Degradation (ANL-EBS-MD-000016, Rev 00, ICN 01) and the review indicates that the revised AMR satisfactorily addresses the agreement.

Additional Information Needed: None at this time. The NRC staff notes that DOE has ongoing studies to address effect of waste package corrosion products and radiolysis on the high level waste glass dissolution under CLST Agreements 4.02-4.05. Results from these studies may require revision to the high level waste glass dissolution model. In addition, if the proposed abstraction is modified in the TSPA code (e.g introducing an additional factor or change in parameter values as suggested in the SSPA), NRC staff will require further review of this document.

Status of Agreement: CLST Agreement 4.11 is "Complete."

#### **12) Container Life and Source Term Agreement 6.02**

Wording of the Agreement: Provide additional justification for the use of a 400 ppm hydrogen criterion or perform a sensitivity analysis using a lower value. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.

NRC Review: NRC reviewed Review of Expected Behaviour of Alpha Titanium Alloys (TDR-EBS-MD-000015, Rev 00, ICN 00) and found that additional justification and results were presented, however, the agreement has not been satisfied.

Though the subject report did contain additional information and justification for the use of a critical hydrogen concentration for cracking, the new critical threshold concentration of 1,000 ppm lacks sufficient justification for its use. The NRC staff needs additional justification and verification that this is the correct threshold, as the majority of the testing reported was for Ti Grade 16 not Ti Grade 7. Furthermore, efforts to examine the possible detrimental effects of fluoride on hydrogen uptake and its effects on the critical hydrogen concentration and subsequent cracking have not been reported. Additionally, no results have been reported for Ti Grade 24 structural drip shield components.

Additional Information Needed:

- 1) Provide better justification and needs to verify the critical hydrogen concentration chosen is a realistic and representative value for the onset of cracking in Ti Grade 7. An evaluation of the critical hydrogen concentration for Ti Grade 24 should also be given.
- 2) Provide an evaluation of possible detrimental effects of fluoride on hydrogen uptake and its effects on the critical hydrogen concentration and subsequent cracking.
- 3) Provide the results for the Ti Grade 24 structural drip shield components.

Status of Agreement: CLST Agreement 6.02 needs additional information to support a potential licensing review.

### **13) Container Life and Source Term Agreement 6.03**

Wording of the Agreement: Provide the technical basis for the assumed fraction of hydrogen absorbed into titanium as a result of corrosion. DOE stated that additional justification will be found in the report "Review of Expected Behaviour of Alpha Titanium Alloys under Yucca Mountain Condition" TDR-EBS-MD-000015, which is in preparation and will be available in January 2001.

NRC Review: NRC reviewed Review of Expected Behaviour of Alpha Titanium Alloys (TDR-EBS-MD-000015, Rev 00, ICN 00) and found that additional justification and results were presented, however, the agreement has not been satisfied.

Though the subject report did contain additional information and justification for the fraction of hydrogen absorbed during corrosion processes, the heavy reliance on weight loss measurements as a measure of corrosion rates makes the calculation of hydrogen generated is questionable. Additionally, the justification for the fraction of hydrogen absorbed during corrosion is still inadequate, especially given the possible effects of fluoride on the stability of the oxide film and possibly acting as a catalyst for hydrogen uptake. Both of these possible effects of fluoride may result in a significant increase in the fraction of hydrogen absorbed by the drip shield and will also increase the overall corrosion rate further increasing the amount of

hydrogen generated. These possible effects have not been reported and need to be evaluated further.

Additional Information Needed:

1) Provide an evaluation of the possible detrimental effects of fluoride on possible hydrogen uptake rates, as well as enhanced corrosion resulting in higher than currently estimated hydrogen generation rates.

Status of Agreement: CLST Agreement 6.03 needs additional information to support a potential licensing review.

#### **14) Container Life and Source Term Agreement 6.04**

Wording of the Agreement: Provide temperature distribution (CCDF) of the drip shield as a function of time under the current EBS design. DOE stated that the temperature distribution will be provided in the next revision of the AMR, ANL-EBS-MD-000049, Rev 00, ICN 01, which will be available in January 2001.

NRC Review: NRC reviewed Multiscale Thermohydrologic Model (ANL-EBS-MD-000049, Rev 00, ICN 01) as it pertains to CLST and found that it does not provide the specific information needed to satisfy CLST Agreement 6.04 regarding the temperature of the drip shield. The information needed is described in more detail below.

The Multiscale Thermohydrologic Model is a collection of models at different scales and representing different processes. The ensemble of models are linked by abstracting results from one model for input to another model. To estimate drip shield temperatures, abstracted results from the ensemble set of models that predict the temperature environment assuming a line averaged heat source are adjusted by the drift-scale thermal conduction model to obtain temperatures at specific locations, such as the drip shield. The methodology for calculating drip shield temperature is consistent with the approach NRC finds acceptable for predicting other aspects of the thermohydrologic environment. Results from fully integrated models developed by NRC indicate that approach of abstracted linkages between models used in the Multiscale Thermohydrologic Model (ANL-EBS-MD-000049, Rev 00, ICN 01) is reasonable for the case of estimating the effect of ventilation on temperature (Painter et al., 2001). However, it is not clear if the drift-scale thermal conduction model can be used to adequately model the in-drift climate for conditions affected by cold trap processes, particularly, condensation on the drip shield caused by thermal gradient across the drip shield. TEF Agreement 2.05 addresses the presentation and documentation of the cold trap model. The NRC analysis of the methodology represented by the ensemble models linked by abstractions is ongoing.

The output files or plots of temperature as a function of time for the drip shield for the no-backfill case are still needed. File names or data tracking numbers could not be identified for the drip shield temperature output. Plots of maximum drip shield temperatures were provided for the backfill case, but not for the no-backfill case. A CCDF of the waste package temperature was provided for the no-backfill case that can be considered as an upper bound for the drip shield temperature. However, the information is not clearly presented. The reference to the CCDF corresponding to the temperature distribution is unclear in the wording of the

agreement. The DOE response should incorporate at least all the spatial heterogeneity across the repository and uncertainty estimates, either in models or in the values of the parameters.

In addition, it is recognized that future design and model changes or refinements will likely cause changes to the predicted temperatures of the drip shield. The NRC cannot complete its review of the drip shield temperature profile until all aspects of the design and model have been introduced and finalized.

Additional Information Needed:

1) Provide the output files or plots of temperature as a function of time for the drip shield for the no-backfill case.

Status of Agreement: CLST Agreement 6.04 needs additional information to support a potential licensing review.