RAI Volume 2, Chapter 2.1.1.7, Second Set, Number 1: Explain the rationale for using three out of six Waste Package configurations to demonstrate compliance with 10 CFR 63.112(e) and (f) [See SAR Section 1.5.2.1.1].

In SAR Section 1.5.2.1.1, it is stated that three waste package configurations are analyzed to determine the acceptability of all waste package configurations for repository operations. However, the rationale for this approach is not provided. This information is needed to verify compliance with 10 CFR 63.112(e) and (f).

1. RESPONSE

SUMMARY OF THE WASTE PACKAGE DESIGN AND MULTIPLE CONFIGURATION APPROACH

The DOE does not use the three waste package configurations identified in SAR 1.5.2.1.1 to demonstrate the acceptability of all six waste package configurations for repository operations. For repository operations, DOE will qualify the remaining three representative waste package configurations using the structural design methodology described in SAR Section 1.5.2.1.1. The detail of the structural design methodology is described fully in the *Waste Package Component Design Methodology Report*, which was included as a primary supporting reference to the LA. The LA specifies, in SAR Section 5.10, proposed license specifications to be incorporated as Administrative Controls to ensure that each waste package configuration is fully analyzed and qualified for repository operations prior to use.

1.1 WASTE PACKAGE DESIGN AND ANALYZED CONFIGURATIONS

The three waste package configurations identified in SAR Section 1.5.2.1.1 that DOE already has qualified using this methodology are described below. These three waste package configurations represent the majority of HLW and SNF by heavy metal mass—or equivalent (greater than 90% of the MTHM total for the facility) and well over half of the total number of waste packages (~85% per Table 1.5.2-2) to be emplaced. They also represent the limiting values for the design parameters of mass (Naval Long waste package and TAD canister waste package), diameter (5-DHLW/DOE Short Codisposal waste package), length (TAD canister and Naval Long waste package) and maximum thermal power output (TAD canister waste package). Nevertheless, these values do not bound the analyses to be performed with respect to the remaining three configurations, nor are they intended to in the SAR.

Each configuration must be analyzed using the methodology defined in the *Waste Package Component Design Methodology Report*, cited in SAR Section 1.5.2.6.1.5 as part of the comprehensive qualification program discussed in Section 1.2 of this response. The report describes the analyses used to develop the conclusions contained in both the "Summary of Structural Analyses for Normal Loads" (SAR Table 1.5.2-8), including dead weight, internal pressure, and thermal expansion, and the "Summary of Structural Analyses of Outer Corrosion Barrier for Event Sequences" (SAR Table 1.5.2-9) using the "Tiered Screening Criteria for Material Failure for Mechanical Loading" (identified in SAR Table 1.5.2-10) as acceptance criteria. This same document also describes the Demand and Capability Analysis methodology used to perform calculations to support reliability evaluations. These tables reflect the analyses performed for the three waste package configurations analyzed to date and are not intended to show compliance for all six waste package configurations.

1.2 APPROACH TO DEMONSTRATE COMPLIANCE OF ADDITIONAL WASTE PACKAGE DESIGN CONFIGURATIONS

As described in SAR 1.2.6.5.1, the methodology defined in the *Waste Package Component Design Methodology Report* forms the basis for the performance of the thermal and structural design evaluations necessary to demonstrate compliance with the normal operational criteria and those criteria associated with the evaluation of Preclosure Safety Analysis (PCSA) event sequences as described in SAR Table 1.5.2-9. Supporting documents provide additional assurance that the methodology has been implemented on the three configurations described in the License Application, confidence that the acceptance criteria are appropriate, and representative calculations showing that the specific acceptance criteria can be met. An additional component of the qualification program is to show compliance with the Preclosure Safety Analysis Nuclear Safety Design Bases, as described in SAR Table 1.5.2-6. The response to RAI 2.2.1.1.7-2-003 provides a description of the probabilistic analyses that have been performed for the three qualified waste packages. The "Technical Requirements Manual" will contain the comprehensive set of acceptance criteria for waste package qualification, including the two sets described above.

SAR Section 5.10.2.3 and SAR Table 5.10-2 identify that the waste package configurations described in the SAR will be included in the Design Features section of the Licensing Specifications, when they are prepared. This would include the six waste package configurations currently described in SAR Section 1.5.2. Acceptability for repository operations of the remaining three configurations will be subject to additional confirmatory analyses and the final qualification of waste package designs are to be included in proposed administrative controls.

SAR Section 5.10.2.4.2 describes that programs will be used to develop the administrative controls described in SAR Table 5.10-3. SAR Table 5.10-3 identifies that the "Technical Requirements Manual" will include the acceptance criteria and designation of waste packages acceptable for emplacement in accordance with the Waste Form and Waste Package Qualification Program, once compliance with the acceptance criteria has been accomplished. The acceptance criteria for the thermal and structural evaluations will require completion of the analyses showing compliance to the *Waste Package Component Design Methodology Report* for the specific waste package configurations to be accepted at the repository.

In summary, although the three waste package configurations described in SAR Section 1.5.2 represent greater than 90% of the MTHM total for the facility and approximately 85% of the waste packages to be emplaced, the SAR does not rely on the three waste package configurations (or the analyses performed in connection with these waste package configurations) to demonstrate the compliance of all six waste package configurations. Further, the three remaining configurations will be analyzed, consistent with the methodology, prior to their use in repository operations.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

None.

RAI Volume 2, Chapter 2.1.1.7, Second Set, Number 2: Provide the technical bases for the waste package structural and thermal analyses results shown in SAR Tables 1.5.2-8 and 1.5.2-9. This information is needed to verify compliance with 10 CFR 63.112(f).

1. RESPONSE

1.1 DESCRIPTION OF THE TECHNICAL BASES FOR WASTE PACKAGE STRUCTURAL DESIGN

The results shown in SAR Tables 1.5.2-8 and 1.5.2-9 reflect the analyses performed for the three waste package configurations identified in SAR Section 1.5.2.1.1 and demonstrate that these configurations meet the specified normal loads and the ASME Code tiered-margin compliance criteria for event sequences. As described below, the technical bases for these results of the waste package structural and thermal analyses appear in a series of calculations. This response identifies these calculations and the related design reports that summarize the results of these calculations: (1) *Naval Waste Package Design Report* (BSC 2007a), (2) *HLW/DOE SNF Co-Disposal Waste Package Design Report* (BSC 2008a), and (3) *TAD Waste Package Design Report* (BSC 2008b). The design reports synthesize the results of the calculations with commentary to demonstrate compliance. In some cases, the reports demonstrate how analyses performed for a given waste package configuration are applicable to or conservative for another waste package configuration. These three reports are enclosed with this response.

To clarify the analyses' results for individual waste package configurations, Table 1 is based on SAR Table 1.5.2-8, which links the analysis with the associated criterion. The references identified in Table 1 also contain the technical bases supporting each entry. These calculations are evaluated in the design reports to show satisfaction of the normal or ASME Code tiered-margin acceptance criteria for event sequences. For example, in the "Summary of Structural Analyses of Outer Corrosion Barrier for Event Sequences" (SAR Table 1.5.2-9), it can be seen that the waste package-to-waste package impact in the drift during emplacement is bounded by (1) the 2-MCO/2-DHLW waste package impact with (2) the 5-DHLW/DOE Short Codisposal waste package by (3) an overdriven transport and emplacement vehicle (TEV).

The bases summarized in the design reports relevant to SAR Table 1.5.2-8 appear in the following calculations:

- *Emplacement Pallet Lift and Degraded Static Analysis* (BSC 2007b)
- *Waste Package Axial Thermal Expansion Calculation* (BSC 2003a)
- *21-PWR Waste Package Internal Pressure Estimate* (BSC 2006)
- *Waste Package Outer Shell Stresses Due to Internal Pressure at Elevated Temperatures* (BSC 2003b).

The bases summarized in the design reports relevant to SAR Table 1.5.2-9 appear in the following documents:

- *Naval Long Oblique Impact Inside TEV* (BSC 2007c)
- *5-DHLW/DOE SNF—Short Co-Disposal Waste Package Oblique Impact Inside TEV* (ANATECH Corporation 2007a)
- *TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package* (BSC 2007d)
- *5-DHLW/DOE SNF—Short Co-Disposal Waste Package and Emplacement Pallet Drop* (ANATECH Corporation 2007b)
- *Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages* (BSC 2007e)
- *Nonlithophysal Rock Fall on Waste Packages* (BSC 2007f).

As stated in the clarification call between the DOE and the NRC on February 18, 2009, the DOE is enclosing with this response a copy of *Emplacement Pallet Lift and Degraded Static Analysis* (BSC 2007b), which is applicable to the three analyzed waste package configurations, as a representative sample of the calculations listed above for SAR Table 1.5.2-8. As stated in the above-referenced clarification call, the DOE is also providing two other calculations, which serve as representative samples of the calculations listed for SAR Table 1.5.2-9: (1) *Naval Long Oblique Impact Inside TEV* (BSC 2007c), which is applicable to both the TAD waste package configuration and the Naval Long waste package configuration, and (2) *Nonlithophysal Rock Fall on Waste Packages* (BSC 2007f), which is calculated independently for the TAD, HLW/DOE SNF Codisposal, and Naval waste package configurations.

In addition to the calculations identified above, the DOE is supplying an additional three calculations that involve the event sequences identified in SAR Table 1.5.2-9. These calculations are referenced by the PCSA in its analysis of the waste package outer corrosion barrier. They include the following: (1) *Naval Long Waste Package Vertical Impact On Emplacement Pallet and Invert* (BSC 2007g), which is applicable to the three analyzed waste package configurations; (2) *Waste Package Capability Analysis for Nonlithophysal Rock Impacts* (BSC 2007h), which is applicable to the three analyzed waste package configurations; and (3) *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Packages to a Hypothetical Fire Accident* (BSC 2007i).

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ANATECH Corporation 2007a. *5-DHLW/DOE SNF—Short Co-Disposal Waste Package Oblique Impact Inside TEV*. ANA-QA-0190, Rev. 1. San Diego, California: ANATECH Corporation. ACC: ENG.20071105.0005.

ANATECH Corporation 2007b. *5-DHLW/DOE SNF—Short Co-Disposal Waste Package and Emplacement Pallet Drop*. ANA-QA-0189. San Diego, California: ANATECH Corporation. ACC: ENG.20071015.0003.

BSC (Bechtel SAIC Company) 2001. *Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes*. CAL-EBS-ME-000011 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011212.0222.

BSC 2003a. *Waste Package Axial Thermal Expansion Calculation*. 000-00C-EBS0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030416.0001.

BSC 2003b. *Waste Package Outer Shell Stresses Due to Internal Pressure at Elevated Temperatures*. 000-00C-EBS0-00600-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030430.0003.

BSC 2006. *21-PWR Waste Package Internal Pressure Estimate*. 000-00C-DSU0-03500-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061108.0004; ENG.20070402.0003.

BSC 2007a. *Naval Waste Package Design Report*. 000-00C-DNF0-00800-000-00B CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071030.0043; ENG.20080724.0014.

BSC 2007b. *Emplacement Pallet Lift and Degraded Static Analysis*. 000-00C-SSE0-00800-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070813.0017.

BSC 2007c. *Naval Long Oblique Impact Inside TEV*. 000-00C-DNF0-01200-000-00A CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070806.0016; ENG.20071024.0004.

BSC 2007d. *TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package*. 000-00C-MGR0-04100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070904.0033.

BSC 2007e. *Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages*. 000-00C-MGR0-04400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071030.0041.

BSC 2007f. *Nonlithophysal Rock Fall on Waste Packages*. 000-00C-MGR0-01400-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070724.0015.

BSC 2007g. *Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert*. 000-00C-DNF0-00100-000-00C CACN 002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071017.0001; ENG.20071116.0011; ENG.20080401.0004.

BSC 2007h. *Waste Package Capability Analysis for Nonlithophysal Rock Impacts*. 000-00C-MGR0-04500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071113.0017.

BSC 2007i. *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Packages to a Hypothetical Fire Accident*. 000-00C-WIS0-02900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070220.0008.

BSC 2008a. *HLW/DOE SNF Co-Disposal Waste Package Design Report*. 000-00C-DS00-00600-000-00F CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080222.0016; ENG.20080301.0006.

BSC 2008b. *TAD Waste Package Design Report*. 000-00C-DSC0-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080212.0006

Table 1.

Case	Description	Acceptance Criteria	Results	Comments	Waste Package Configuration: TAD	5-DHWL/DOE SNF Codisposal Long	5-DHWL/DOE SNF Codisposal Short	2-MCO/2-DHLW	Naval Long	Naval Short
Tensile Stresses from Static Loading on Waste Package Emplacement Pallet	Analysis determines the structural response of the outer corrosion barrier while statically resting on a waste package emplacement pallet.	The tensile stresses imposed on the Alloy 22 (UNS N06022) of the waste package outer barrier shall be less than 257 MPa (the approximate stress corrosion cracking threshold for Alloy 22).[1]	Calculated results indicate tensile stresses less than 257 MPa within the waste package outer barrier while resting on the pallet.		*Emplacement Pallet Lift and Degraded Static Analysis* (BSC 2007b)		*Emplacement Pallet Lift and Degraded Static Analysis* (BSC 2007b)		*Emplacement Pallet Lift and Degraded Static Analysis* (BSC 2007b)	
Contact Stresses from Axial Thermal Expansion	The inner vessel has a greater thermal expansion coefficient than the outer corrosion barrier. The waste package is designed with an initial axial gap at room temperature to prevent interference between the inner vessel and outer corrosion barrier at elevated temperatures or with high overall heat transfer rates.	To eliminate the possibility of induced stress corrosion cracking, the inner vessel and outer corrosion barrier has an axial gap in between. These distances account for differences in thermal expansion values for Alloy 22 and Stainless Steel Type 316.	There is no interaction between the inner vessel and outer corrosion barrier if the axial gap is at least 10 mm (0.394 in.). The different waste package design configurations are illustrated in Figures 1.5.2-3 through 1.5.2-8. The configurations are designed with axial gaps much greater than 10 mm to accommodate postclosure parameters.[2]		*Waste Package Axial Thermal Expansion Calculation* (BSC 2003a)		*Waste Package Axial Thermal Expansion Calculation* (BSC 2003a)		*Waste Package Axial Thermal Expansion Calculation* (BSC 2003a)	
Contact Stresses from Radial Thermal Expansion	The waste package is designed with a radial gap to prevent interference between the inner vessel and outer corrosion barrier at elevated temperatures or with high overall heat transfer rates.	To eliminate the possibility of induced stress corrosion cracking, the inner vessel and outer corrosion barrier has a radial gap in between. These distances account for differences in thermal expansion values for Alloy 22 and Stainless Steel Type 316.	There is zero tangential stress from thermal expansion if the radial gap is 1.0 mm or greater for all waste package configurations. The different waste package design configurations are illustrated in Figures 1.5.2-3 through 1.5.2-8. The radial gaps are greater than 1.0 mm.[2]		*Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes* (BSC 2001)		*Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes* (BSC 2001)	*Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes* (BSC 2001)	*Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes* (BSC 2001)	
Tensile Stresses from Internal Pressurization	Internal pressure is a result of increased temperature and decreased volume between the inner vessel and outer corrosion barrier, which is caused by thermal expansion. This internal pressure creates hoop and longitudinal tensile stress in the outer corrosion barrier. The calculation is based on an outer surface temperature of 239°C.	The tensile stresses imposed on the Alloy 22 of the waste package outer barrier shall be less than 257 MPa (the approximate stress corrosion cracking threshold for Alloy 22).[1]	The maximum tensile stresses for 21°C (70°F) and 250°C (482°F) are located in the outer corrosion barrier of the waste package with values of 56.8 MPa, which are significantly less than the 257 MPa limit.		*Waste Package Outer Shell Stresses Due to Internal Pressure at Elevated Temperatures* (BSC 2003b)	*Waste Package Outer Shell Stresses Due to Internal Pressure at Elevated Temperatures* (BSC 2003b)			*Waste Package Outer Shell Stresses Due to Internal Pressure at Elevated Temperatures* (BSC 2003b)	

[1]As stated in RAI 3.2.2.1.2.2-004, the Alloy 22 yield strength used in the TSPA is 351 MPa; therefore, the lower bound of the stress threshold distribution for the initiation of stress corrosion cracking on the Alloy 22 waste package outer corrosion barrier is (0.9 × 351 MPa) about 316 MPa. As this value is significantly greater than the 257 MPa residual tensile stress surface damage criterion, there is significant design margin used in the definition of this surface damage criterion.

[2]Calculation identifies minimum clearances necessary. Information can be verified in figures.

(yellow) - calculation for another configuration is shown to be appropriate for this configuration in the design report

(green) - calculation is applicable to multiple configurations

(pink) - specific calculation for this configuration was performed

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Table 1 (Continued).

Case	Description	Acceptance Criteria	Results	Comments	TAD	5-DHWL/DOE SNF Codisposal Long	5-DHWL/DOE SNF Codisposal Short	2-MCO/2-DHLW	Naval Long	Naval Short
Vibratory Ground Motion Damages Waste Package in TEV	The TEV will not tip over due to vibratory ground motion; however, it may derail. Given a derailment, the waste package will be subject to dynamic forces as it interacts with the TEV.	Meet tiered screening criteria of SAR Table 1.5.2-10.	The analysis of this event used the drop velocities and resulting wall-averaged stress intensity to determine that a velocity of 5.76 m/s is required before the wall-averaged stress intensity reaches the project-tiered second condition acceptance criteria of 0.77.	The results of this analysis provide input to the probabilistic analysis utilized for the preclosure safety analysis described in Sections 1.6 through 1.9.	*Naval Long Oblique Impact Inside TEV* (BSC 2007c)		*5-DHLW/DOE SNF—Short Co-Disposal Waste Package Oblique Impact Inside TEV* (ANATECH Corporation 2007a)		*Naval Long Oblique Impact Inside TEV* (BSC 2007c)	
Collision with Emplaced Waste Package	If the TEV is overdriven, it could collide with a line of emplaced waste packages causing loading on the packages.	Meet tiered screening criteria of SAR Table 1.5.2-10.	To illustrate compliance with this case, a conservative analysis was performed. The use of a 2-MCO/2-DHLW waste package on the opposite end of the 5-DHLW/DOE Short Codisposal waste package impacted by the overdriven TEV will produce a conservative structural response. The orientation of the neighboring waste package as well as the size of the neighboring waste package will have an effect on the structural response of the 5-DHLW/DOE Short Codisposal waste package. The rationale for this assumption is that the 2-MCO/2-DHLW waste package has the smallest diameter of the configurations of waste packages expected to be emplaced in the repository and because of the smaller diameter, it is expected to create a smaller area of contact and higher concentration of the collision force to produce a higher structural response in the 5-DHLW/DOE Short Codisposal waste package. The total driving force exerted on the impacted waste package will be equal to that generated by the TEV in order to propel itself at a speed of 2.0 mph. The TEV force generated and then transferred to the impacted waste package is found by calculating the tractive effort required by the fully loaded, 300-ton vehicle. Calculation of maximum stress intensity indicates the maximum calculated stress intensity values in the outer corrosion barrier of the TEV impacted waste package are below 0.7 σ_u and hence meet Tier 1 of the screening criteria of SAR Table 1.5.2-10.		*TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package* (BSC 2007d)		*TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package* (BSC 2007d)		*TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package* (BSC 2007d)	
Oblique Waste Package Drop in TEV	During handling operations, the waste package has been lifted in a horizontal position to a height of 2.49 ft (0.759 m). The waste package is dropped and impacts the TEV rail ledge obliquely.	Meet tiered screening criteria of SAR Table 1.5.2-10.	The Naval Long waste package configuration was dropped obliquely onto the TEV surface from a height of 0.759 m. The Naval Long configuration is the maximum weight and is thus considered bounding for this event; hence, all configurations will meet these criteria. The calculation shows that the project-tiered acceptance criteria of wall-averaged σ_{int} <0.77σ_u is met at the assumed failure or breach location.		*Naval Long Oblique Impact Inside TEV* (BSC 2007c)		*5-DHLW/DOE SNF—Short Co-Disposal Waste Package and Emplacement Pallet Drop* (ANATECH Corporation 2007b)		*Naval Long Oblique Impact Inside TEV* (BSC 2007c)	

- calculation for another configuration is shown to be appropriate for this configuration in the design report

- calculation is applicable to multiple configurations

- specific calculation for this configuration was performed

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Table 1 (Continued).

Case	Description	Acceptance Criteria	Results	Comments	TAD	5-DHWL/DOE SNF Codisposal Long	5-DHWL/DOE SNF Codisposal Short	2-MCO/2-DHLW	Naval Long	Naval Short
Vibratory Ground Motion Damages Horizontally Oriented Waste Package during Transfer to TEV	During loadout operations within the surface facilities, vibratory ground motion causes damage to the waste package. The waste package shall not breach in an event where the waste package while horizontal inside the waste package transfer trolley on the waste package transfer carriage is subjected to the dynamics imposed by vibratory ground motion. The waste package is ejected from the emplacement pallet and falls into the shielded enclosure of the waste package transfer trolley or TEV.	Meet tiered screening criteria of SAR Table 1.5.2-10.	Using the velocity of 5.76 m/s in which the waste package dropped in this configuration reaches the project-tiered second condition acceptance criteria of effective wall-averaged stress intensity ratio of wall-averaged 0.77 and using Newton's equation of motion, the minimum drop height at which the waste package will reach this velocity can be determined: $V^2 = V_o^2 + 2gh$ where V_o = initial velocity V = final velocity g = acceleration due to gravity h = vertical drop height For this calculation: V = 5.76 m/s (waste package final velocity) V_o = 0.0 m/s (waste package initially at rest) g = 9.81 m/s2 (acceleration due to gravity) Solving for h: $h = (V^2 - V_o^2) / 2g = 1.691$ m A drop height of 1.691 m is more than twice any possible drop that the waste package might experience during loadout operations.		*Naval Long Oblique Impact Inside TEV* (BSC 2007c)		*5-DHLW/DOE SNF—Short Co-Disposal Waste Package and Emplacement Pallet Drop* (ANATECH Corporation 2007b)		*Naval Long Oblique Impact Inside TEV* (BSC 2007c)	
General Drift Collapse in the Lithophysic Portion of the Subsurface	Prior to drip shield emplacement, the waste package shall not breach in the event of general drift collapse in the lithophysic portions of the repository caused by vibratory ground motion.	Meet tiered screening criteria of SAR Table 1.5.2-10.	The maximum stress intensities observed in the outer corrosion barrier were less than $\sigma_{int} < 0.7\sigma_u$.		*Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages* (BSC 2007e)		*Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages* (BSC 2007e)		*Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages* (BSC 2007e)	

(yellow) - calculation for another configuration is shown to be appropriate for this configuration in the design report

(green) - calculation is applicable to multiple configurations

(pink) - specific calculation for this configuration was performed

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Table 1 (Continued).

Case	Description	Acceptance Criteria	Results	Comments	TAD	5-DHWL/DOE SNF Codisposal Long	5-DHWL/DOE SNF Codisposal Short	2-MCO/2-DHLW	Naval Long	Naval Short
Rockfall on Waste Package in the Nonlithophysal Portions of the Subsurface	For the preclosure period, the drip shields have not yet been emplaced, so rocks in the nonlithophysal portions of the repository may fall onto the emplaced waste packages. Three waste package configurations for the license application are investigated to determine their structural response to rock fall sequences. A finite element analysis is performed by using the commercially available LS-DYNA finite element code.	Meet tiered screening criteria of SAR Table 1.5.2-10.	The largest credible rockfall in the nonlithophysal portions of the repository is a 20-MT block. Bounding rockfall calculations were performed on the three representative waste package configurations. The maximum stress intensities observed in the outer corrosion barrier were less than σ_{int} <0.7σ_u. Consequently, the three representative waste packages meet Tier 1 of the screening criteria of SAR Table 1.5.2-10.	A companion waste package capability analysis was performed for the rock fall analysis to determine the margin in the code compliance case. The capability of the waste package in response to the maximum credible preclosure emplacement drift rock fall in terms of the outer corrosion barrier expended toughness fraction is 0.0993. That is, the outer corrosion barrier has received only 10% of the energy required for breach. Figure 1.5.2-12 shows the capacity of the waste package against failure given a rock fall event. This result is compared with the deterministic analysis of the outer corrosion barrier structural response to the same maximum credible preclosure rock fall which showed that the peak effective wall-averaged stress intensity at the governing location is 91% of the first tier level ductile rupture criterion (using the 0.7σ_u Stress Intensity threshold of SAR Table 1.5.2-10).	*Nonlithophysal Rock Fall on Waste Packages* (BSC 2007f)		*Nonlithophysal Rock Fall on Waste Packages* (BSC 2007f)		*Nonlithophysal Rock Fall on Waste Packages* (BSC 2007f)	

- calculation for another configuration is shown to be appropriate for this configuration in the design report

- calculation is applicable to multiple configurations

- specific calculation for this configuration was performed

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Table 1 (Continued).

Case	Description	Acceptance Criteria	Results	Comments	TAD	5-DHWL/DOE SNF Codisposal Long	5-DHWL/DOE SNF Codisposal Short	2-MCO/2-DHLW	Naval Long	Naval Short
Horizontal Drop on Emplacement Pallet	The purpose of this calculation is to determine the structural response of the Naval Long waste package with the emplacement pallet when they are subjected to event sequence impacts onto horizontal surfaces including the drift invert steel structure. This calculation includes considerations of noncentered and angled orientations of the waste package, emplacement pallet, and invert steel. This calculation can address either a drop by the TEV or a vertical impact within the emplacement drift due to a seismic event. This calculation addresses both emplacement pallet and invert steel contacts with the outer corrosion barrier between its end sleeves.	Meet tiered screening criteria of SAR Table 1.5.2-10.	Considering realistic orientations between the waste package and emplacement pallet that can occur during a drop of the waste package on the emplacement pallet from the TEV or in the drifts during vertical motion dominated seismic events, the worst case orientation determined was for a 20 in., room temperature drop (3.15 m/s impact) of the waste package onto the worst case location of the emplacement pallet on a flat surface. The results indicate an effective wall averaged stress intensity value of 587 MPa. The ratio of this value to room temperature true tensile strength (σ_u = 971 MPa) is 0.60. This ratio satisfies the acceptance criteria in SAR Table 1.5.2-10.	A companion expended toughness fraction analysis was performed for the 20 in. drop analysis to determine the margin in the code compliance case. The expended toughness fraction for the 20 in. drop is 0.25. That is, the outer corrosion barrier has received only 25% of the energy required for breach while the governing effective wall averaged stress intensity for the deterministic 20 in. drop is $0.6\sigma_u$ which has a minimum "damage fraction" of 0.67 (using the highest $0.9\sigma_u$ limit of SAR Table 1.5.2-10). Figure 1.5.2-13 shows the capacity of the waste package given a horizontal drop on emplacement pallet.	*Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert* (BSC 2007g)		*5-DHLW/DOE SNF—Short Co-Disposal Waste Package and Emplacement Pallet Drop* (ANATECH Corporation 2007b)		*Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert* (BSC 2007g)	

- calculation for another configuration is shown to be appropriate for this configuration in the design report

- calculation is applicable to multiple configurations

- specific calculation for this configuration was performed

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RAI Volume 2, Chapter 2.1.1.7, Second Set, Number 3: Explain how the structural and thermal analyses results (SAR Tables 1.5.2-8 and 1.5.2-9) for the selected Waste Package configurations, are used to demonstrate compliance of the six waste package configurations with the preclosure performance objectives. This information is required to verify compliance with 10 CFR 63.112(e) and (f).

1. RESPONSE

1.1 DEMONSTRATION OF WASTE PACKAGE CONFORMANCE

As discussed in RAI 2.2.1.1.7-2-001, the DOE does not assert that the information provided in the SAR Section 1.5.2 demonstrates compliance for the three waste package configurations that have not yet been analyzed. The analyses results in SAR Tables 1.5.2-8 (Summary of Structural Analyses for Normal Loads) and 1.5.2-9 (Summary of Structural Analyses of Outer Corrosion Barrier for Event Sequences) are relied upon to demonstrate, in part, compliance of the three waste package configurations with the preclosure performance objectives. The results in these tables reflect the analyses performed for the three waste package configurations identified in SAR Section 1.5.2.1.1 and demonstrate that these configurations will meet the specified loads and the ASME tiered-margin compliance criteria. As described in Section 1.2 below, that information appears in separate calculations and reference documents described below.

SAR Table 1.5.2-9 describes structural analyses and not thermal analyses associated with event sequences and, therefore, this table does not apply to thermal event sequence performance objectives. SAR Table 1.5.2-8 applies to normal structural and thermal loads and, therefore, does not apply to event sequence performance objectives. Thermal loads on the waste package associated with event sequences derive from fire initiating events. The nuclear safety design bases to comply with performance objectives of event sequences associated with fire are described in Section 1.2.3 below.

The full set of references for the analyzed waste package configurations has been identified in the response to RAI 2.2.1.1.7-2-002, Table 1. Consistent with the agreement reached during the teleconference between the DOE and the NRC on February 19, 2009, only three representative analyses are being provided as a part of that response.

1.2 DEVELOPMENT OF SAR TABLE 1.5.2-6 LIMITS AND ASSOCIATED CALCULATIONS AND ANALYSES

Information demonstrating compliance of the analyzed waste package configurations with the preclosure performance objectives is contained in documents separate from the structural analyses described in Table 1 and the response to RAI 2.2.1.1.7-2-002. The section below describes the documents, approaches, and compliance demonstration for the preclosure safety analysis (PCSA) probabilistic analyses for drop and impact events, seismic events, and fire hazards.

1.2.1 Drops and Impacts

The failure probabilities for passive failure of the waste package outer corrosion barrier due to drops and impacts on the waste package developed for the PCSA are documented in Section 6.3.2.2 of the analyses listed below, which were submitted as references at the time of the submittal of the license application.

- *Subsurface Operations Reliability and Event Sequence Categorization Analysis* (BSC 2008a)

- *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008b)

- *Initial Handling Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008c)

Evaluations of waste package outer corrosion barrier performance to show compliance with the limits for drops and impacts identified in SAR Table 1.5.2-6 are also shown in Section 6.3.2.2. Further detail is found in Appendix D, Section D1.4 of these analyses.

Informed by the waste package structural calculations identified in Table 1 in RAI 2.2.1.1.7-2-002, and the additional waste package structural calculations identified below, the PCSA identified four bounding scenarios to be evaluated for the potential loss of containment by waste packages due to drops and impacts:

- Two-foot horizontal drop
- 3.4-mph end-to-end impact
- Rockfall on waste package in subsurface tunnels (normal and seismic)
- Drop of a waste package shield ring (waste package transfer trolley shield lid) onto a waste package.

Nuclear safety design bases, as reported in SAR Table 1.5.2-6 were developed based on these bounding scenarios. Table 1 shows the mapping of SAR Table 1.5.2-6 (Controlling Parameters and Values to the Analysis) to the analyses described above.

The PCSA applies point estimate load approximations for these events. Event sequence analysis is used to define conservative conditions for the load approximation rather than performing analyses over all possible ranges of such parameters. Therefore, the calculation of the probability of failures due to drops and impacts is based on the response or resistance characteristics (capability) of the waste package outer corrosion barrier, given the conservative point value for the drop or impact load (demand) defined for a given event sequence. Calculation of the probability of failure is based on the variability in the strength (capability) of the waste package outer corrosion barrier as derived from stress analysis, including finite element analysis, detailed in Attachment D of each of the analyses identified above. Loss of containment probability analyses were informed by the following waste package structural calculations (i.e., they were used as the source of relevant waste package material properties, bounding effective toughness fraction and variance):

- *Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert* (BSC 2007a)
- *Naval Long Oblique Impact Inside TEV* (BSC 2007b)
- *Waste Package Capability for Nonlithophysal Rock Impacts* (BSC 2007c).

The analyses have applied essentially the same methods that include: finite element analysis to determine the structural response of the waste package to drop and impact loads; development of a fragility function for the material used in the respective waste package configuration; and, calculation of responses (toughness index) with the fragility function to derive the probability of the waste package outer corrosion barrier breach (which is assumed to be a waste package breach).

Failure probabilities of less than 1.0×10^{-8} are predicted for these drop and impact events based on facility and component configurations. Additional conservatism is then incorporated in the PCSA by using a failure probability of 1.0×10^{-5} in the overall event sequence categorization performed in these analyses, unless further justification is provided. This additional conservatism is added to account for (1) future evolutions of waste package and canister designs, and (2) uncertainties such as undetected material defects, undetected manufacturing deviations, and undetected damage associated with handling before the waste package or container reaches the repository.

1.2.2 Seismic Induced Events

For seismically induced rockfall impacts, the compliance demonstration during the preclosure period is based on defining a bounding rockfall event together with the design capability of the waste package outer corrosion barrier. Demonstrating that the entire event sequence will have a mean probability of occurrence of less than 1.0×10^{-6}/yr, or less than 1 chance in 10,000 over the preclosure period of 100 years allows the event sequence to be screened from further consideration as beyond Category 2. The PCSA probabilistic analysis determined, for the range of credible seismic events that could occur over the preclosure period, the bounding characteristics of the credible rocks that could impact a waste package. An analysis documented in *Probabilistic Characterization of Preclosure Rockfalls in Emplacement Drifts* (BSC 2007d) (provided at the time of the submittal of the license application), established that the bounding kinetic energy at impact on a waste package (e.g., for the rocks that would impact a waste package over the preclosure period, the kinetic energy that has a probability less than 1/10,000 of being exceeded) is one million joules, realized by a rock of 20 metric tons impacting a waste package at 10 m/s. *Waste Package Capability for Nonlithophysal Rock Impacts* (BSC 2007c) established the toughness index for a waste package subjected to such an impact. Evaluations performed in Attachment F of Section 3.1.2 of *Seismic Event Sequence Quantification and Categorization Analysis* (BSC 2008d) show that there is a probability of less than 1.0×10^{-8} of the waste package outer corrosion barrier losing its containment function. This analysis demonstrates that the seismically-induced event sequences leading to a breach of a waste package from impacts by rockfalls over the preclosure period can be categorized as beyond Category 2. This conclusion is documented in Section 6.9 of *Seismic Event Sequence Quantification and Categorization Analysis* (BSC 2008d).

1.2.3 Fire Events

The fire probability analysis is used as the basis for the following two Controlling Parameters and Values included in SAR Table 1.5.2-6:

DN.SS.04. The mean conditional probability of breach of a canister inside a sealed waste package as a result of the spectrum of fires shall be less than or equal to 1×10^{-4} per fire event; and

DS.SS.04. The mean conditional probability of breach of other canisters inside a sealed waste package as a result of the spectrum of fires shall be less than or equal to 3×10^{-4} per fire event.

The calculation of the conditional probability of failure of waste form containers due to fire events is described in Section 6.3.2.3 of the calculations identified in Table 2. Table 6.3-5 in these calculations summarizes the results, specifically the calculated mean conditional failure probability of a thin-walled canister in a waste package is 3.2×10^{-4} and the calculated mean conditional failure probability of a thick-walled canister in a waste package is 1.0×10^{-4}. Naval SNF canisters are modeled as thick-walled. Other canisters are modeled as thin-walled. Further detail is found in Appendix D, Section D2 of the calculations shown in Table 2. The failure probability analysis is informed by the following waste package thermal structural analysis: *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Packages to a Hypothetical Fire Accident* (BSC 2007e).

Section F5 of Attachment F of the calculations identified in Table 2 explains the analysis performed to determine fire initiating event frequencies. A listing of the fire initiating event frequencies is presented in Table 6.5-4 in *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008b), *Initial Handling Facility Reliability and Event Sequence Categorization Analysis* (BSC 2008c), and in Table 6.5-1 in *Subsurface Operations Reliability and Event Sequence Categorization Analysis* (BSC 2008a) of these calculations. The mean frequency values for fire initiating events that are a hazard to a waste form container in a waste package are less than 1.0×10^{-4} over the preclosure period.

Multiplying the fire initiating event frequencies by the specified conditional probability of failure (breach) of a canister inside a waste package results in overall event frequencies beyond the Category 2 threshold and thus the event has been screened from further consideration in the PCSA.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007a. *Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert*. 000-00C-DNF0-00100-000-00C CACN 002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071017.0001; ENG.20071116.0011; ENG.20080401.0004.

BSC 2007b. *Naval Long Oblique Impact Inside TEV*. 000-00C-DNF0-01200-000-00A CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070806.0016; ENG.20071024.0004.

BSC 2007c. *Waste Package Capability Analysis for Nonlithophysal Rock Impacts*. 000-00C-MGR0-04500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071113.0017.

BSC 2007d. *Probabilistic Characterization of Preclosure Rockfalls in Emplacement Drifts*. 800-00C-MGR0-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070329.0009.

BSC 2007e. *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Packages to a Hypothetical Fire Accident*. 000-00C-WIS0-02900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070220.0008.

BSC 2008a. *Subsurface Operations Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0034.

BSC 2008b. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00A CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0031; ENG.20080331.0007.

BSC 2008c. *Initial Handling Facility Reliability and Event Sequence Categorization Analysis*. 51A-PSA-IH00-00200-000-00A CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0031; ENG.20080406.0002.

BSC 2008d. *Seismic Event Sequence Quantification and Categorization Analysis*. 000-PSA-MGR0-01100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080311.0032; ENG.20080404.0006.

Table 1

Table 1.5.2-6 Controlling Parameters and Values	Links to Table 6.9.1 in PCSA Calculation		Representative Event Sequence ID
	Title	**Document ID**	
DS.IH.01 – 1 × 10^{-8} / impact	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-HLW Sequence 4-6
DS.IH.02 – 1 × 10^{-5} / drop	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-HLW Sequence 3-6
DS.IH.03 – 1 × 10^{-5} / impact	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-HLW Sequence 5-6
DN.IH.01 – 1 × 10^{-8} / impact	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-NVL Sequence 4-6
DN.IH.02 – 1 × 10^{-5} / drop	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-NVL Sequence 3-6
DN.IH.03 – 1 × 10^{-5} / impact	*Initial Handling Facility Reliability and Event Sequence Categorization Analysis*	51A-PSA-IH00-00200-000-00A	IHF-ESD-11-NVL Sequence 5-6
DS.CR.01 – 1 × 10^{-8} / impact	*Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*	060-PSA-CR00-00200-000-00A	CRCF-ESD13-WP-TAD Sequence 2-4
DS.CR.02 – 1 × 10^{-5} / drop	*Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*	060-PSA-CR00-00200-000-00A	CRCF-ESD15-WP-TAD Sequence 3-4
DS.CR.03 – 1 × 10^{-5} / impact	*Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*	060-PSA-CR00-00200-000-00A	CRCF-ESD15-WP-TAD Sequence 3-4
DS.SS.01 – 1 × 10^{-8} / impact	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 6-3
DS.SS.02 – 1 × 10^{-5} / drop	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD01-WP Sequence 6-4
DS.SS.03 – 1 × 10^{-8} / impact	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 2-3
DS.SS.04 – 3 × 10^{-4} / fire	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD05-WP Sequence 3-4

Table 1. (Continued)

Table 1.5.2-6 Controlling Parameters and Values	**Links to Table 6.9.1 in PCSA Calculation**		**Representative Event Sequence ID**
	Title	**Document ID**	
DS.SS.05 – 1×10^{-6} / year	*Seismic Event Sequence Quantification and Categorization Analysis* Table 6.10-6	000-PSA-MGR0-01100-000-00A	Based on screening analysis of physical and thermal impacts from rockfalls; see Section 6.9.2
DS.SS.06 – 1×10^{-6} / year	*Seismic Event Sequence Quantification and Categorization Analysis* Table 6.10-6	000-PSA-MGR0-01100-000-00A	Based on screening analysis of waste package impacts in the emplacement drift; see Section 6.9.2
DN.SS.01 – 1×10^{-8} / impact	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 6-3
DN.SS.02 – 1×10^{-5} / drop	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 6-4
DN.SS.03 – 1×10^{-8} / impact	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 2-3
DN.SS.04 – 1×10^{-4} / fire	*Subsurface Operations Reliability and Event Sequence Categorization Analysis*	000-PSA-MGR0-00500-000-00A	SSO-ESD03-WP Sequence 3-4
DN.SS.05 – 1×10^{-6} / year	*Seismic Event Sequence Quantification and Categorization Analysis* Table 6.10-6	000-PSA-MGR0-01100-000-00A	Based on screening analysis of physical and thermal impacts from rockfalls; see Section 6.9.2
DN.SS.06 – 1×10^{-6} / year	*Seismic Event Sequence Quantification and Categorization Analysis* Table 6.10-6	000-PSA-MGR0-01100-000-00A	Based on screening analysis of waste package impacts in the emplacement drift; see Section 6.9.2

NOTE: Facility Codes: CR: Canister Receipt and Closure Facility; IH: Initial Handling Facility; SS: Subsurface Facility. System Codes: DN: Naval Spent Nuclear Fuel Waste Package; DS: DOE and Commercial Waste Package System.

Table 2

Document Title	Document ID	Participant Acc. No.
Subsurface Operations Reliability and Event Sequence Categorization Analysis (BSC 2008a)	000-PSA-MGR0-00500-000-00A	ENG.20080312.0034
Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis (BSC 2008b)	060-PSA-CR00-00200-000-00A 060-PSA-CR00-00200-000-00A CACN 001	ENG.20080311.0031 ENG.20080331.0007
Initial Handling Facility Reliability and Event Sequence Categorization Analysis (BSC 2008c)	51A-PSA-IH00-00200-000-00A 51A-PSA-IH00-00200-000-00A CACN 001	ENG.20080312.0031 ENG.20080406.0002

NOTE: These analyses were provided with initial submittal of the license application.