RAI Volume 2, Chapter 2.1.1.4, Eighth Set, Number 1:

> Clarify whether the "throughput" numbers listed in SAR Tables 1.2.1-1 and 1.7-5 represent the maximum numbers for each waste form configuration during the preclosure period.
>
> DOE has used "throughput" numbers for waste form configurations presented in SAR Tables 1.2.1-1 and 1.7-5 for the preclosure safety analyses. In BSC 2007bh, Section 4.3, DOE appears to imply that "throughput" numbers are expected values that will not be exceeded. Therefore, it is not clear whether or not these numbers represent the maximum capacity and rate of receipt for the operations at the geologic repository operations area, as required by 10 CFR 63.21(c)(5).

1. RESPONSE

The throughput numbers listed in SAR Tables 1.2.1-1 and 1.7-5 represent the maximum capacity and rate of receipt for preclosure operations at the geologic repository operations area (GROA). As such, they will not be exceeded and correspond to the maximum numbers for each waste form to be processed during the preclosure period, although the actual values are expected to be lower. SAR Table 1.2.1-1 presents the number of canisters and fuel assemblies expected to be received during the operational period of the GROA. In the preclosure safety analysis (PCSA), the event sequences consider the waste handling activities for each facility and for individual waste form configurations. In SAR Table 1.7-5, the throughput numbers have embedded several bounding scenarios for each waste handling facility to support the PCSA.

Waste Form Throughputs for Preclosure Safety Analysis (BSC 2007) documents the calculation of throughput numbers for the PCSA. These throughput numbers are developed using conservative assumptions regarding the various waste forms' maximum numbers and handling scenarios (BSC 2007, Section 4.3). For example, all transportation, aging, and disposal (TAD) canisters received into the GROA are counted as being handled in the Receipt Facility and all TAD canisters received into the GROA are also counted as being handled through the Canister Receipt and Closure Facility (CRCF). Because some TAD canisters will be handled only in the CRCF (and not received in the Receipt Facility) and because all TAD canisters are counted as going through a single CRCF, the throughput numbers are not only maxima but are bounding. Due to such conservative assumptions, the throughput numbers used for the PCSA exceed the actual throughputs that would take place on a facility by facility basis.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Waste Form Throughputs for Preclosure Safety Analysis*. 000-PSA-MGR0-01800-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071106.0001.

RAI Volume 2, Chapter 2.1.1.4, Eighth Set, Number 2:

> Provide technical basis for not including 1165 of the Transportation Aging and Disposal (TAD) canisters, as a part of the total throughput in the event sequence, CRCF-ESD09-TAD, for assessment of structural challenges to TADs (Table A.4.9-1, BSC 2008ac). These TAD canisters are transferred from Site Transfer Casks to Aging Overpacks in the Wet Handling Facility (Section 6.1.2.23, BSC 2008bq), using the Canister Transfer Machine.

1. RESPONSE

The 1,165 transportation, aging, and disposal (TAD) canisters produced in the Wet Handling Facility are included as a part of the total throughput in event sequence CRCF-ESD09-TAD, for assessment of structural challenges to TADs. For the TAD canister waste form, 15,121 units are considered in the evaluation of event sequence CRCF-ESD09-TAD (BSC 2009, Table A4.9-1). This value includes the potential for double handling of 6,978 TADs received in transportation casks and single handling of the 1,165 TADs produced in the Wet Handling Facility (BSC 2007, Section 6.2.4).

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Waste Form Throughputs for Preclosure Safety Analysis*. 000-PSA-MGR0-01800-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071106.0001.

BSC 2009. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0004.

RAI Volume 2, Chapter 2.1.1.4, Ninth Set, Number 1:

Provide calculations supporting seismic fragility curves and probability of failure values for the ITS surface facilities listed in Table 6.2-1 of BSC 2008bg (SAR Section 1.7.2.4).

SAR Section 1.7.2.4 provides a general description of the methodology used to generate seismic fragility curves for the ITS surface facilities. However, the calculations of the fragility curves and probability of failures for the facilities are not provided in the SAR or reports submitted by DOE. BSC (2008bg, Table 6.2-1) only provides a summary of fragility parameters and probabilities of failure for the surface facilities.

1. RESPONSE

The calculations supporting seismic fragility curves and the probability of failure values listed in Table 6.2-1 of *Seismic Event Sequence Quantification and Categorization Analysis* (BSC 2009) are described for the Canister Receipt and Closure Facility (CRCF). The CRCF is representative of the important to safety surface facilities, as discussed in the June 23, 2009, clarification call with the NRC.

1.1 SEISMIC FRAGILITY CURVES

The development of seismic fragility curves for the CRCF is described in Section 6.9 of *Canister Receipt and Closure Facility (CRCF) Seismic Fragility Evaluation* (BSC 2007), which is included with this response. Section 6.2 of the fragility evaluation (BSC 2007) provides the high confidence of low probability of failure capacity equal to 1.82 g for Limit State A, as listed in Table 6.2-1 of the event sequence analysis (BSC 2009).

1.2 PROBABILITY OF FAILURE VALUES

The probability of failure values (listed as frequency of failure) in Table 6.2-1 of the event sequence analysis (BSC 2009) are calculated using the SAPHIRE software by convolution of the seismic hazard curve with the building fragility curve, as represented by the median fragility, A_m, and composite uncertainty, β_c, parameters. The SAPHIRE convolution algorithm results for the CRCF are reproduced in Table 1 using the following formulas:

A_m = high confidence of low probability of failure $\times e^{2.326\,\beta c} = 1.82\text{ g} \times e^{2.326 \times 0.4} = 4.61$ g
for $\beta_c = 0.4$ and high confidence of low probability of failure = 1.82 g

Interval Mean Fragility = Standard normal cumulative distribution of
$[(\ln(\text{Interval Acceleration}) - \ln(A_m)) / \beta_c]$

Interval Frequency of Failure = Interval Mean Fragility × Interval Frequency

Failure Frequency = Σ Interval Frequency of Failure

The interval accelerations and interval frequencies, which are calculated from the seismic hazard curve using the methodology provided in Attachment I of the event sequence analysis (BSC 2009), are listed in Table 6.1-3 of the event sequence analysis (BSC 2009). The frequency of failure value of 7.83×10^{-7} per year shown in Table 1 of this response matches the rounded value listed in Table 6.2-1 of the event sequence analysis (BSC 2009) for the CRCF.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007. *Canister Receipt and Closure Facility (CRCF) Seismic Fragility Evaluation*. 060-SYC-CR00-01100-000-00A CACN 001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071114.0001; ENG.20080303.0006.

BSC 2009. *Seismic Event Sequence Quantification and Categorization Analysis*. 000-PSA-MGR0-01100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company.
ACC: ENG.20090112.0013.

Table 1. Probability of Failure Calculation for the CRCF

Interval	Interval Acceleration (g)	Interval Mean Fragility	Interval Frequency (/year)	Interval Frequency of Failure (/year)
1	0.047	9.9351×10^{-31}	5.53×10^{-3}	5.4941×10^{-33}
2	0.061	1.4974×10^{-27}	4.41×10^{-3}	6.6035×10^{-30}
3	0.079	1.4012×10^{-24}	3.31×10^{-3}	4.6381×10^{-27}
4	0.102	8.0538×10^{-22}	2.57×10^{-3}	2.0698×10^{-24}
5	0.132	3.2554×10^{-19}	1.96×10^{-3}	6.3806×10^{-22}
6	0.171	8.9182×10^{-17}	1.37×10^{-3}	1.2218×10^{-19}
7	0.222	1.6848×10^{-14}	9.31×10^{-4}	1.5686×10^{-17}
8	0.288	2.0665×10^{-12}	6.15×10^{-4}	1.2709×10^{-15}
9	0.373	1.6286×10^{-10}	4.09×10^{-4}	6.6611×10^{-14}
10	0.483	8.5066×10^{-9}	2.49×10^{-4}	2.1182×10^{-12}
11	0.626	2.9943×10^{-7}	1.44×10^{-4}	4.3119×10^{-11}
12	0.811	6.9864×10^{-6}	8.53×10^{-5}	5.9594×10^{-10}
13	1.050	1.0840×10^{-4}	4.79×10^{-5}	5.1923×10^{-9}
14	1.360	1.1371×10^{-3}	2.54×10^{-5}	2.8884×10^{-8}
15	1.758	7.9735×10^{-3}	1.31×10^{-5}	1.0445×10^{-7}
16	2.264	3.7724×10^{-2}	6.17×10^{-6}	2.3275×10^{-7}
17	2.916	1.2610×10^{-1}	1.95×10^{-6}	2.4589×10^{-7}
18	3.775	3.0869×10^{-1}	4.00×10^{-7}	1.2348×10^{-7}
19	4.888	5.5819×10^{-1}	7.45×10^{-8}	4.1585×10^{-8}
			Failure Frequency (/year):	7.83×10^{-7}

Source: Original

RAI Volume 2, Chapter 2.1.1.4, Ninth Set, Number 4:

> Provide technical basis for using Equation 4-3 of ASCE (2005), to compute the capacity of low rise concrete shear walls without boundary elements at one or both ends (SAR Section 1.7.2.4, DOE 2007ba; Section B4.3, Step 3).
>
> In developing fragility curves for low-rise concrete shear walls without boundary elements at one or both ends, DOE used Equation 4-3 of ASCE 2005, to compute the component capacity (DOE 2007ba, Section B4.3, Step 3). However, this equation is only applicable to shear walls with boundary elements or end walls (ASCE 2005, Section 4.2.3), and may overestimate the capacity of shear walls without boundary elements (Hwang, et al., 2001; and Gulec, et al., 2008).

1. RESPONSE

The layout of the important to safety (ITS) facilities and planned detailing at piers effectively provide shear walls with end walls or boundary elements. Therefore, the use of Equation 4-3 of ASCE/SEI 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*, to compute the capacity of low-rise concrete shear walls for development of fragility curves is appropriate and does not overestimate the capacity of the ITS facilities.

1.1 FRAGILITY EVALUATIONS OF THE IMPORTANT TO SAFETY FACILITIES

Per Sections 4.2.2 and 4.2.3 of ASCE/SEI 43-05, the capacity of low-rise shear walls as prescribed in ACI 349-01/349R-01, *Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01) and Commentary (ACI 349R-01)*, may be too conservative. In lieu of the code provisions, the shear strength of low-rise walls with boundary elements (i.e., wall edges strengthened by providing additional reinforcement and concrete confinement) or end walls (i.e., walls oriented perpendicular to the shear wall) can be calculated using Equation 4-3 of ASCE/SEI 43-05.

In the fragility evaluations of the ITS facilities, different equations are used to determine the in-plane shear wall strength, depending on the aspect ratio of the wall (i.e., the ratio of the height of the wall or pier, h_w, to the length of the wall or pier, l_w). For low-rise (squat) walls with $h_w/l_w \leq 2.0$, Equation 4-3 of ASCE/SEI 43-05 is used to calculate the shear strength, and the total shear wall capacity is calculated using Equations 4-4 and 4-5. For walls with $h_w/l_w > 2.0$, the shear wall provisions of ACI 349-01/349R-01 (e.g., Equation 11-8) are used to calculate the shear wall capacity, consistent with Section 4.2.3 of ASCE/SEI 43-05.

In the ITS surface structures, most of the shear walls have end or cross walls on one or both sides. These end or cross walls are of similar thickness and have similar reinforcement, and thus will function as flanges. In cases where there are no end or cross walls (e.g., a pier between openings), the vertical reinforcement displaced by the opening is placed as additional reinforcement on the two sides of the opening. If required, confinement reinforcement is also provided to enhance ductility. Final reinforcement details will be developed in the detailed design for construction. These typical detailing practices in effect create a boundary element,

thus enhancing ductile behavior and precluding concrete failure under high compressive stresses. Therefore, the layout of the ITS facilities and the planned detailing at piers result in equivalent walls with boundary elements or end walls, and the use of Equation 4-3 of ASCE/SEI 43-05 is appropriate for fragility evaluations.

1.2 EXPERIMENTAL RESEARCH DATA

Numerous scaled tests have been performed on rectangular shear walls and shear walls with barbells and flanges. Barbell cross sections represent walls framed by columns at both ends and flanged cross sections represent walls framed by other walls oriented in the perpendicular direction (e.g., end or cross walls in a typical shear wall structure). Both barbell and flanged cross sections represent shear walls with boundary elements.

"Shear Strength of Squat Rectangular Reinforced Concrete Walls" (Gulec et al. 2008) reviewed and evaluated compiled test data for rectangular walls in comparison to predictive equations of shear strength available in literature, including the provisions of ACI 349-01/349R-01 and Equation 4-3 of ASCE/SEI 43-05. "Shear Strength of Squat Reinforced Concrete Walls with Flanges and Barbells" (Gulec et al. 2007) conducted a similar study for walls with barbells and flanges. The reviews concluded that the shear walls with barbells and flanges have greater shear capacity than rectangular walls due to the larger effective shear area, and that the equations of ASCE/SEI 43-05 produced the best predictions of ultimate shear strength in squat walls with barbells and flanges compared to experimentally measured strength (Gulec et al. 2007).

Because shear walls in the ITS surface facilities are similar to walls with barbells and flanges, use of Equation 4-3 of ASCE/SEI 43-05 does not overestimate the shear strength of these walls.

1.3 CONCLUSION

Considering the layout and planned detailing of the ITS facilities, the shear walls effectively have either flanges or boundary elements. Thus, the shear capacities calculated using ASCE/SEI 43-05 equations for low-rise walls and ACI 349-01/349R-01 equations for walls with $h_w/l_w > 2.0$ are appropriately determined. Therefore, the resulting seismic fragility capacities are not overestimated for probabilistic evaluations.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ACI 349-01/349R-01. 2001. *Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01) and Commentary (ACI 349R-01)*. Farmington Hills, Michigan: American Concrete Institute. TIC: 252732.

ASCE/SEI 43-05. 2005. *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*. Reston, Virginia: American Society of Civil Engineers. TIC: 257275.

Gulec, C.K.; Whittaker, A.S.; and Stojadinovic, B. 2007. "Shear Strength of Squat Reinforced Concrete Walls with Flanges and Barbells." *Transactions, SMiRT 19*. Toronto, Canada.

Gulec, C.K.; Whittaker, A.S.; and Stojadinovic, B. 2008. "Shear Strength of Squat Rectangular Reinforced Concrete Walls." *ACI Structural Journal, 105*, (4), 488-497. Detroit, Michigan: American Concrete Institute. TIC: 260389.

RAI Volume 2, Chapter 2.1.1.4, Ninth Set, Number 5:

> Provide technical basis to support a percentage of critical structural damping $\xi = 10$ percent for the analysis of ITS buildings subjected to Beyond Design Basis Ground Motions (BDBGMs). Also, demonstrate that the High Confidence of Low Probability Failure (HCLPF) capacity is not overestimated by using $\xi = 10$ percent in the structural analyses and including the nonlinear hysteretic energy capacity parameter, F_μ, in the HCLPF computation.

1. RESPONSE

The seismic response analyses of important to safety (ITS) surface facilities subjected to beyond design basis ground motion (DBGM) use a percentage of critical structural damping that is in accordance with ASCE/SEI 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*. The seismic fragility evaluations of ITS surface facilities use factors of inelastic energy absorption, F_μ, which are also in accordance with ASCE/SEI 43-05, to calculate the high confidence of low probability of failure capacities. The use of the damping value for calculation of beyond DBGM demands, in conjunction with the specified inelastic energy absorption factors for calculation of high confidence of low probability of failure capacities, is appropriate and does not overestimate the high confidence of low probability of failure capacity.

1.1 DAMPING VALUE

ASCE/SEI 43-05 defines levels of acceptable structural damage in terms of limit states. Limit State A is described as large permanent distortion, short of collapse, and is appropriate when building collapse is the only event considered in an event sequence. Limit State D is described as essentially elastic behavior, and is appropriate when no damage to the structure is permitted (e.g., building confinement is determined to be critical in an event sequence). As shown in SAR Tables 1.7-8, 1.7-10, 1.7-12, and 1.7-14, building confinement is not relied upon in any seismic event sequence. Therefore, the appropriate limit state for seismic fragility evaluations is Limit State A.

ASCE/SEI 43-05 defines damping values (as a percentage of critical damping) to be used in linear elastic analyses as a function of the seismic response level. Linear elastic models are used in the response spectrum analyses of the ITS surface facilities that provide the beyond DBGM seismic demands on the structural members. Section 3.4.3 of ASCE/SEI 43-05 states that Response Level 3 damping may be used for evaluating seismic-induced forces and moments in structural members by elastic analysis without consideration of the actual response level for Limit States A, B, or C. Consistent with Table 3-2 of ASCE/SEI 43-05, Response Level 3 critical damping value $\xi = 10\%$ is appropriately used in the beyond DBGM seismic response analyses.

1.2 INELASTIC ENERGY ABSORPTION FACTOR

The inelastic energy absorption factor (stated as the nonlinear hysteretic energy capacity parameter in the RAI), F_μ, represents the inelastic energy dissipation from yielding of the structural members. Seismic fragility evaluations of the ITS facilities are based on the

conservative deterministic failure margin method. Per Section B3 of *Seismic Analysis and Design Approach Document* (BSC 2007), the high confidence of low probability of failure capacity, C_{HCLPF}, calculated by the conservative deterministic failure margin method closely approximates the 1% probability of unacceptable performance seismic capacity, $C_{1\%}$, and the terms may be used interchangeably. The C_{HCLPF} capacity is estimated from $C_{HCLPF} = F_s \times F_\mu \times E$, where F_s is the linear elastic computed capacity to demand ratio, and E is the beyond DBGM parameter being evaluated (e.g., horizontal peak ground acceleration).

Table 5-1 of ASCE/SEI 43-05 provides F_μ values. For Limit State A and $h_w/l_w < 2.0$, where h_w is wall height and l_w is wall length, the F_μ value for in-plane shear of reinforced concrete shear walls is 2.0. The F_μ value is appropriately modified to account for weak story effects in accordance with Section 5.1.2.1 of ASCE/SEI 43-05. NUREG/CR-6925, *Assessment of Analysis Methods for Seismic Shear Wall Capacity Using JNES/NUPEC Multi-Axial Cyclic and Shaking Table Test Data* (Xu et al. 2007), calculated F_μ values using different approaches, and obtained relatively good comparison with test data results. For shear walls with aspect ratios (h_w/l_w) between 0.4-0.9, F_μ values were approximately four. Thus, $F_\mu = 2.0$ for Limit State A, as specified in ASCE/SEI 43-05, is conservative, and does not overestimate the C_{HCLPF} capacity.

Use of the Response Level 3 damping value and inelastic energy absorption factors specified in accordance with ASCE/SEI 43-05 is appropriate. The methodology used in seismic fragility evaluations of the ITS facilities results in realistic and reasonably conservative probabilistic estimates of high confidence of low probability of failure capacities.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ASCE/SEI 43-05. 2005. *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*. Reston, Virginia: American Society of Civil Engineers. TIC: 257275.

BSC (Bechtel SAIC Company) 2007. *Seismic Analysis and Design Approach Document*. 000-30R-MGR0-02000-000-001 ACN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071220.0029; ENG.20090311.0013.

Xu, J.; Nie, J.; Braverman, J.; and Hofmayer, C. 2007. *Assessment of Analysis Methods for Seismic Shear Wall Capacity Using JNES/NUPEC Multi-Axial Cyclic and Shaking Table Test Data*. NUREG/CR-6925. Washington, D.C.: U.S. Nuclear Regulatory Commission.