OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT CALCULATION COVER SHEET

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Page: 1 Of: 12

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Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages

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CAL-EBS-ME-000001 REV 00

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1. PURPOSE

The purpose of this activity is to determine the structural performance of waste packages (WP) subject to rock fall design basis event (DBE) dynamic loads (see p. I-3, Ref. 7) and document the calculation results that describe the threshold rock sizes for crack-initiation and through-cracks in waste package shells. This activity is associated with the waste package design. *AP-3.12Q, Revision 0, ICN 0, Calculations*, is used to develop the calculation.

Referencing in this calculation refers to the input document numbers appearing in column 2a of the Document Input Reference Sheets, Attachment I hereto.

2. METHOD

Finite element solution was performed by making use of the commercially available ANSYS V5.4 finite element code. The results of this calculation were provided in terms of maximum stresses and material thicknesses.

3. ASSUMPTIONS

In the course of developing this document, assumptions were made regarding the waste package structural calculations. These are identified below.

- 3.1 Some of the temperature dependent material properties were not available for SB-575 N06022 (Alloy 22). Therefore, room temperature (20 °C) material properties were assumed for all materials. The basis for this assumption is that the impact of using room temperature material properties is anticipated to be small because the mechanical properties of the subject materials do not significantly change at the WP temperatures encountered after emplacement. This assumption is used in Section 5.1.
- 3.2 The contact stiffness between the waste package and the target surface is assumed to be 1.5×10^8 N/m. The basis for this assumption is explained below:

The magnitude of the contact stiffness between surfaces is one of the parameters that affects the results. If the stiffness value is very large, stiffness matrix ill-conditioning and divergence occur. Similarly, an extremely small stiffness value results in compatibility violations. Therefore, an optimum value for the contact stiffness is one that is between and is arrived at iteratively. The result of iterations revealed that the contact stiffness between the waste package and the target surface that works best is 1.5×10^8 N/m. In order to determine the effect of this parameter on the results, for the case of crack initiation on WP shells, the contact stiffness was doubled to 3.0×10^8 N/m and the resulting stresses (see Ref. 14, filename: m20s.out, line numbers: 47 and 67) were compared to previous results (see Table 6.1-1, results for the shell thicknesses of 20 mm outer shell and 50 mm inner shell). These results of stress on the waste package outer shell showed that the change in the stiffness has

no significant effect on the stress magnitudes. Therefore, the accuracy and precision of the contact stiffness used in the finite element simulation is deemed acceptable for the subject transient dynamic solution. This assumption is used in Section 5.2.

- 3.3 The coefficients of static and dynamic friction values have been provided for steel on steel, which have been obtained from the limited data in the literature (to be used in lieu of rock on steel). The basis for this assumption is that since there is no significant relative displacement between the rock and the WP along the surface perpendicular to the line of impact, the friction coefficients do not have significant effect on the results. However, the following numbers had to be specified in order to meet the computational requirements:

Coefficient of static friction = 0.6 (Ref. 8, p. 441)

Coefficient of kinetic friction = 0.4 (Ref. 8, p. 441)

This assumption is used in Section 5.2.

- 3.4 A spherical geometry is assumed for the rock. The basis for this assumption is that the pointed tip of a rock would crush upon impact before any failure is observed on the waste package. Therefore, an initial point contact would eventually become an area. The finite element solution inherently includes the calculation of an initial point of contact turning into an area between a sphere (rock) and a cylinder (WP) as the impact occurs. Considering the fact that the tensile strength of metals is significantly larger than that of rock, this is a realistic assumption. This assumption is used in Section 5.2.
- 3.5 Some of the rate-dependent material properties were not available for the materials used. Therefore, the material properties obtained under the static loading conditions were assumed for all materials. In general, this is a notably conservative assumption, nonetheless, in this case, the impact of using material properties obtained under the static loading conditions is anticipated to be small. The basis for this assumption is that the mechanical properties of subject materials do not significantly change at the peak strain rates in the course of the rock fall DBE. This assumption is used in Section 5.2.
- 3.6 The number of cracks developed in the waste package shells due to rock fall is assumed to be one. The basis for this assumption is that the stress is highly localized in the vicinity of the impact region on the waste package shells, made of highly ductile materials, and if the stress exceeds the allowable limit for developing a crack, it will initiate and cause propagation only for one crack that is considered to be the most vulnerable section to the impact loads. This assumption is used in Section 5.2.

4. USE OF COMPUTER SOFTWARE AND MODELS

The finite element analysis computer code used for this calculation is ANSYS version (V) 5.4 which is identified with the Computer Software Configuration Item (CSCI) 30040 V5.4 and was obtained from Software Configuration Management in accordance with appropriate procedures. ANSYS V5.4 is a commercially available finite element analysis code and is appropriate for structural calculations for waste packages. The calculations using the ANSYS V5.4 software were executed on Hewlett-Packard (HP) workstations. The software qualification of the ANSYS V5.4 software, including problems of the type analyzed in this report, is summarized in the Software Qualification Report for ANSYS V5.4 (Ref. 9). Qualification of ANSYS V5.4 on the Waste Package Operations HP UNIX workstations is documented in Refs. 10, 15, and 16. The ANSYS V5.4 evaluations performed for this design are fully within the range of the validation performed for the ANSYS V5.4 code.

5. CALCULATION

5.1 Calculation Data

The waste package containment shells are made of the materials listed in this section. Some of the temperature dependent material properties were not available for SB-575 N06022; therefore, room temperature material properties were used in calculations (Assumption 3.1).

SB-575 N06022 (ASTM B 575) (Alloy 22) (Outer shell material, see p. II-1):

- Density = 8690 kg/m^3 (0.314 lb/in^3) (Ref. 1)
- Yield strength = 310 MPa (45 ksi) (Ref. 1) (at 20 °C)
- Tensile strength = 690 MPa (100 ksi) (Ref. 1) (at 20 °C)
- % elongation = 45 (Ref. 1) (at 20 °C)
- Poisson's ratio was not available for SB-575 N06022. Since the chemical compositions of SB-575 N06022 and SB-443 N06625 (Inconel 625) are similar (Ref. 1, and Ref. 2), Poisson's ratio of SB-443 N06625 is used for SB-575 N06022:
Poisson's ratio = 0.278 (Ref. 2) (at 20 °C)
- Modulus of elasticity = 203 GPa ($29.4 * 10^6 \text{ psi}$) (Ref. 3) (at 93 °C or 200 °F since the WP shells are expected to reach this temperature and this specific material property is available at this temperature)

316NG stainless steel (SS) (Inner shell material, see p. II-1) (316NG SS and 316 SS have the same mechanical and physical properties, see Ref. 11):

- Density = 7980 kg/m^3 (Ref. 4)
- Modulus of elasticity = 195 GPa ($28.3 * 10^6 \text{ psi}$) (Ref. 5) (at 20 °C)
- Yield strength = 207 MPa (30 ksi) (Ref. 5) (at 20 °C)
- Tensile strength = 517 MPa (75 ksi) (Ref. 5) (at 20 °C)
- % elongation = 40 (Ref. 6) (at 20 °C)
- Poisson's ratio = 0.298 (Ref. 2) (at 20 °C)

TSw2 rock:

- Density = 2274 kg/m³ (Ref. 12)

5.2 Finite Element Representation

A three-dimensional (3-D) finite element representation (FER) of the 21 PWR waste package is developed in order to determine the effects of a rock fall design basis event on the waste package inner and outer shells. The 3-D finite element representation is developed using the dimensions provided in the sketch in Attachment II. The finite element representation includes the inner and outer shells of the waste package; no structural credit is taken for the internal structure of the waste package since the thickness of side guides is small compared to the total thickness of the containment shells.

The FER makes use of the two-plane-symmetry geometry of the waste package. The inner and outer shells will be shrunk fit (Ref. 13); therefore, the finite element representation includes solid connections at the adjacent surfaces of the inner and outer shells. The shells are constrained in a direction perpendicular to the symmetry planes.

The material properties obtained under the static loading conditions were assumed for all materials (see Assumption 3.5).

A spherical geometry is assumed for the rock (Assumption 3.4). The FER is developed such that the rock is the moving object and the waste package outer shell outer surface is the stationary target. In order to simulate this dynamic impact problem, contact elements are defined between the rock and the waste package surfaces. Initial configuration of the finite element representation includes the rock positioned at 3.1 m above the waste package as specified in the design basis events document (Ref. 7). The rock is initially at rest, and then it accelerates due to the gravitational acceleration until it impacts the waste package surface. The simulation is then continued throughout the impact until the rock begins to rebound, at which time the stress peaks and the maximum displacements have been obtained.

The magnitude of the contact stiffness between surfaces is assumed to be 1.5×10^8 N/m (Assumption 3.2).

In order to meet the computational requirements in the finite element representation, an assumption is made by using the coefficients of static and dynamic friction provided for steel on steel, which have been obtained from the limited data in the literature (Assumption 3.3).

Based on the assessment made in Assumption 3.2 and the nonlinear nature of the finite element solution with increased number of elements used in the vicinity of the impact region, the accuracy, precision, and representativeness of the results are deemed acceptable and no limitations are identified on the results.

The number of cracks developed in the waste package shells due to rock fall is assumed to be one (Assumption 3.6).

5.3 Calculations for Tangent Moduli

The results of this impact simulation are required to include elastic and plastic deformations for all materials. When the materials are driven into the plastic range, the slope of the stress-strain curve continuously changes. Thus, a simplification for this curve is needed to incorporate plasticity into the finite element solution. A standard approximation is commonly used in engineering by using a straight line that connects the yield point to the ultimate tensile strength point of the material. The following parameters will be used in subsequent calculations:

S_y = Yield strength of the material

S_u = Ultimate tensile strength

e_1, e_2, e_3 = Strain magnitudes

E = Elastic modulus (slope of the line in the elastic region)

E_t = Tangent modulus (slope of the line in the plastic region)

The slope, E_t is determined by:

$e_1 = S_y / E$ and $e_2 = e_3 - e_1$ where e_3 = elongation specified for material.

Hence, for SB-575 N06022:

$$E_t = (S_u - S_y) / e_2 = (0.690 - 0.310) / (0.45 - (0.310 / 203)) = 0.847 \text{ GPa (see Section 5.1)}$$

For 316NG SS:

$$E_t = (0.517 - 0.207) / (0.40 - (0.207 / 195)) = 0.777 \text{ GPa (see Section 5.1)}$$

6. RESULTS

Unqualified data were used in the development of the results in this document. If the results from this document are used as input into documents directly relied upon for radiological safety or waste isolation issues, then unqualified inputs are required to be identified and tracked as TBV in accordance with appropriate procedures (see *AP-3.15Q, Revision 0, ICN 0, Managing Technical Product Inputs, Attachment 3*).

The structural response of the waste package to rock fall is reported using maximum stress values obtained from the finite element solution to the problem. The results are given in two separate tables. Table 6-1 includes threshold rock sizes for crack-initiation in the waste package outer shell as a function of the remaining wall thickness. In this case, at least one containment shell remains intact for the specified rock size dynamic load. Table 6-2, on the other hand, presents threshold rock sizes for through-cracks in the waste package inner and outer shells as a function of the remaining wall thickness. Allowable stress limits were obtained from Ref. 5, *1995 American Society of Mechanical Engineers Boiler and Pressure Vessel Code*, Division 1, Appendix F, Article F-1341.2. The code requirement for the membrane stress (S_m) is that S_m shall be less than 0.7 times the material ultimate tensile strength, S_u . An upper limit is also set for the membrane plus bending stress (S_{m+b}) that shall be less than 0.9 times S_u . These requirements are summarized in terms of stress magnitudes in Table 6-1 and Table 6-2.

Table 6-1. Rock Fall Calculation Results (initiation of crack through WP outer shell)

Dynamic Impact Analysis at Different Levels of Degradation		Finite Element Representation Results to Initiate Crack on Waste Package Outer Shell					
Remaining Outer Shell Thickness (mm)		20 (z20-81)	18 (z18-81)	16 (z16-81)	10 (z10-81)	5 (z5-81)	3.5 (z3-82)
Remaining Inner Shell Thickness (mm)		50 (z20-80)	50 (z18-80)	50 (z16-80)	50 (z10-80)	50 (z5-80)	50 (z3-81)
Outer Shell	S_m	475 (m20-47)	477 (m18-47)	476 (m16-47)	464 (m10-47)	456 (m5-47)	442 (m3-47)
	Allowable S_m	483	483	483	483	483	483
	S_{m+b}	593 (m20-67)	580 (m18-67)	554 (m16-67)	501 (m10-67)	463 (m5-67)	445 (m3-67)
	Allowable S_{m+b}	621	621	621	621	621	621
Inner Shell	S_m	84 (m20-166)	105 (m18-166)	114 (m16-166)	63 (m10-166)	73 (m5-166)	80 (m3-166)
	Allowable S_m	362	362	362	362	362	362
	S_{m+b}	312 (m20-184)	245 (m18-184)	239 (m16-184)	323 (m10-184)	299 (m5-184)	382 (m3-184)
	Allowable S_{m+b}	465	465	465	465	465	465
Critical Rock Mass to Initiate Crack (metric tons)		13 (z20-6152)	12 (z18-6160)	11 (z16-6176)	9 (z10-6224)	7 (z5-6240)	6 (z3-4728)
Rock Size Radius for Critical Rock Mass Values (m)		1.11 (z20-79)	1.08 (z18-79)	1.05 (z16-79)	0.98 (z10-79)	0.90 (z5-79)	0.86 (z3-80)

 S_m : Membrane stress S_{m+b} : Membrane plus bending stress

Parentheses: (filename in Ref. 14 – line number)

All stresses in MPa

Table 6-2. Rock Fall Calculation Results (crack through both WP shells)

Dynamic Impact Analysis at Different Levels of Degradation		Finite Element Representation Results for Critical Rock Mass not to Cause Through Crack on Waste Package Shells					
Remaining Outer Shell Thickness (mm)		20 (z20t-81)	18 (z18t-81)	16 (z16t-81)	10 (z10t-81)	5 (z5t-81)	3.5 (z3t-82)
Remaining Inner Shell Thickness (mm)		50 (z20t-80)	50 (z18t-80)	50 (z16t-80)	50 (z10t-80)	50 (z5t-80)	50 (z3t-81)
Outer Shell	S_m	419 (m20t-47)	385 (m18t-47)	468 (m16t-47)	251 (m10t-47)	561 (m5t-47)	574 (m3t-47)
	Allowable S_m	483	483	483	483	483	483
	S_{m+b}	679 (m20t-67)	690 (m18t-67)	734 (m16t-67)	552 (m10t-67)	822 (m5t-65)	582 (m3t-67)
	Allowable S_{m+b}	621	621	621	621	621	621
Inner Shell	S_m	313 (m20t-166)	311 (m18t-166)	220 (m16t-166)	313 (m10t-166)	144 (m5t-166)	182 (m3t-166)
	Allowable S_m	362	362	362	362	362	362
	S_{m+b}	358 (m20t-184)	356 (m18t-184)	428 (m16t-184)	366 (m10t-184)	383 (m5t-184)	429 (m3t-184)
	Allowable S_{m+b}	465	465	465	465	465	465
Critical Rock Mass not to Cause Through Crack (metric tons)		45 (z20t-6152)	40 (z18t-6160)	34 (z16t-6176)	30 (z10t-6224)	22 (z5t-6240)	20 (z3t-4728)
Rock Size Radius for Critical Rock Mass Values (m)		1.68 (z20t-79)	1.61 (z18t-79)	1.53 (z16t-79)	1.47 (z10t-79)	1.32 (z5t-79)	1.28 (z3t-80)

S_m : Membrane stress
 S_{m+b} : Membrane plus bending stress
 Parentheses: (filename in Ref. 14 – line number)
 All stresses in MPa

7. ATTACHMENTS

Attachment I (6 pages): Document Input Reference Sheets

Attachment II (1 page): Single CRM 21-PWR WP design sketch

Attachment III has been moved to Ref. 14. The following is the list of electronic files including file names, dates, times, and sizes available in Ref. 14. Note that this is no longer an attachment to this document; the subject files are listed for information only.

File Name	Size	Type	Date/Time
i10.out	9KB	OUT File	07/29/1999 3:04 PM
i10t.out	69KB	OUT File	07/30/1999 8:40 AM
i16.out	10KB	OUT File	07/29/1999 3:05 PM
i16t.out	67KB	OUT File	07/29/1999 3:05 PM
i18.out	10KB	OUT File	07/29/1999 3:07 PM
i18t.out	10KB	OUT File	07/29/1999 3:07 PM
i20.out	10KB	OUT File	07/29/1999 3:08 PM
i20s.out	10KB	OUT File	07/29/1999 3:10 PM
i20t.out	10KB	OUT File	07/29/1999 3:13 PM
i3.out	12KB	OUT File	07/29/1999 3:11 PM
i3t.out	9KB	OUT File	07/29/1999 3:11 PM
i5.out	10KB	OUT File	07/29/1999 3:12 PM
i5t.out	68KB	OUT File	07/29/1999 3:12 PM
m10.out	10KB	OUT File	07/29/1999 3:04 PM
m10t.out	10KB	OUT File	07/30/1999 8:40 AM
m16.out	10KB	OUT File	07/29/1999 3:05 PM
m16t.out	10KB	OUT File	07/29/1999 3:05 PM
m18.out	10KB	OUT File	07/29/1999 3:07 PM
m18t.out	10KB	OUT File	07/29/1999 3:07 PM
m20.out	10KB	OUT File	07/29/1999 3:08 PM
m20s.out	10KB	OUT File	07/29/1999 3:10 PM
m20t.out	10KB	OUT File	07/29/1999 3:13 PM
m3.out	10KB	OUT File	07/29/1999 3:11 PM
m3t.out	10KB	OUT File	07/29/1999 3:11 PM
m5.out	10KB	OUT File	07/29/1999 3:12 PM
m5t.out	10KB	OUT File	07/29/1999 3:12 PM
pi10.out	13KB	OUT File	07/29/1999 3:04 PM
pi10t.out	13KB	OUT File	07/30/1999 8:40 AM
pi16.out	13KB	OUT File	07/29/1999 3:05 PM
pi16t.out	13KB	OUT File	07/29/1999 3:05 PM
pi18.out	13KB	OUT File	07/29/1999 3:07 PM
pi18t.out	13KB	OUT File	07/29/1999 3:07 PM
pi20.out	13KB	OUT File	07/29/1999 3:08 PM
pi20s.out	13KB	OUT File	07/29/1999 3:10 PM

File Name	Size	Type	Date/Time
pi20t.out	13KB	OUT File	07/29/1999 3:13 PM
pi3.out	13KB	OUT File	07/29/1999 3:11 PM
pi3t.out	13KB	OUT File	07/29/1999 3:11 PM
pi5.out	13KB	OUT File	07/29/1999 3:12 PM
pi5t.out	13KB	OUT File	07/29/1999 3:12 PM
pm10.out	12KB	OUT File	07/29/1999 3:04 PM
pm10t.out	12KB	OUT File	07/30/1999 8:40 AM
pm16.out	12KB	OUT File	07/29/1999 3:05 PM
pm16t.out	12KB	OUT File	07/29/1999 3:05 PM
pm18.out	12KB	OUT File	07/29/1999 3:07 PM
pm18t.out	12KB	OUT File	07/29/1999 3:07 PM
pm20.out	12KB	OUT File	07/29/1999 3:08 PM
pm20s.out	12KB	OUT File	07/29/1999 3:10 PM
pm20t.out	12KB	OUT File	07/29/1999 3:13 PM
pm3.out	12KB	OUT File	07/29/1999 3:11 PM
pm3t.out	12KB	OUT File	07/29/1999 3:11 PM
pm5.out	12KB	OUT File	07/29/1999 3:12 PM
pm5t.out	12KB	OUT File	07/29/1999 3:12 PM
z10.out	373KB	OUT File	07/29/1999 3:04 PM
z10t.out	1.435KB	OUT File	07/30/1999 8:40 AM
z16.out	380KB	OUT File	07/29/1999 3:05 PM
z16t.out	1.724KB	OUT File	07/29/1999 3:05 PM
z18.out	387KB	OUT File	07/29/1999 3:07 PM
z18t.out	453KB	OUT File	07/29/1999 3:07 PM
z20.out	386KB	OUT File	07/29/1999 3:08 PM
z20s.out	385KB	OUT File	07/29/1999 3:10 PM
z20t.out	468KB	OUT File	07/29/1999 3:13 PM
z3.out	331KB	OUT File	07/29/1999 3:11 PM
z3t.out	332KB	OUT File	07/29/1999 3:11 PM
z5.out	378KB	OUT File	07/29/1999 3:12 PM
z5t.out	1.150KB	OUT File	07/29/1999 3:12 PM

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DOCUMENT INPUT REFERENCE SHEET**

1. Document Identifier No./Rev.:		Change:	Title:						
CAL-EBS-ME-000001 REV 00		N/A	Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages						
Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a	American Society for Testing and Materials (ASTM) 1998. Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten	Section	N/A	5.1	(1) Density of Alloy N06022	N/A	N/A	N/A	N/A
1		7.1							
		Table 3	N/A	5.1	(2) Yield strength of Alloy N06022	N/A	N/A	N/A	N/A
1 (continued)	Alloy Plate, Sheet, and Strip. ASTM Designation: B 575-97. West Conshohocken, Pennsylvania: ASTM. TIC: 241816.	Table 3	N/A	5.1	(3) Tensile strength of Alloy N06022	N/A	N/A	N/A	N/A
		Table 3	N/A	5.1	(4) % elongation	N/A	N/A	N/A	N/A
		Table 1	N/A	5.1	(5) Chemical requirements	N/A	N/A	N/A	N/A
					Accepted data				
2	American Society for Metals (ASM) 1980. Metals Handbook Ninth Edition, Volume 3, Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals. Metals Park, Ohio: ASM. TIC: 209801.	Page 143	N/A	5.1	(1) Chemical composition	N/A	N/A	N/A	N/A
		Page 143	N/A	5.1	(2) Poisson's ratio for Alloy 625	N/A	N/A	N/A	N/A
		Page 755	N/A	5.1	(3) Poisson's ratio for 316 SS	N/A	N/A	N/A	N/A
					Accepted data				

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Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
2a	Haynes International 1988. Hastelloy Alloy C-22. Kokomo, Indiana: Haynes International, Inc. TIC: 239938	Page 14	N/A	5.1	(1) Modulus of elasticity This reference is pending for acceptance from DOE AMOPE. <i>See Section 6 for justification on input status.</i>	N/A	✓	N/A	N/A
3									
4	American Society for Testing and Materials 1994. Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens. ASTM Designation: G 1-90. Philadelphia, Pennsylvania: ASTM. TIC: 238771.	Table X1	N/A	5.1	(1) Density for Type 316 stainless steel Accepted data	N/A	N/A	N/A	N/A
5	American Society of Mechanical Engineers (ASME) 1995. ASME Boiler and Pressure Vessel Code. Section II. New York, New York: ASME. TIC: 238901.	Table TM-1	N/A	5.1	(1) Modulus of elasticity for 316 stainless steel	N/A	N/A	N/A	N/A
		Table Y-1	N/A	5.1	(2) Yield strength of 316 stainless steel.	N/A	N/A	N/A	N/A

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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a		Table U	N/A	5.1	(3) Tensile strength for 316 stainless steel Accepted data	N/A	N/A	N/A	N/A
5 (Cont'd)									
6	American Society for Testing and Materials 1997. Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels. ASTM Designation: A 240/A 240M-97a. West Conshohocken, Pennsylvania: ASTM. TIC: 239431.	Table 2	N/A	5.1	(1) % elongation of 316 stainless steel Accepted data	N/A	N/A	N/A	N/A
7	Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) 1997. Waste Package Design Basis Events. BBA000000-01717-0200-00037 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971006.0075.	Table 8-1	N/A	1	(1) Falling objects - side impact	N/A	N/A	N/A	N/A

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SHEET**

1. Document Identifier No./Rev.: CAL-EBS-ME-000001 REV 00		Change: N/A	Title: Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages						
Input Document		4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To			
2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	Meriam, J.L. and Kraige, L.G. 1987. Engineering Mechanics, Volume 1, Statics. Second Edition. Pages 441, 443. New York, New York: John Wiley and Sons. TIC: 241293.	Table D/1	N/A	3	(1) Coefficients of static and kinetic friction Accepted data	N/A	N/A	N/A	N/A
8									
9	CRWMS M&O 1998. Software Qualification Report for ANSYS V5.4, A Finite Element Code. CSCI: 30040 V5.4. DI: 30040-2003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980609.0847.	Entire document	N/A	4	(1) Qualification report for ANSYS V5.4	N/A	N/A	N/A	N/A
10	Doering, T.W. 1998. Qualification of ANSYS V5.4 on the WPO HP UNIX Workstations. Interoffice correspondence from T.W. Doering (CRWMS M&O) to Gregory Carlisle (CRWMS M&O), May 22, 1998, LV.WP.SMB.05/98-100. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980730.0147.	Entire document	N/A	4	(1) Qualification of ANSYS V5.4 on HP UNIX workstations	N/A	N/A	N/A	N/A

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2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	Pasupathi, Venkataraman 1999. Waste Package Structural Material. Interoffice correspondence from Venkataraman Pasupathi (CRWMS M&O) to T. W. Doering (CRWMS M&O), May 7, 1999, LV.WP.VP.05/99-073. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990518.0316.	Entire document	N/A	5.1	(1) Mechanical properties are the same for both 316NG and 316 SS	N/A	N/A	N/A	N/A
11									
12	CRWMS M&O 1995. ESF Ground Support Design Analysis. BABEE0000-01717-0200-00002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960409.0355.	Table V-1	N/A	5.1	(1) TSw2 rock density See Section 6 for justification on input status	N/A	✓	N/A	N/A
13	CRWMS M&O 1999. Waste Package Fabrication Process Report. BBA000000-01717-2500-00010 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990617.0237.	Page 21	N/A	5.2	(1) Shrink fit method meets the current requirement of the design	N/A	N/A	N/A	N/A

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CAL-EBS-ME-000001 REV 00		N/A	Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages						
Input Document		4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To			
2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	CRWMS M&O 1999. Electronic Files for Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages, CAL-EBS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. Compact disc. ACC: MOL.19990921.0095.	Entire document	N/A	6	ANSYS V5.4 input, output, and results files	N/A	N/A	N/A	N/A
14									
15	Doering, T.W. 1998. Qualification of ANSYS V5.4 on New WPO HP UNIX Workstation. Interoffice correspondence from T.W. Doering (CRWMS M&O) to Gregory Carlisle (CRWMS M&O), November 11, 1998, LV.WP.MML.11/98-220. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981217.0106.	Entire document	N/A	4	(1) Qualification of ANSYS V5.4 on New WPO HP UNIX Workstation	N/A	N/A	N/A	N/A
16	Doering, T.W. 1999. Qualification of ANSYS V5.4 on Three New WPO HP UNIX Workstations. Interoffice correspondence from T.W. Doering (CRWMS M&O) to Gregory Carlisle (CRWMS M&O), May 3, 1999, LV.WP.SMB.05/99-071. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990518.0322.	Entire document	N/A	4	(1) Qualification of ANSYS V5.4 on Three New WPO HP UNIX Workstations	N/A	N/A	N/A	N/A

DETAIL A

SECTION A-A

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY ROD
BASKET A-SIDEGUIDE	SA-516 K02700	10	27	32
BASKET A-STIFFENER	SA-516 K02700	10	0.72	64
BASKET B-SIDEGUIDE	SA-516 K02700	10	36	16
BASKET B-STIFFENER	SA-516 K02700	10	1.5	32
BASKET C-STIFFENER	SA-516 K02700	10	2.3	32
BASKET CORNER GUIDE	SA-516 K02700	10	42	16
FUEL BASKET A-PLATE	NEUTRONIT A 978	7	85	8
FUEL BASKET B-PLATE	NEUTRONIT A 978	7	85	8
FUEL BASKET C-PLATE	NEUTRONIT A 978	7	44	16
FUEL BASKET D-PLATE	SB-209 A96061 T4	5	21	8
FUEL BASKET E-PLATE	SB-209 A96061 T4	5	21	8
FUEL BASKET TUBE	SA-516 K02700	5	164	21
INNER SHELL	SA-240 (316NG)	50	8812	1
INNER SHELL LID	SA-240 (316NG)	95	1212	2
OUTER SHELL	SB-575 N06022	20	5464	1
OUTER SHELL LID	SB-575 N06022	25	398	2
WASTE PACKAGE ASSEMBLY	-	-	25619	1
PWR FUEL ASSEMBLY	-	-	773.4	21
WP ASSEMBLY WITH SNF	-	-	41860	1

* CRWMS M&O 1997. WASTE CONTAINER CAVITY SIZE DETERMINATION. BBA00000-01717-0200-00026 REV 00.
LAS VEGAS, NV: CRWMS M&O. ACC: MOL.19980106.0061

SECTION B-B

REVISION 03

ITEM NUMBER	ITEM
1	Ø130 LIFTING FEATURE WAS Ø125 ON TOP VIEW
2	5464 OUTER SHELL MASS WAS 5445 ON DATA TABLE
3	25619 WASTE PACKAGE ASSEMBLY MASS WAS 25600 ON DATA TABLE
4	41860 WP ASSEMBLY WITH SNF WAS 41841 ON DATA TABLE
5	5335 WASTE PACKAGE ASSEMBLY LENGTH WAS 5325 ON SECTION A-A
6	240 SKIRT LENGTH WAS 235 ON DETAIL A
7	345 FLARED SKIRT LENGTH WAS 340 ON DETAIL A
8	265 SKIRT END TO LID LENGTH WAS 260 ON SECTION A-A
9	360 SKIRT END TO INNER LID LENGTH WAS 355 ON SECTION A-A

UNITS: mm

DO NOT SCALE FROM SKETCH

"FOR INFORMATION ONLY"

SINGLE CRM 21-PWR WASTE PACKAGE

SKETCH NUMBER: SK-0132 REV 03

SKETCHED BY: BRYAN HARKINS

DATE: 07/16/99

FILE: /home/pro.library/checkout/sketches/21pwr.home/sk-0132.rev03/sk-0132.rev03.dwg

16 July 99
BH
SMB
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