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CONTENTS

	Page
1. PURPOSE.....	5
2. METHOD	5
3. ASSUMPTIONS.....	5
4. USE OF COMPUTER SOFTWARE AND MODELS	7
4.1 SOFTWARE.....	7
4.2 SOFTWARE ROUTINES	7
4.3 MODELS	8
5. CALCULATION	8
5.1 MATERIAL PROPERTIES	8
5.2 CALCULATIONS FOR TANGENT MODULI	10
5.3 MASS AND GEOMETRIC DIMENSIONS OF MCO.....	11
5.4 MASS AND GEOMETRIC DIMENSIONS OF DHLW GLASS CANISTER.....	11
5.4.1 Calculation of Density of DHLW Glass Canister.....	11
5.5 INITIAL VELOCITY OF WASTE PACKAGE	12
5.6 FINITE ELEMENT REPRESENTATION	14
6. RESULTS	16
7. REFERENCES	17
8. ATTACHMENTS.....	19

FIGURES

	Page
1. Tip-Over Geometry	12
2. Tip-Over Orientation (Cross-Sectional View - Case 1)	14
3. Tip-Over Orientation (Cross-Sectional View - Case 2)	14

TABLES

Page

1. File Names, Dates, Times, and Sizes	19
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1. PURPOSE

The objective of this calculation was to determine the structural response of multi-canister overpacks (MCO) and the 2-MCO/2-Defense High-Level Waste (DHLW) Waste Package (WP) subjected to tip-over onto an unyielding surface (US). The scope of this calculation was limited to reporting the calculation results in terms of maximum stress intensities. This calculation is associated with the waste package design and was performed by the Waste Package Design Section in accordance with the *DOE SNF Analysis Plan for FY 2000* (See Ref. 6). AP-3.12Q, Revision 0, ICN 2, *Calculations*, was used to perform the calculation and develop the document (See Ref. 15).

2. METHOD

The finite element calculation was performed by using the commercially available ANSYS Version (V) 5.4 and LS-DYNA V950 finite element codes. The results of this calculation were provided in terms of maximum stress intensities. The control of this document was accomplished in accordance with AP-6.1Q, *Controlled Documents* (Ref. 16), which provides for electronic source file verification. In process work is controlled through the checking process, which is governed by AP-3.12Q, *Calculations* (Ref. 15). The transmittal of the final product was conducted over established Yucca Mountain Project electronic infrastructure (e.g., e-mail, network servers). The fidelity of these systems was provided by other organizations and procedures. These controls meet the intent of AP-SV.1Q, *Control of the Electronic Management of Data* (Ref. 17).

3. ASSUMPTIONS

In the course of developing this document, the following assumptions were made regarding the WP structural calculations.

- 3.1 Some of the temperature-dependent material properties were not available for SB-575 N06022 (Alloy 22), SA-240 S31600 (316NG [nuclear grade] stainless steel [SS]), SA-516 K02700 (516 carbon steel [CS]), and SA-240 S30403 (304L SS). Therefore, room-temperature (20 °C) material properties were assumed for all materials. The impact of using room-temperature material properties was anticipated to be small. The rationale for this assumption was that the mechanical properties of these materials do not change significantly at the temperatures experienced during handling and lifting operations. This assumption was used in Section 5.1.
- 3.2 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. The impact of using material properties obtained under static loading conditions was anticipated to be small. The rationale for this assumption was that the mechanical properties of subject materials do not significantly change at the peak strain rates in the course of the tip-over. This assumption was used in Section 5.1.

- 3.3 The Poisson's ratio of Alloy 22 was not available in literature. Therefore, the Poisson's ratio of Alloy 625 (SB-443 N06625) was assumed for Alloy 22. The impact of this assumption was anticipated to be negligible. The rationale for this assumption was that the chemical compositions of Alloy 22 and Alloy 625 are similar (see Ref. 3 and Ref. 1, respectively). This assumption was used in Section 5.1.
- 3.4 The target surface was conservatively assumed to be unyielding with a large elastic modulus for the target surface material compared to the WP materials. The rationale for this assumption was that a bounding set of results was required in terms of stresses, and it was known that the use of an US with high stiffness ensures slightly higher stresses in the WP. This assumption was used in Section 5.6.
- 3.5 The exact geometry of the MCO internals was simplified for the purpose of this calculation in such a way that its total mass, 8746.4 kg minus the mass of the external shell (see Section 5.3), was assumed to be distributed as mass elements along the inner wall of the MCO. The rationale for this conservative assumption was to provide the set of bounding results, while simplifying the finite element representation (FER). This assumption was used in Section 5.6.
- 3.6 The exact geometry of the DHLW Glass Canister was simplified for the purpose of this calculation in such a way that its total mass, 4200 kg (see Section 5.4), was assumed to be distributed within a cylinder with uniform mass density. The rationale for this conservative assumption was to provide the set of bounding results, while simplifying the FER. This assumption was used in Section 5.6.
- 3.7 Poisson's ratio was not available for 516 CS. Therefore, Poisson's ratio of cast carbon steel was assumed for 516 CS. The impact of this assumption was anticipated to be negligible. The rationale for this assumption was that the elastic constants of cast carbon steels are only slightly affected by changes in composition and structure (see Ref. 2). This assumption was used in Section 5.1.
- 3.8 The Poisson's ratio of 304L SS was not available in literature. Therefore, the Poisson's ratio of 304 SS was assumed for 304L SS. The impact of this assumption was anticipated to be negligible. The rationale for this assumption was that the chemical compositions of 304L SS and 304 SS are similar (see Ref. 3 and Ref. 8, respectively). This assumption was used in Section 5.1.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE

One of the finite element analysis computer codes used for this calculation is ANSYS V5.4, which was obtained from Software Configuration Management in accordance with appropriate procedures, and is identified by the Computer Software Configuration Item (CSCI) 30040 V5.4. ANSYS V5.4 is a commercially available finite element analysis code and is appropriate for structural calculations of waste packages as performed in this calculation. The calculation using the ANSYS V5.4 software was executed on the Hewlett-Packard (HP) workstation identified with CRWMS M&O (Civilian Radioactive Waste Management System Management and Operating Contractor) tag number 700315. The software qualification of ANSYS V5.4 was summarized in Reference 5. Qualification of ANSYS V5.4 on the Waste Package Operations (WPO) HP UNIX workstations was documented in Reference 10. The ANSYS evaluation performed for this calculation is fully within the range of the validation performed for the ANSYS V5.4 code. Access to the code was granted by the Software Configuration Secretariat in accordance with the appropriate procedures.

The input files (identified by .inp file extensions) and output files (identified by .out file extensions) for ANSYS V5.4 are provided in Attachments IV, V, and VI.

The second finite element analysis computer code, used for this calculation is Livermore Software Technology Corporation (LSTC) LS-DYNA V950, which is unqualified software (see Ref. 7). The interim use of LS-DYNA V950 (SAN: LV-2000-103, STN: 10300-950-00) in support of the site recommendation is delineated in Section 5.11 of AP-SI.1Q, *Software Management*, (Ref. 18). LS-DYNA V950 qualification is being performed as part of the qualification of ANSYS V5.6 since LS-DYNA V950 is available both as a component (module) of ANSYS and as a separate finite element code. Currently, Waste Package Department licensed LS-DYNA V950 directly from LSTC. Software Activity Plan (SAP) for ANSYS V5.6, SDN: 10145-SAP-5.6-00, SAN: LV-1999-124, identifies the intended use of LS-DYNA V950 prior to qualification. LS-DYNA V950 was obtained from the Software Configuration Secretariat. LS-DYNA V950 is appropriate for its intended use. LS-DYNA V950 validation will be performed in accordance with AP-SI.1Q, *Software Management*, Section 5.11. The calculations were executed on a Hewlett-Packard (HP) 9000 series workstation (CRWMS M&O tag number 117162).

The input files (identified by .k and .inc file extensions) and output files (d3hsp) for LS-DYNA V950 are provided in Attachments IV, V, and VI.

4.2 SOFTWARE ROUTINES

None used.

4.3 MODELS

None used.

5. CALCULATION

5.1 MATERIAL PROPERTIES

Material properties used in this calculation are listed in this section. Some of the temperature-dependent and rate-dependent material properties were not available for Alloy 22, 316NG SS, 516 CS, and 304L SS. Therefore, room-temperature material properties obtained under the static loading conditions were used in this calculation (Assumptions 3.1 and 3.2).

SB-575 N06022 (Alloy 22) (Outer shell, outer shell lids, extended outer shell lid base, outer shell lifting features, upper and lower trunnion collar sleeves, and inner shell support ring):

- Density = 8690 kg/m^3 (0.314 lb/in^3) (Ref. 3, SB-575 Section 7.1)
- Yield strength = 310 MPa (45 ksi) (Ref. 3, SB-575 Table 3)
- Tensile strength = 690 MPa (100 ksi) (Ref. 3, SB-575 Table 3)
- Elongation = 0.45 (Ref. 3, SB-575 Table 3)
- Poisson's ratio = 0.278 (Ref. 1, p. 143; see Assumption 3.3)
- Modulus of elasticity = 206 GPa ($29.9 \cdot 10^6 \text{ psi}$) (Ref. 11, p. 14)

SA-240 S31600 (see Ref. 3) (Identical to ASTM A 240) (316NG SS, which is 316 SS with tightened control on carbon and nitrogen content and has the same material properties as 316 SS [see Ref. 12]) (Inner shell, inner shell lids, and inner shell lifting feature):

- Density = 7980 kg/m^3 (Ref. 4, p. 7)
- Yield strength = 205 MPa (30 ksi) (Ref. 3, SA-240 Table 2)
- Tensile strength = 515 MPa (75 ksi) (Ref. 3, SA-240 Table 2)
- Elongation = 0.40 (Ref. 3, SA-240 Table 2)
- Poisson's ratio = 0.3 (Ref. 1, Figure 15, p. 755)

- Modulus of elasticity = 195 *GPa* ($28.3 \cdot 10^6$ *psi*) (Ref. 3, Table TM-1)

SA-516 K02700 (A-Plate dividers and MCO support stand):

- Density = 7850 *kg/m*³ (Ref. 3, SA-20/SA20M, Section 14.1)
- Yield strength = 262 *MPa* (38 *ksi*) (Ref. 3, Section D, Table Y-1)
- Tensile strength = 483 *MPa* (70 *ksi*) (Ref. 3, Section D, Table U)
- Elongation = 0.21 (Ref. 3, SA-516, Table 2)
- Poisson's ratio = 0.3 (Ref. 2, p. 374; see Assumption 3.7)
- Modulus of elasticity = 203 *GPa* ($29.5 \cdot 10^6$ *psi*) (Ref. 3, Section D, Table TM-1)

SA-240 S30403 (see Ref. 3) (Identical to ASTM A 240) (304L SS) (MCO):

- Density = 7940 *kg/m*³ (Ref. 4, Table X1, p. 7)
- Yield strength = 170 *MPa* (25 *ksi*) (Ref. 3, SA-240, Table 2)
- Tensile strength = 485 *MPa* (70 *ksi*) (Ref. 3, SA-240, Table 2)
- Elongation = 0.40 (Ref. 3, SA-240, Table 2)
- Poisson's ratio = 0.3 (Ref. 1, Figure 15, p. 755; see Assumption 3.8)
- Modulus of elasticity = 195 *GPa* ($28.3 \cdot 10^6$ *psi*) (Ref. 3, Section D, Table TM-1)

5.2 CALCULATIONS FOR TANGENT MODULI

The results of this simulation are required to include elastic and plastic deformations for Alloy 22, 316NG SS, 516 CS, and 304L SS. When the materials are driven into the plastic range, the slope of stress-strain curve continuously changes. Thus, a simplification for this curve is needed to incorporate plasticity into the FER. A standard approximation commonly used in engineering is to use a straight line that connects the yield point and the ultimate tensile strength point of the material. The following parameters were used in the subsequent calculations:

S_y = yield strength

S_u = tensile strength

e_y = strain corresponding to yield strength

e_u = elongation (strain corresponding to tensile strength)

E = modulus of elasticity

E_t = tangent modulus (slope of the stress-strain curve in the plastic region)

In the case of 316NG SS, the strain corresponding to the yield strength is:

$$e_y = S_y / E = 205 \cdot 10^6 / 195 \cdot 10^9 = 1.051 \cdot 10^{-3} \text{ (see Section 5.1)}$$

Hence, the tangent modulus is:

$$E_t = (S_u - S_y) / (e_u - e_y) = (0.515 - 0.205) / (0.40 - 1.051 \cdot 10^{-3}) = 0.777 \text{ GPa (see Section 5.1)}$$

Similarly, for Alloy 22:

$$E_t = (S_u - S_y) / (e_u - e_y) = (0.690 - 0.310) / (0.45 - 0.310/206) = 0.847 \text{ GPa (see Section 5.1)}$$

For 516 CS:

$$E_t = (S_u - S_y) / (e_u - e_y) = (0.483 - 0.262) / (0.21 - 0.262/203) = 1.059 \text{ GPa (see Section 5.1)}$$

And for 304L SS:

$$E_t = (S_u - S_y) / (e_u - e_y) = (0.485 - 0.170) / (0.40 - 0.170/195) = 0.789 \text{ GPa (see Section 5.1)}$$

5.3 MASS AND GEOMETRIC DIMENSIONS OF MCO

This calculation was performed by using the following mass and geometric dimensions of the MCO:

Total mass = 8746.4 *kg* (19,242 *lbs*) (Ref. 14, Table 4-1, p. 33)

Outer diameter = 60.92 *cm* (23.985 *in*) (Ref. 14, Figure 4-1, p. 24)

Inner diameter = 58.382 *cm* (22.985 *in*) (Ref. 14, Figure 4-1, p.24)

Overall length = 422.707 *cm* (166.420 *in*) (Ref. 14, Figure 4-1, p. 24)

Inner cavity length = 356.545 *cm* (166.420 *in*) (Ref. 14, Figure 4-1, p.24)

Upper lid diameter = 64.287 *cm* (25.310 *in*) (Ref. 14, Figure 4-1, p.24)

Shell bottom thickness = 5.11 *cm* (2.01 *in*) (Ref. 14, Section 4.1, p.23)

5.4 MASS AND GEOMETRIC DIMENSIONS OF DHLW GLASS CANISTER

This calculation was performed by using the following mass and geometric dimensions of the DHLW glass canister:

Total mass = 4200 *kg* (Ref. 19, Table I-1, p. 10)

Outer diameter = 61.0 *cm* (Ref. 19, Table I-1, p. 10)

Overall length = 4.5 *m* (Ref. 19, Table I-1, p. 10)

5.4.1 Calculation of Density of DHLW Glass Canister

This calculation was performed by using the following density of the DHLW glass canister.

$$\text{Volume} = \pi \cdot r^2 \cdot h = \pi \cdot \left(\frac{0.61}{2} \right)^2 \cdot 4.5 = 1.315 \text{ m}^3$$

$$\text{Density} = \frac{m}{v} = \frac{4200}{1.315} = 3193.649 \frac{\text{kg}}{\text{m}^3}$$

5.5 INITIAL VELOCITY OF WASTE PACKAGE

To reduce the computer execution time while preserving all features of the problem relevant to the structural calculation, the WP is set in a position just before impact and given an appropriate initial angular velocity.

Figure 1. Tip-Over Geometry

Using the following parameters:

g = acceleration due to gravity = 9.81 m/s^2

M = total mass = $4.715 \cdot 10^4 \text{ kg}$ (Attachment VI, d3hsp, line 32333)

mass moment of inertia about z axis located at the center of gravity (I_z) was calculated using LS-DYNA V950 with the unyielding surface omitted (see Attachment VI). LS-DYNA V950 calculates the mass properties of the FER prior to solving the problem. The following results block was taken in the exact format from Attachment VI, d3hsp, lines 32332 through 32341:

```

m a s s   p r o p e r t i e s   o f   b o d y
total mass of body           =      .4715E+05
x-coordinate of mass center =      .8786E+00
y-coordinate of mass center =      .2527E+01
z-coordinate of mass center =     -.1362E-05

inertia tensor of body
row1=      .1062E+06      -.2982E+05      .1026E+04
row2=     -.2982E+05      .3079E+05      -.3571E+03
row3=      .1026E+04     -.3571E+03      .1165E+06

```

In this case, the WP is rotating about the z axis, thus $I_z = I_{zz} = 1.165 \cdot 10^5 \text{ kg} \cdot \text{m}^2$

The following geometric parameters were also used in subsequent calculations:

$x = 0.879 \text{ m}$ = distance in the x direction to the center of gravity from the origin

$y = 2.523 \text{ m}$ = distance in the y direction to the center of gravity from the origin

Since this forms a right triangle:

$$l = \sqrt{x^2 + y^2} = \sqrt{0.879^2 + 2.523^2} = 2.672 \text{ m}$$

$w = \frac{1}{2}$ the outer diameter of the trunnion collar sleeve = 0.907m (Attachment I-1)

Again, since this forms a right triangle:

$$c = \sqrt{l^2 + w^2} = \sqrt{2.672^2 + 0.907^2} = 2.822 \text{ m}$$

Also,

$$\gamma = \text{angle necessary for tip-over} = \tan^{-1}\left(\frac{w}{l}\right) = 19^\circ$$

Using the parallel axis theorem, the mass moment of inertia about the point of rotation:

$$I = I_z + Mc^2 = 1.165 \cdot 10^5 + 4.715 \cdot 10^4 \cdot 2.822^2 = 4.920 \cdot 10^5 \text{ kg} \cdot \text{m}^2$$

Using Newton's second law of motion:

$$\sum M = I \cdot \alpha$$

$M \cdot g \cdot c \cdot \cos\theta = I \cdot \alpha$, where θ is the angle of rotation and α is the rotational acceleration
it follows that:

$$\alpha = \frac{M \cdot g \cdot c \cdot \cos\theta}{I} = \frac{4.715 \cdot 10^4 \cdot 9.81 \cdot 2.822 \cdot \cos\theta}{4.920 \cdot 10^5} = 2.653 \cdot \cos\theta$$

Knowing:

$v = \frac{ds}{dt}$ and $a = \frac{dv}{dt}$, where s is displacement, v is velocity, and a is acceleration, velocity in terms of acceleration can be found by rearranging and substituting:

$$dt = \frac{dv}{a}$$

$$v = \frac{ds}{\frac{dv}{a}}$$

$$v \cdot \frac{dv}{a} = ds$$

Thus: $v \cdot dv = a \cdot ds$ or for rotational velocity: $\omega \cdot d\omega = \alpha \cdot d\theta$

Integrating over angle of tip-over:

$$\int_0^{\omega} \omega \cdot d\omega = \int_{\frac{\pi}{2}}^{\gamma} \alpha \cdot d\theta$$

$$\frac{\omega^2}{2} = 2.657 \cdot (\sin \theta) \Big|_{\frac{\pi}{2}}^{\gamma} = 2.657 \cdot \left[-\sin \left(19 \cdot \frac{\pi}{180} \right) + \sin \left(\frac{\pi}{2} \right) \right] = 1.79$$

$$\omega = 1.89 \frac{\text{rad}}{\text{s}}$$

5.6 FINITE ELEMENT REPRESENTATION

A full three-dimensional (3-D) FER of the WP was developed in ANSYS V5.4 by using the dimensions provided in Attachment I. The FER was created with the largest possible radial gap of 4 mm between the inner and outer shells (Ref. 8). The initial orientation of the inner shell maintains this 4-mm gap around the circumference of the shell. This gap results in a slightly lower total mass of the WP than that listed in Attachment I, which shows a nominal 0-mm radial gap between the inner and outer shells, but the difference is small and the impact was anticipated to be negligible. The internal structure of the WP was simplified in several ways. First, the A-plate dividers were created as shell elements with an assigned thickness of 10 mm. Next, the internals of the MCO were reduced to mass elements uniformly distributed along the inner walls of the MCO (Assumption 3.5). Finally, the structure of the DHLW glass canisters was reduced to cylinders of uniform mass density and assumed to be unyielding (Assumption 3.6). The total mass and geometric dimensions of the DHLW canister (see Section 5.3) define the density. The benefit of using this approach was to reduce the computer execution time while preserving all features of the problem relevant to the structural calculation.

Figure 2. Tip-Over Orientation (Cross-Sectional View - Case 1)

Figure 3. Tip-Over Orientation (Cross-Sectional View - Case 2)

The MCOs and DHLW glass canisters were oriented in the waste package, such that they were diagonally across from each other (see Figure 2). This provides a center of gravity close to the geometric center of the waste package. The tip-over calculation was performed for two different initial configurations. This was done to find the most critical tip-over orientation of the two limiting configurations. The first configuration was oriented, such that one MCO and one DHLW canister were at the bottom and the same set on top, with the vertical A-plate divider being perpendicular to the unyielding surface (see Figure 2). The second configuration was oriented, such that one MCO was directly at the bottom of the WP and the DHLW canisters were at the sides (see Figure 3).

The target surface was conservatively assumed to be unyielding with a large elastic modulus (Assumption 3.4).

The mesh of the FER was appropriately generated and refined in the contact region according to standard engineering practice. Thus, the accuracy and representativeness of the results of this calculation were deemed acceptable.

The initial tip-over angle was reduced to 0.1° and the WP was given an initial angular velocity corresponding to the rigid-body motion of the WP (see Section 5.5).

The FER was then used in LS-DYNA V950 to perform the transient dynamic analysis for the 2-MCO/2-DHLW WP tip-over design basis event.

6. RESULTS

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

The results obtained from LS-DYNA V950 were reported in terms of maximum shear stress. Since the maximum stress intensities were desired, the results needed to be translated. The maximum shear stress is defined as one half the difference between maximum and minimum principal stress. Stress intensity is defined as the difference between maximum and minimum principal stress. Therefore, the results obtained from LS-DYNA V950 were multiplied by two, to obtain the corresponding stress intensities.

The maximum stresses were found by carefully examining each time step taken by LS-DYNA V950, which outputs the element with the highest magnitude of stress, at each step, for each defined part. The results show that the maximum stress intensities occurred in the first case for each part, except for the upper trunnion collar sleeve. The maximum stress intensities were in the upper trunnion collar sleeve with a magnitude of 532 *MPa* (see Figure III-9), which exceeded the yield strength, but was less than the tensile strength of Alloy 22 (see Section 5.1). However, the upper trunnion collar sleeve was not part of the containment barrier. It acted as an impact limiter for the containment barrier in this case. The maximum stress intensity in the outer shell had a magnitude of 429 *MPa* (see Figure III-4), which exceeded the yield strength, but was less than the tensile strength of Alloy 22 (see Section 5.1).

The maximum stress intensity in the inner shell was 325 *MPa* (see Figure III-5). Again, the yield strength was exceeded, but the magnitude was less than the tensile strength of 316NG SS (see Section 5.1).

For the A-plate dividers, the maximum stress intensity was 437 *MPa* (see Figure III-6), which exceeded the yield strength, but was less than the tensile strength of 516 CS (see Section 5.1).

The maximum stress intensity in the MCO outer shell occurred in the MCO placed in the bottom and had a magnitude of 226 *MPa* (see Figure III-7), which exceeded the yield strength, but was less than the tensile strength of 304L SS (see Section 5.1). Also, the MCO placed on the bottom in the first case, received the most deformation. Looking at the elements placed on the top side of the outer shell in the region of most deformation, A through D in Figure III-8, and those on the bottom side of the MCO, E through H in Figure III-8, the maximum deflection was approximately 19 *mm*.

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8. ATTACHMENTS

Attachment I (3 pages): Design sketches (*2-MCO/2-DHLW Waste Package Configuration for Site Recommendation* [SK-0198 REV 03]; three sheets)
(This attachment uses References 13 and 17, and Attachment II)

Attachment II (1 page): Weld configuration sketches (*2-MCO/2-DHLW Waste Package Weld Configuration* [SK-0199 REV 01]; one sheet)

Attachment III (13 pages): Figures obtained from LS-DYNA V950

Attachments IV, V, and VI (Compact Disc):

ANSYS V5.4 and LS-DYNA V950 electronic files. Table 1 contains a list of Attachments IV, V, and VI in electronic form including names, dates, times, and sizes of files available on compact disc.

Table 1. File Names, Dates, Times, and Sizes

Attachment IV			
Name	Date	Time	Size
nreact5.inp	06/15/2000	10:50 am	31 KB
main1.k	06/15/2000	10:46 am	3 KB
element.inc	06/15/2000	10:46 am	893 KB
nodes.inc	06/15/2000	10:46 am	910 KB
bcnodes.inc	06/15/2000	10:46 am	1 KB
d3hsp	06/15/2000	10:46 am	4.66 MB
case1.out	06/15/2000	10:50 am	564 KB
Attachment V			
Name	Date	Time	Size
nreact6.inp	06/15/2000	10:51 am	31 KB
main2.k	06/15/2000	10:47 am	3 KB
element2.inc	06/15/2000	10:47 am	893 KB
nodes2.inc	06/15/2000	10:47 am	910 KB
bcnodes2.inc	06/15/2000	10:47 am	1 KB
d3hsp	06/15/2000	10:47 am	4.63 MB
case2.out	06/15/2000	10:51 am	564 KB
Attachment VI			
Name	Date	Time	Size
nreactNU.inp	06/15/2000	10:54 am	30 KB
main.k	06/15/2000	10:48 am	2 KB
element.inc	06/15/2000	10:48 am	879 KB
nodes.inc	06/15/2000	10:48 am	892 KB
bcnodes.inc	06/15/2000	10:48 am	2 KB
d3hsp	06/15/2000	10:48 am	2.20 MB
nouy.out	06/15/2000	10:54 am	557 KB

NOTE: The file sizes may vary with operating system.

WASTE PACKAGE DEPARTMENT			
M&O Civilian Radioactive Waste Management System			
MANAGEMENT & OPERATING CONTRACTOR			
SKETCH NUMBER	SK-0198		REVISION
SCALE			03
			SHEET 2

SEE DETAIL A

SECTION A-A

SEE DETAIL B

DETAIL A

REVISION TABLE			
REV	DESCRIPTION	OWN BY	DATE
00	ISSUED APPROVED	BH	03/08/00
01	FUEL SUPPORT ASSEMBLY WELD ADDED TO WP ASSEMBLY	BH	05/09/00
01	WELD SYMBOL FOR FUEL SUPPORT ASSEMBLY WELD ADDED TO DETAIL B	BH	05/09/00
01	FUEL SUPPORT ASSEMBLY WELD ADDED TO WELD TABLE AS WELD 11	BH	05/09/00
01	TOTAL CARBON STEEL WELDS ADDED TO WELD TABLE	BH	05/09/00
01	LOCATION OF DETAIL B FROM SECTION A-A WAS MODIFIED	BH	05/09/00

WELD	MATERIAL	MASS (KG)	QTY ROD
1	SFA-5.14 N06022	15	1
2	SFA-5.14 N06022	38	1
3	SFA-5.14 N06022	107	1
4	SFA-5.14 N06022	3.5	2
5	SFA-5.14 N06022	4.2	1
6	SFA-5.9 S31680	82	2
7	SFA-5.14 N06022	15	2
8	SFA-5.14 N06022	9.1	2
9	SFA-5.14 N06022	15	1
10	SFA-5.14 N06022	41	1
11	SFA-5.18 K10726	0.19	2
TOTAL ALLOY 22 WELDS .		SFA-5.14 N06022	276
TOTAL 316 WELDS		SFA-5.9 S31680	164
TOTAL CARBON STEEL WELDS		SFA-5.18 K10726	0.38

DETAIL B

"FOR INFORMATION ONLY"

UNITS: mm

DO NOT SCALE FROM SKETCH

2-MCO / 2-DHLW WASTE PACKAGE WELD CONFIGURATION

SKETCH NUMBER: SK-0199 REV 01

SKETCHED BY: BRYAN HARKINS

DATE:

05/09/00

FILE:

/home/pro_library/checkout/sketches/2mco_2dhlw/sk-0199rev01.dwg

Handwritten notes:
 BH
 24 May 00
 SMB
 05/24/00
 WES/24 May 00

Time = 0.00059995

Figure III-1. Cross-Sectional View of Finite Element Representation of the 2-MCO/2-DHLW with A-Plate Dividers

Time = 0.00059995

Figure III-2. Cross-Sectional View of Finite Element Representation of the 2-MCO/2-DHLW without A-Plate Dividers Showing MCO and DHLW

Time = 0.0054
Contours of Maximum Shear Stress
max ipt. value
min=22774.5, at elem# 5631
max=2.6433e+08, at elem# 4717

Fringe Levels

2.643e+08
2.379e+08
2.115e+08
1.850e+08
1.586e+08
1.322e+08
1.057e+08
7.931e+07
5.288e+07
2.645e+07
2.277e+04

Figure III-3. Shear Stress Plot of Complete Waste Package (Case 1)

Time = 0.0055998
Contours of Maximum Shear Stress
max ipt. value
min=2.33086e+06, at elem# 8878
max=2.14325e+08, at elem# 3365

Fringe Levels

2.143e+08
1.931e+08
1.719e+08
1.507e+08
1.295e+08
1.083e+08
8.713e+07
6.593e+07
4.473e+07
2.353e+07
2.331e+06

Figure III-4. Shear Stress Plot of Outer Shell and Lids (Case 1)

Time = 0.0077998
Contours of Maximum Shear Stress
max ipt. value
min=2.0433e+06, at elem# 1403
max=1.62486e+08, at elem# 517

Fringe Levels

1.625e+08
1.464e+08
1.304e+08
1.144e+08
9.831e+07
8.226e+07
6.622e+07
5.018e+07
3.413e+07
1.809e+07
2.043e+06

Figure III-5. Shear Stress Plot of Inner Shell and Inner Lid (Case 1)

Time = 0.0138
 Contours of Maximum Shear Stress
 max ipt. value
 min=1.07774e+07, at elem# 163
 max=2.18576e+08, at elem# 5659

Fringe Levels

2.186e+08
 1.978e+08
 1.770e+08
 1.562e+08
 1.355e+08
 1.147e+08
 9.390e+07
 7.312e+07
 5.234e+07
 3.156e+07
 1.078e+07

Figure III-6. Shear Stress Plot of A-Plate Dividers (Case 1)

Time = 0.0097999
Contours of Maximum Shear Stress
max ipt. value
min=842165, at elem# 11021
max=1.12968e+08, at elem# 4996

Fringe Levels

1.130e+08
1.018e+08
9.054e+07
7.933e+07
6.812e+07
5.691e+07
4.569e+07
3.448e+07
2.327e+07
1.205e+07
8.422e+05

Figure III-7. Shear Stress Plot of MCOs (Case 1)

Figure III-8. Time History of MCO Deformation in Y Direction (Case 1)

Time = 0.0053998
Contours of Maximum Shear Stress
max ipt. value
min=79684.2, at elem# 11271
max=2.66037e+08, at elem# 4545

Fringe Levels

2.660e+08
2.394e+08
2.128e+08
1.862e+08
1.597e+08
1.331e+08
1.065e+08
7.987e+07
5.327e+07
2.668e+07
7.968e+04

Figure III-9. Shear Stress Plot of Complete Waste Package (Case 2)

Time = 0.0057997
Contours of Maximum Shear Stress
max ipt. value
min=910188, at elem# 8562
max=2.10593e+08, at elem# 2733

Fringe Levels

2.106e+08
1.896e+08
1.687e+08
1.477e+08
1.267e+08
1.058e+08
8.478e+07
6.382e+07
4.285e+07
2.188e+07
9.102e+05

Figure III-10. Shear Stress Plot of Outer Shell and Lids (Case 2)

Time = 0.0053998
Contours of Maximum Shear Stress
max ipt. value
min=242947, at elem# 6661
max=1.54701e+08, at elem# 861

Fringe Levels

1.547e+08
1.393e+08
1.238e+08
1.084e+08
9.292e+07
7.747e+07
6.203e+07
4.658e+07
3.113e+07
1.569e+07
2.429e+05

Figure III-11. Shear Stress Plot of Inner Shell and Inner Lid (Case 2)

Time = 0.0176
Contours of Maximum Shear Stress
max ipt. value
min=8.24913e+06, at elem# 49
max=2.06097e+08, at elem# 32

Fringe Levels

2.061e+08
1.863e+08
1.665e+08
1.467e+08
1.270e+08
1.072e+08
8.739e+07
6.760e+07
4.782e+07
2.803e+07
8.249e+06

Figure III-12. Shear Stress Plot of A-Plate Dividers (Case 2)

Time = 0.0142
Contours of Maximum Shear Stress
max ipt. value
min=1.19623e+06, at elem# 5388
max=1.0865e+08, at elem# 5015

Fringe Levels

1.087e+08
9.790e+07
8.716e+07
7.641e+07
6.567e+07
5.492e+07
4.418e+07
3.343e+07
2.269e+07
1.194e+07
1.196e+06

Figure III-13. Shear Stress Plot of MCOs (Case 2)

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SPECIAL INSTRUCTION SHEET

1. QA: QA

Page: 1 of: 1

Complete Only Applicable Items

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