OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: QA

Page: 1 Of: 19

2. Calculation Title
Tip-Over of the 2-MCO/2-DHLW Waste Package on Unyielding Surface

3. Document Identifier (including Revision Number)
CAL-EDC-ME-000002 REV 00

4. Total Attachments
6

5. Attachment Numbers - Number of pages in each
I-3, II-1, III-13, Attachments IV,V, & VI are electronic files provided on compact disc

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9. Remarks

Revision History

10. Revision No.	11. Description of Revision
00	Initial Issue

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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* ($29.9 \cdot 10^6$ *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_1 = 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:

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

Hence, the tangent modulus is:

$E_1 = (S_u - S_y)/(e_u - e_y) = (0.515 - 0.205)/(0.40 - 1.051 \cdot 10^{-3}) = 0.777\ GPa$ (see Section 5.1)

Similarly, for Alloy 22:

$E_1 = (S_u - S_y)/(e_u - e_y) = (0.690 - 0.310)/(0.45 - 0.310/206) = 0.847\ GPa$ (see Section 5.1)

For 516 CS:

$E_1 = (S_u - S_y)/(e_u - e_y) = (0.483 - 0.262)/(0.21 - 0.262/203) = 1.059\ GPa$ (see Section 5.1)

And for 304L SS:

$E_1 = (S_u - S_y)/(e_u - e_y) = (0.485 - 0.170)/(0.40 - 0.170/195) = 0.789\ GPa$ (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.

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

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

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.

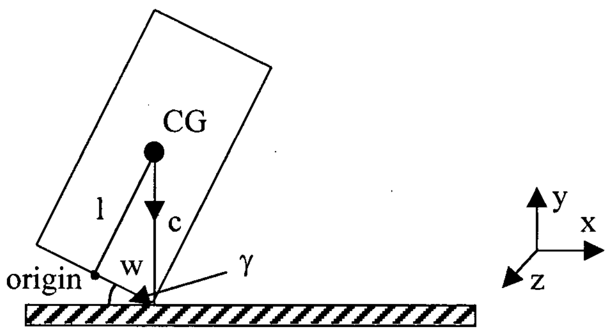


Figure 1. Tip-Over Geometry

Using the following parameters:

g = acceleration due to gravity $= 9.81\ m/s^2$
M = total mass $= 4.715 \cdot 10^4\ kg$ (Attachment VI, d3hsp, line 32333)

mass moment of inertia about z axis located at the center of gravity (Iz) 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 Iz = Izz $= 1.165 \cdot 10^5\ kg \cdot m^2$

The following geometric parameters were also used in subsequent calculations:

$x = 0.879\ m$ = distance in the x direction to the center of gravity from the origin
$y = 2.523\ m$ = distance in the y direction to the center of gravity from the origin

Since this forms a right triangle:

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

w = ½ the outer diameter of the trunnion collar sleeve = 0.907*m* (Attachment I-1)

Again, since this forms a right triangle:

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

Also,

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

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

$$I = Iz + Mc^2 = 1.165 \cdot 10^5 + 4.715 \cdot 10^4 \cdot 2.822^2 = 4.920 \cdot 10^5\ kg \cdot m^2$$

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:

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

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

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

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.

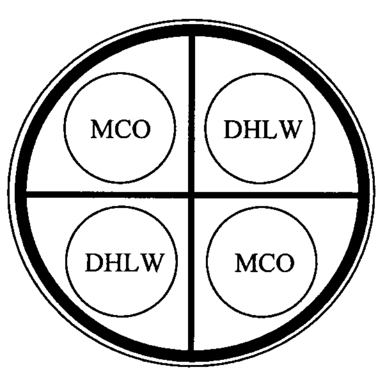


Figure 2. Tip-Over Orientation (Cross-Sectional View - Case 1)

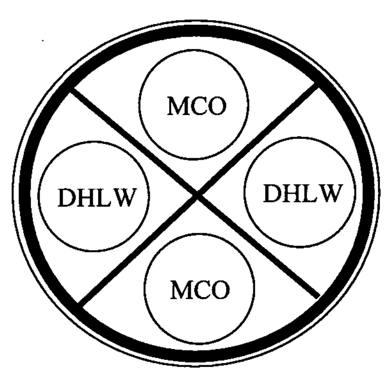


Figure 3. Tip-Over Orientation (Cross–Sectional View - Case 2)

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*.

7. REFERENCES

1. American Society for Metals 1980. *Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals.* Volume 3 of *Metals Handbook.* 9th Edition. Metals Park, Ohio: American Society for Metals. TIC: 209801.

2. ASM International 1990. *Properties and Selection: Irons, Steels, and High-Performance Alloys.* Volume 1 of *Metals Handbook.* 10th Edition. Materials Park, Ohio: ASM International. TIC: 245666.

3. ASME (American Society of Mechanical Engineers) 1995. "Materials." Section II of *1995 ASME Boiler and Pressure Vessel Code.* New York, New York: American Society of Mechanical Engineers. TIC: 245287.

4. ASTM G 1-90 (Reapproved 1999). 1990. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 238771.

5. 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.

6. CRWMS M&O 2000. *DOE SNF Analysis Plan for FY 2000.* Development Plan TDP-EDC-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000510.0169.

7. CRWMS M&O 2000. *Software Code: LSTC LS-DYNA.* V950. HP 9000. 10300-950-00. URN-0368

8. CRWMS M&O 2000. *Waste Package Operations Fabrication Process Report.* TDR-EBS-ND-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000217.0244.

9. DOE (U.S. Department of Energy) 1999. *Waste Acceptance System Requirements Document.* DOE/RW-0351, Rev. 03. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19990226.0001.

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 G. Carlisle, May 22, 1998, LV.WP.SMB.05/98-100. ACC: MOL.19980730.0147.

11. Haynes International 1997. *Hastelloy C-22 Alloy.* Kokomo, Indiana: Haynes International. TIC: 238121.

12. Pasupathi, V. 1999. "Waste Package Structural Material." Interoffice correspondence from V. Pasupathi (CRWMS M&O) to T.W. Doering, May 7, 1999, LV.WP.VP.05/99-073. ACC: MOL.19990518.0316.

13. Smith, K.E. 1997. *Multi-Canister Overpack Design Report.* HNF-SD-SNF-DR-003, Rev. 0. Richland, Washington: Duke Engineering Services Hanford. ACC: MOL.19980625.0219.

14. Taylor, L.L. 2000. *N Reactor (U-metal) Fuel Characteristics for Disposal Criticality Analysis.* DOE/SNF/REP-056. Idaho Falls, Idaho: Bechtel BWXT Idaho, LLC. TIC: 247956.

15. AP-3.12Q, Rev. 0, ICN 2. *Calculations.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000620.0068.

16. AP-6.1Q, Rev. 5, ICN 0. *Controlled Documents.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000608.0009.

17. AP-SV.1Q, Rev. 0, ICN 1. *Control of the Electronic Management of Data.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL. 20000512.0068.

18. AP-SI.1Q, Rev. 2, ICN 4. *Software Management.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000223.0508.

19. CRWMS M&O 1999. *Defense High Level Waste Disposal Container System Description Document.* SDD-DDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991217.0510.

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)

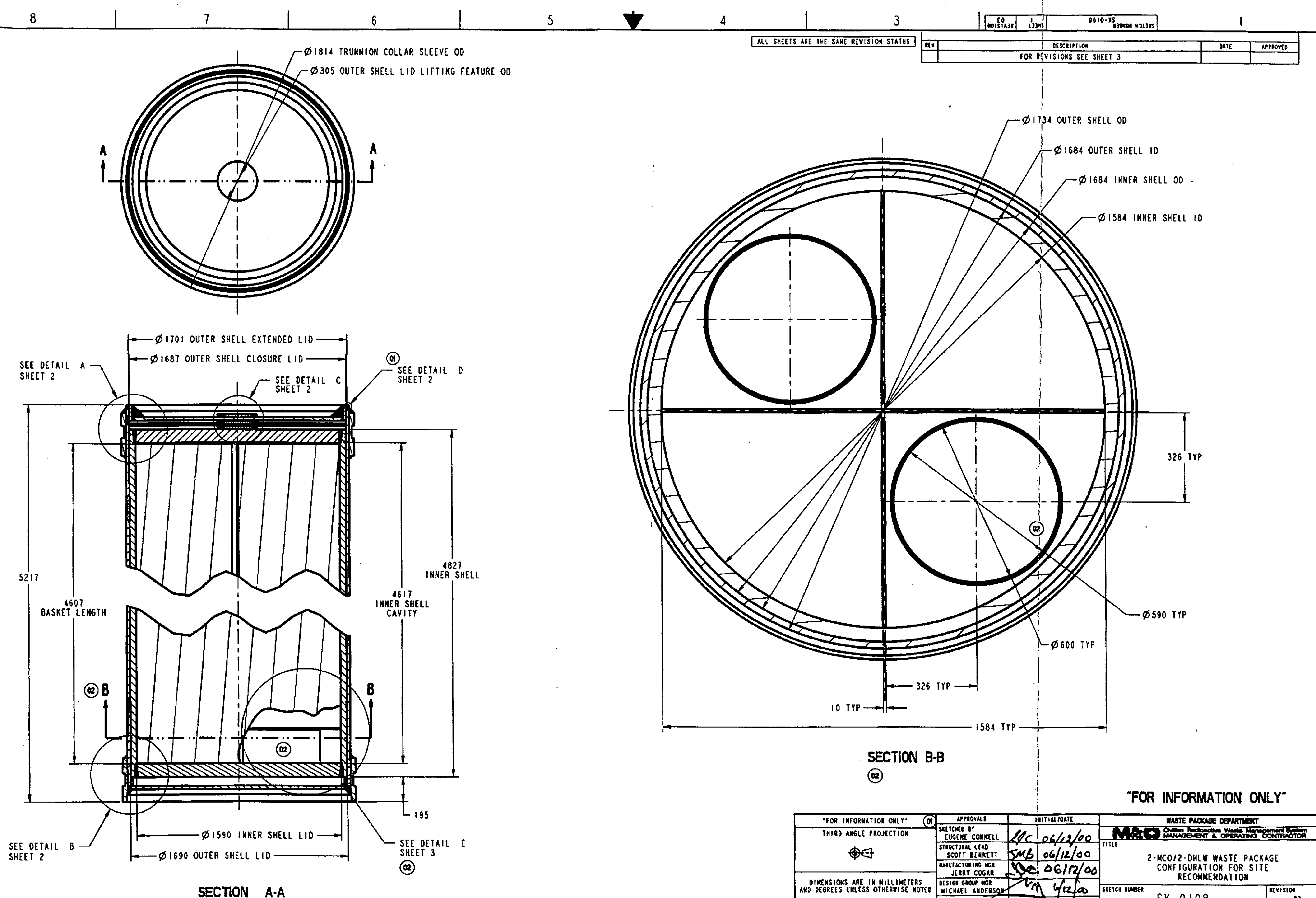
Attachment III (13 pages): Figures obtained from LS-DYNA V950

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

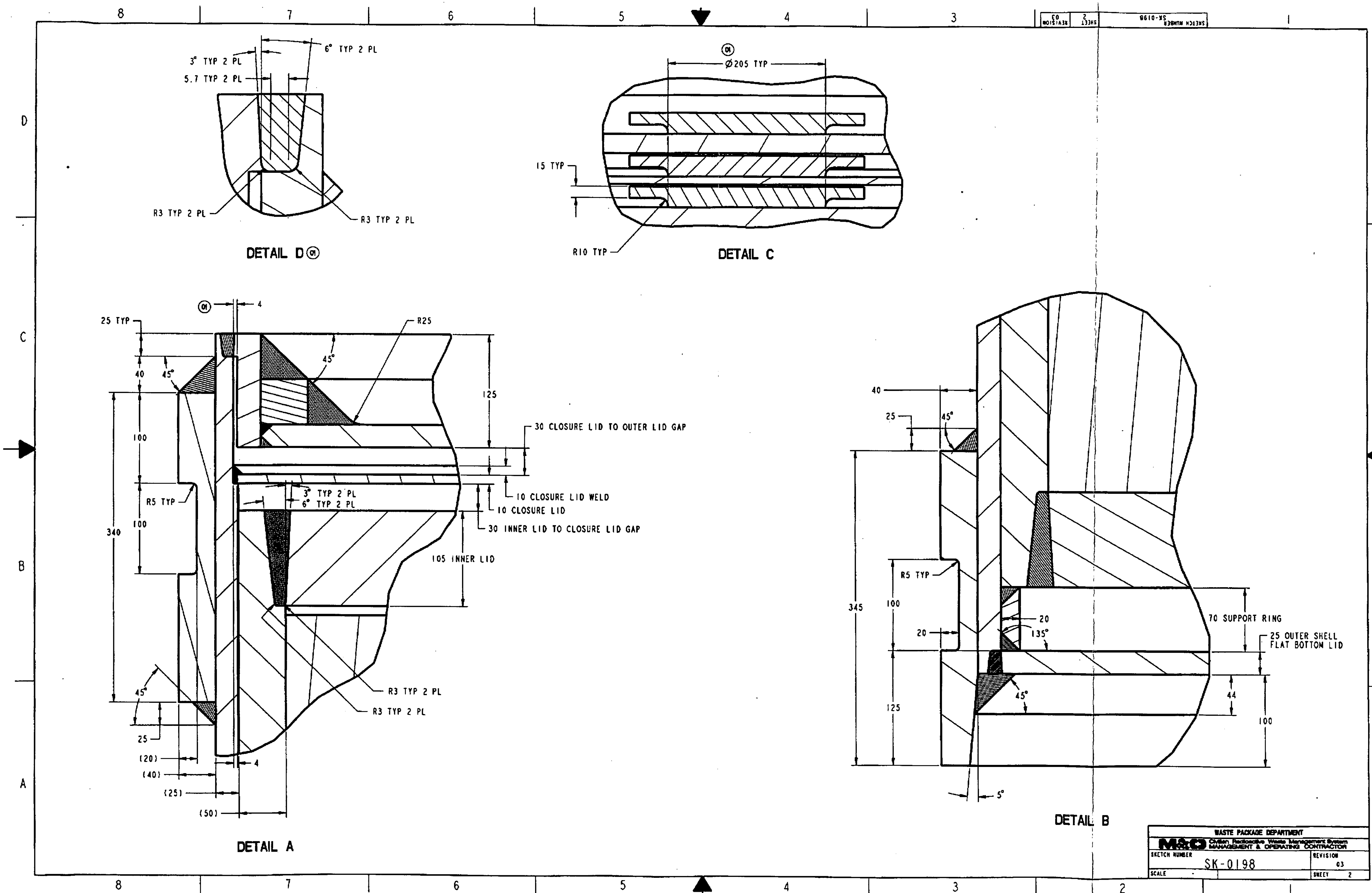
Attachment IV			
Name	**Date**	**Time**	**Size**
nreact5.inp	06/15/2000	10:50 am	31 KB
main1.k	06/15/2000	10:46 am	3 KB
element.inc	06/15/2000	10:46 am	893 KB
nodes.inc	06/15/2000	10:46 am	910 KB
bcnodes.inc	06/15/2000	10:46 am	1 KB
d3hsp	06/15/2000	10:46 am	4.66 MB
case1.out	06/15/2000	10:50 am	564 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.



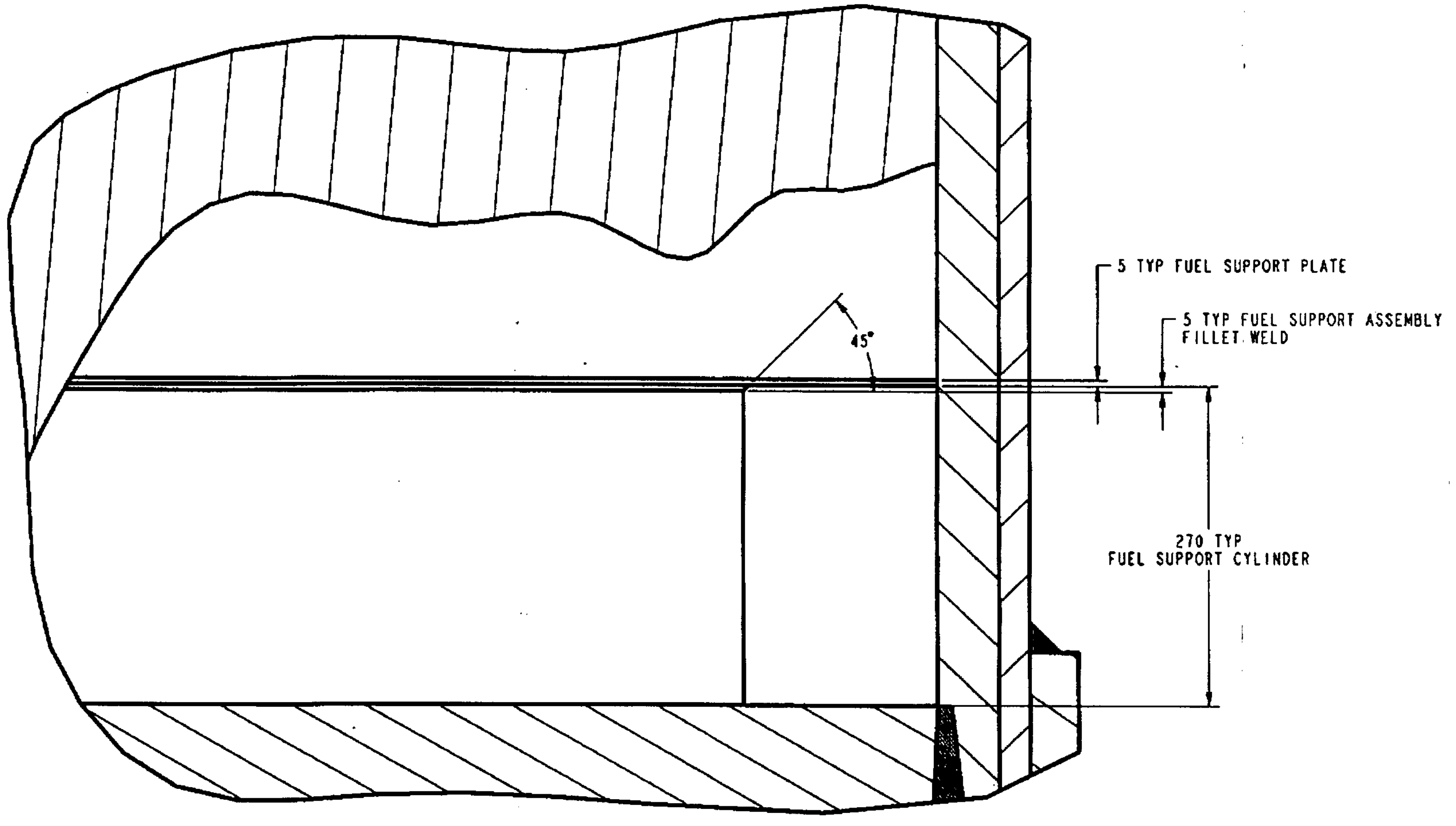
"FOR INFORMATION ONLY"

"FOR INFORMATION ONLY" (01)	APPROVALS	INITIAL/DATE	WASTE PACKAGE DEPARTMENT
THIRD ANGLE PROJECTION	SKETCHED BY EUGENE CONNELL	EJC 06/12/00	M&O Civilian Radioactive Waste Management System MANAGEMENT & OPERATING CONTRACTOR
	STRUCTURAL LEAD SCOTT BENNETT	SMB 06/12/00	TITLE 2-MCO/2-DHLW WASTE PACKAGE CONFIGURATION FOR SITE RECOMMENDATION
DIMENSIONS ARE IN MILLIMETERS AND DEGREES UNLESS OTHERWISE NOTED	MANUFACTURING MGR JERRY COGAR	JC 06/12/00	SKETCH NUMBER SK-0198
DO NOT SCALE FROM SKETCH	DESIGN GROUP MGR MICHAEL ANDERSON	MA 6/12/00	REVISION 03 / SCALE .08 / SHEET 1


3° TYP 2 PL
6° TYP 2 PL
5.7 TYP 2 PL
R3 TYP 2 PL
R3 TYP 2 PL
DETAIL D
Ø205 TYP
15 TYP
R10 TYP
DETAIL C
25 TYP
4
R25
45°
40
45°
125
100
30 CLOSURE LID TO OUTER LID GAP
R5 TYP
3° TYP 2 PL
6° TYP 2 PL
10 CLOSURE LID WELD
10 CLOSURE LID
30 INNER LID TO CLOSURE LID GAP
340
100
105 INNER LID
R3 TYP 2 PL
R3 TYP 2 PL
45°
25
(20)
4
(40)
(25)
(50)
DETAIL A
40
25
45°
R5 TYP
345
100
20
20
135°
70 SUPPORT RING
25 OUTER SHELL FLAT BOTTOM LID
45°
44
125
100
5°
DETAIL B
WASTE PACKAGE DEPARTMENT
M&O
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
SKETCH NUMBER
SK-0198
REVISION
03
SCALE
SHEET 2

REVISION TABLE

REV	DESCRIPTION	DRW BY	DATE
00	ISSUED APPROVED	DM	01/25/00
01	MASS 9743 "WAS" 9730, MASS 1641 "WAS" 1647, MASS 5897 "WAS" 4670, MASS 561 "WAS" 558, MASS 550 "WAS" 547, MASS 276 "WAS" 274, MASS 23801 "WAS" 21846, MASS 49300 "WAS" 48066, THICKNESS 25 "WAS" 20, SKETCHED BY "WAS" ORIGINATOR, "CREATED" DETAIL D, "ADDED" Ø TO DETAIL C, "DELETED" WELD DIMENSIONS FROM DETAIL A	BH	03/09/00
02	MASS 23159 "WAS" 23081, MASS 49378 "WAS" 49300, "ADDED" FUEL SUPPORT ASSEMBLY, "MODIFIED COMPONENTS LIST, "CREATED" DETAIL E, MOVED COMPONENTS LIST TO SHEET 3, "MOVED" REVISION TABLE TO SHEET 3, "MODIFIED REVISION TABLE FORMAT, "ADDED" DIMENSIONS TO SECTION B-B,	BH	05/18/00
03	DOE/RW-0351 "WAS" DOE/RW-0315P, "ADDED" NEW FORMAT, "MODIFIED" REVISION TABLE	EJC	06/09/00



DETAIL E

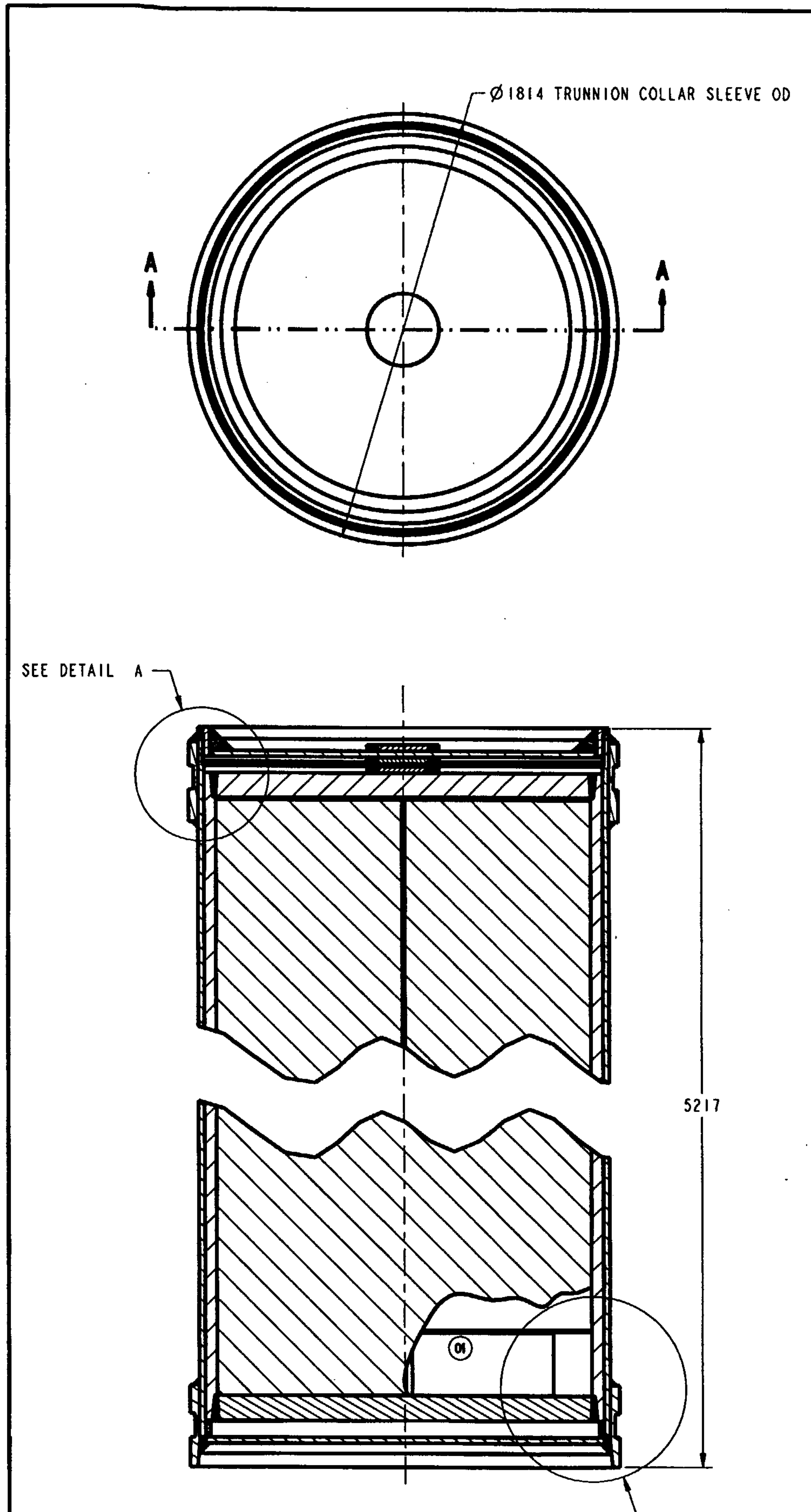
COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY RQD
A-PLATE	SA-516 K02700	10	571	2
(02) FUEL SUPPORT PLATE	SA-516 K02700	5	19	2
(02) FUEL SUPPORT CYLINDER	SA-516 K02700	5	20	2
INNER SHELL	SA-240 S31600	50	(01) 9743	1
INNER SHELL LID	SA-240 S31600	105	(01) 1641	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	(01) 25	(01) 5897	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	146	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	450	1
EXTENDED OUTER LID REINFORCING RING	SB-575 N06022	50	108	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	194	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	484	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	(01) 561	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	(01) 550	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	45	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	(01) 276	***
TOTAL 316 WELDS	SFA-5.9 S31680	-	164	***
(02) TOTAL CARBON STEEL WELDS	SFA-5.18 K10726	-	0.37	***
WASTE PACKAGE ASSEMBLY	-	- (01)	(02) 23159	1
HLW GLASS ASSEMBLY	-	-	4200*	2
MCO	-	-	8909.6**	2
WP ASSEMBLY WITH SNF	-	- (01)	(02) 49378	1

* WASTE ACCEPTANCE SYSTEM REQUIREMENTS DOCUMENT. E00000000-00811-1708-00001 REV 03, (03) DOE/RW-0351. ACC: HQO.19990226.0001, PAGE 18, SECTION 4.2.3.1.A.4.

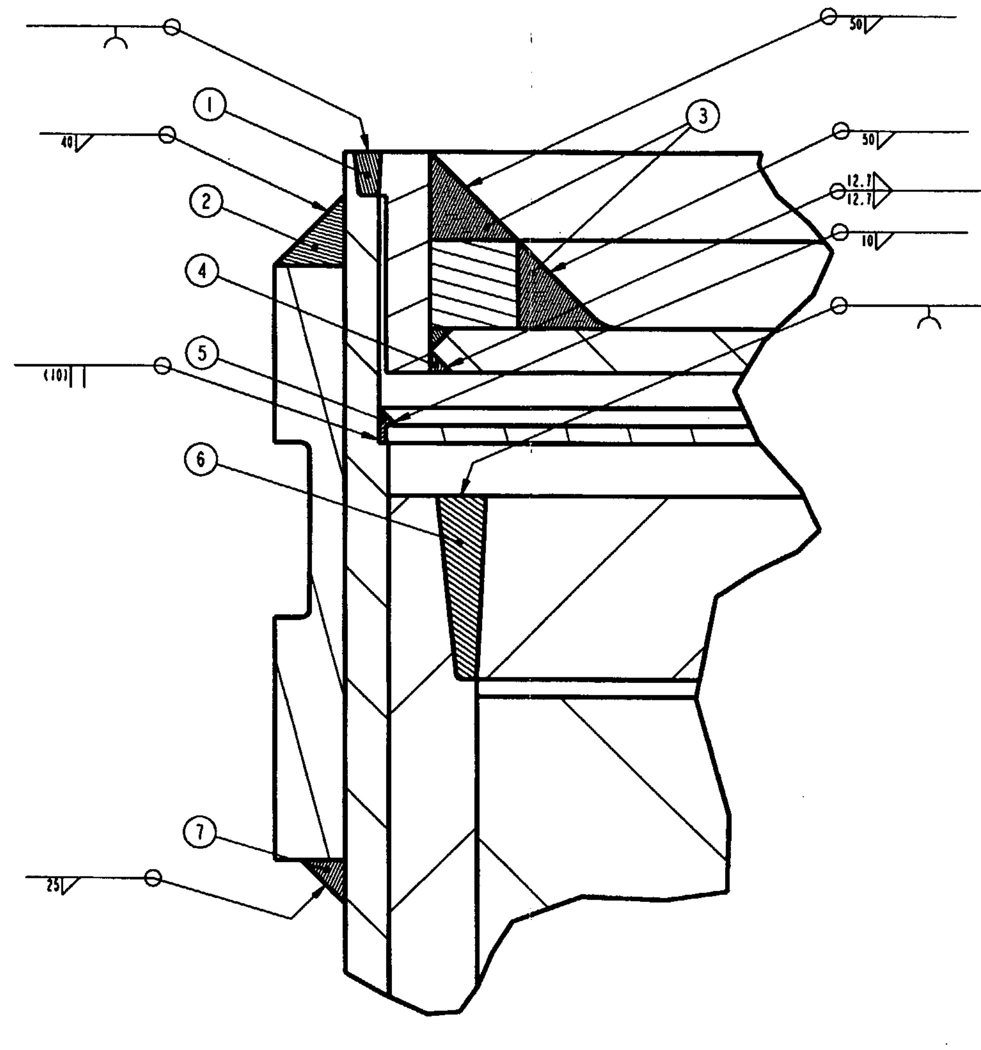
** DES HANFORD 1997. MULTI-CANISTER OVERPACK DESIGN REPORT. HNF-SD-SNF-DR-003 REV 0. JUNE 9, 1997. RICHLAND, WASHINGTON: U.S. DEPARTMENT OF ENERGY, RICHLAND OPERATIONS OFFICE, DUKE ENGINEERING SERVICES HANFORD, INC. ACC: MOL.19980625.0219.

*** SEE SK-0199 FOR WELD CONFIGURATION AND MASSES.

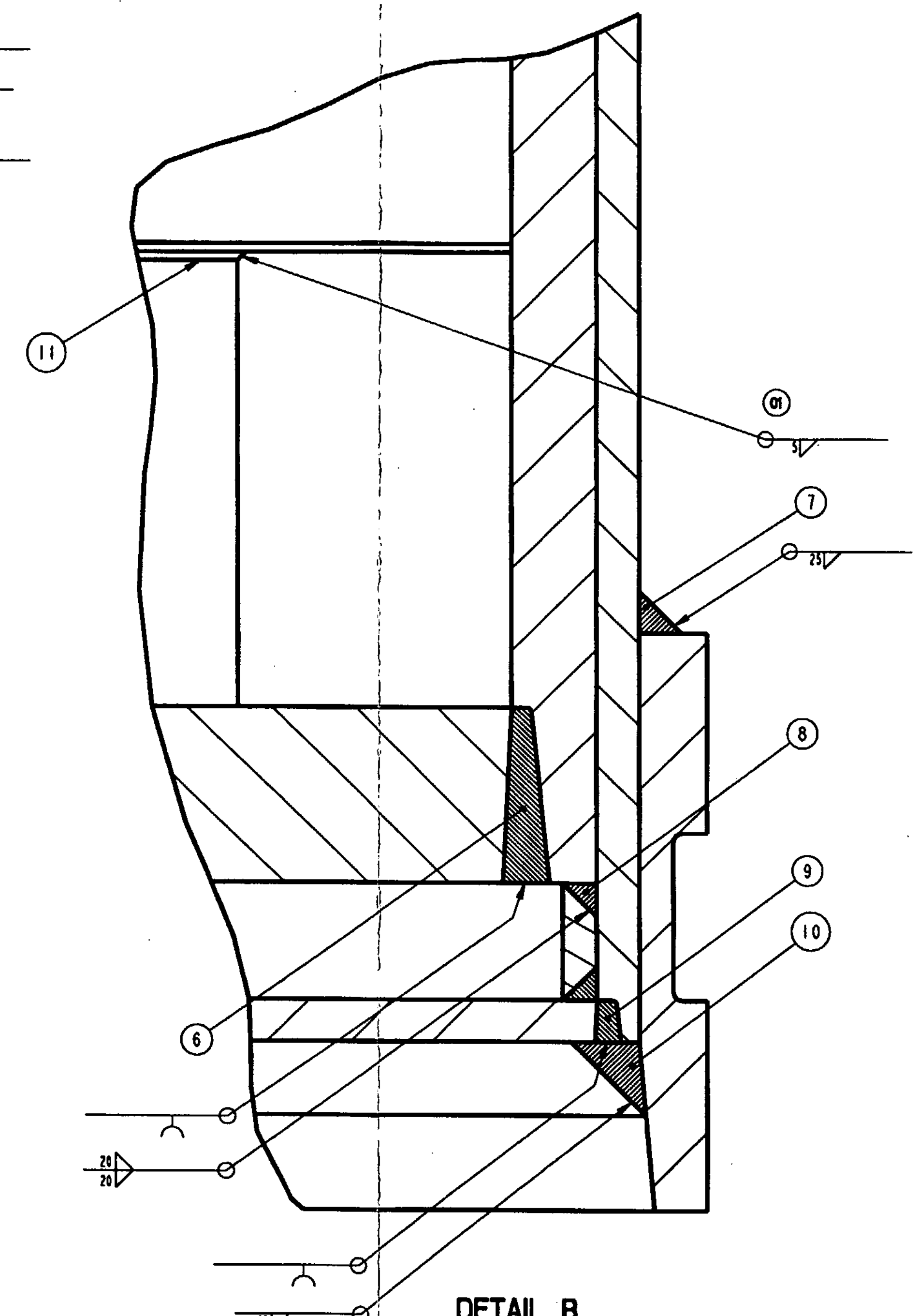
WASTE PACKAGE DEPARTMENT	
M&O Civilian Radioactive Waste Management System MANAGEMENT & OPERATING CONTRACTOR	
SKETCH NUMBER SK-0198	REVISION 03
SCALE .40	SHEET 3



SECTION A-A



DETAIL A



DETAIL B

REVISION TABLE			
REV	DESCRIPTION	DRW 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 RQD
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
(01) 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	-
(01) TOTAL CARBON STEEL WELDS	SFA-5.18 K10726	0.38	-

UNITS: mm

DO NOT SCALE FROM SKETCH

"FOR INFORMATION ONLY"

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

BH 24May00 SMB 05/24/00 5/24/00

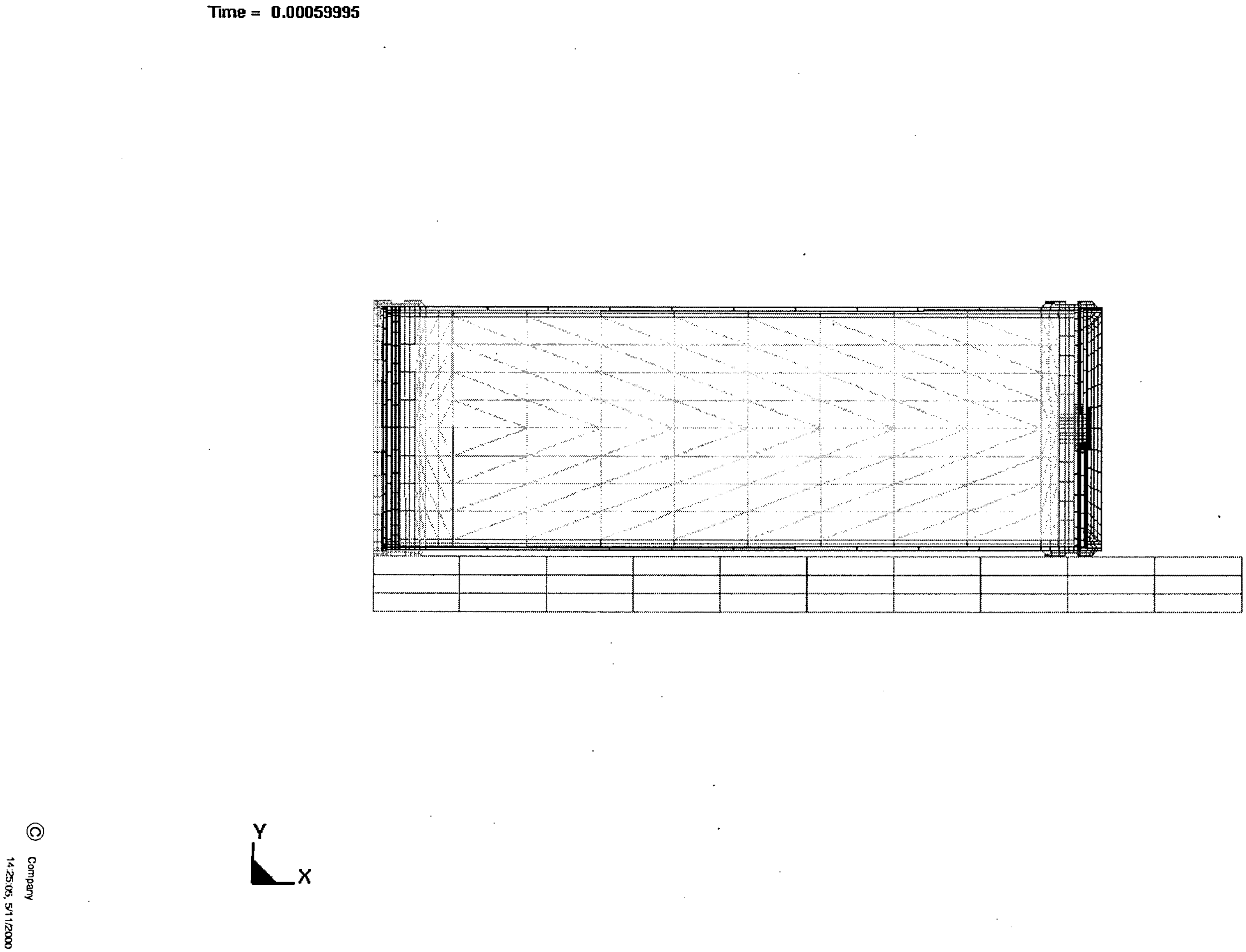


Figure III-1. Cross-Sectional View of Finite Element Representation of the 2-MCO/2-DHLW with A-Plate Dividers

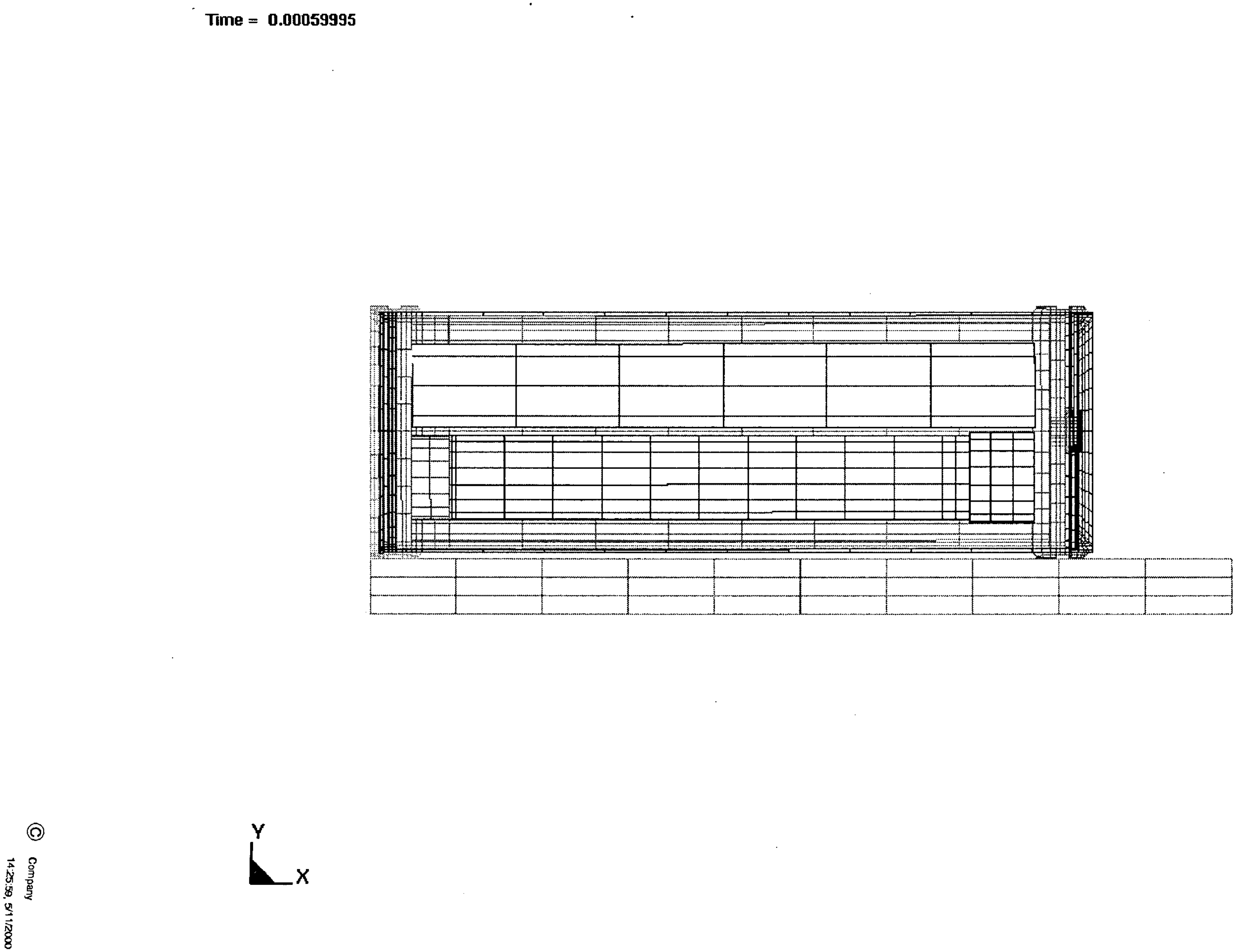


Figure III-2. Cross-Sectional View of Finite Element Representation of the 2-MCO/2-DHLW without A-Plate Dividers Showing MCO and DHLW

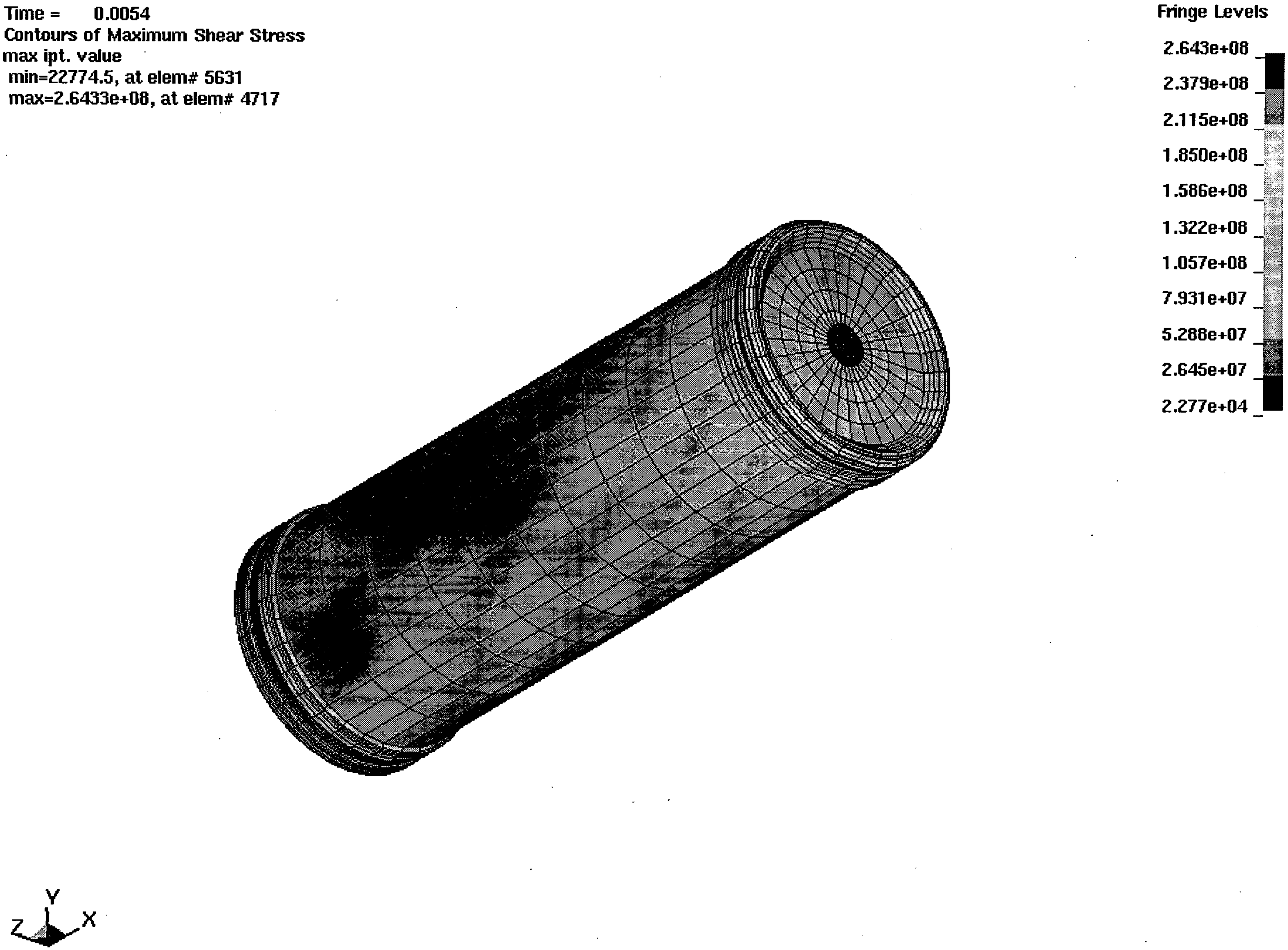


Figure III-3. Shear Stress Plot of Complete Waste Package (Case 1)

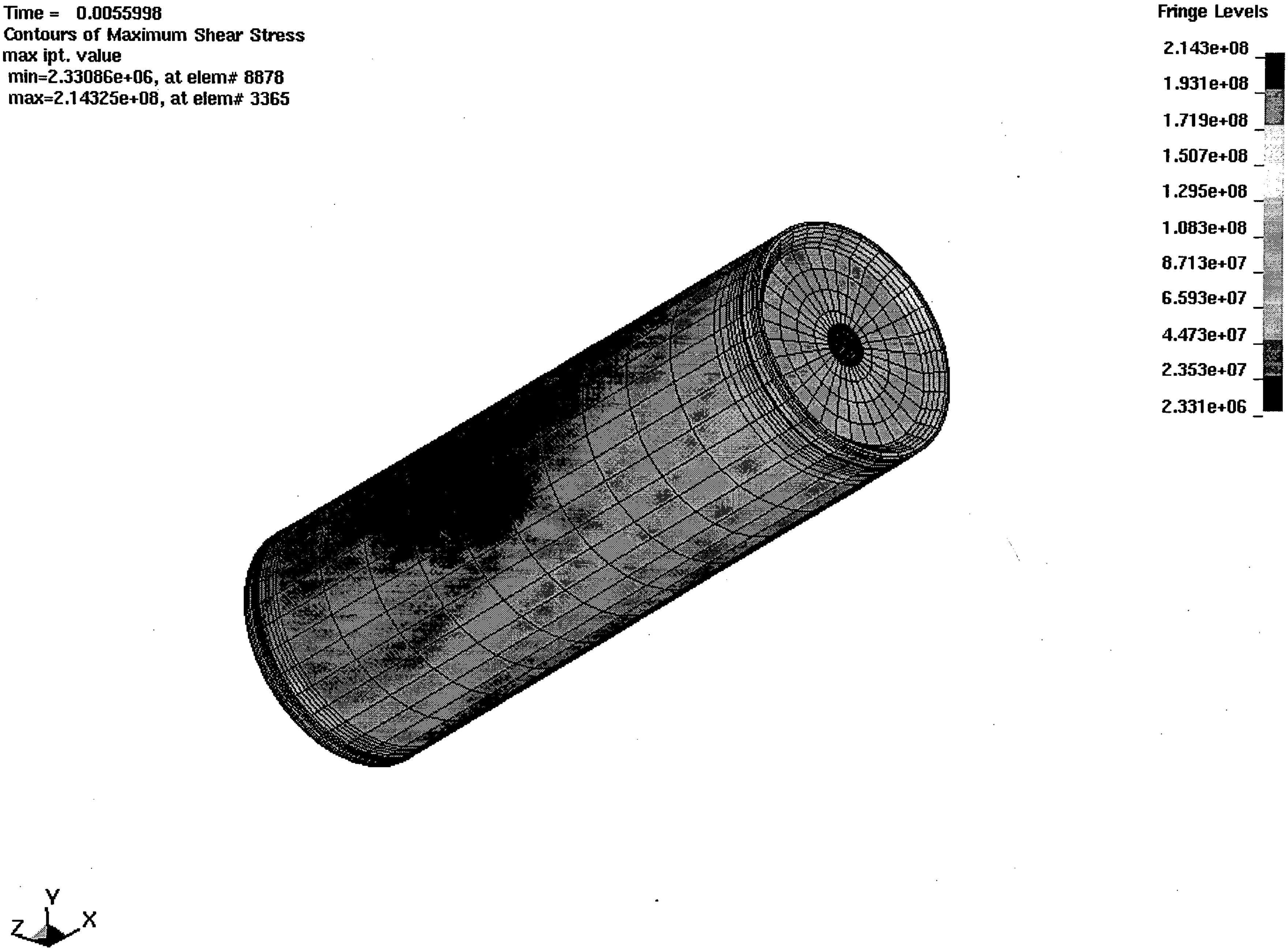


Figure III-4. Shear Stress Plot of Outer Shell and Lids (Case 1)

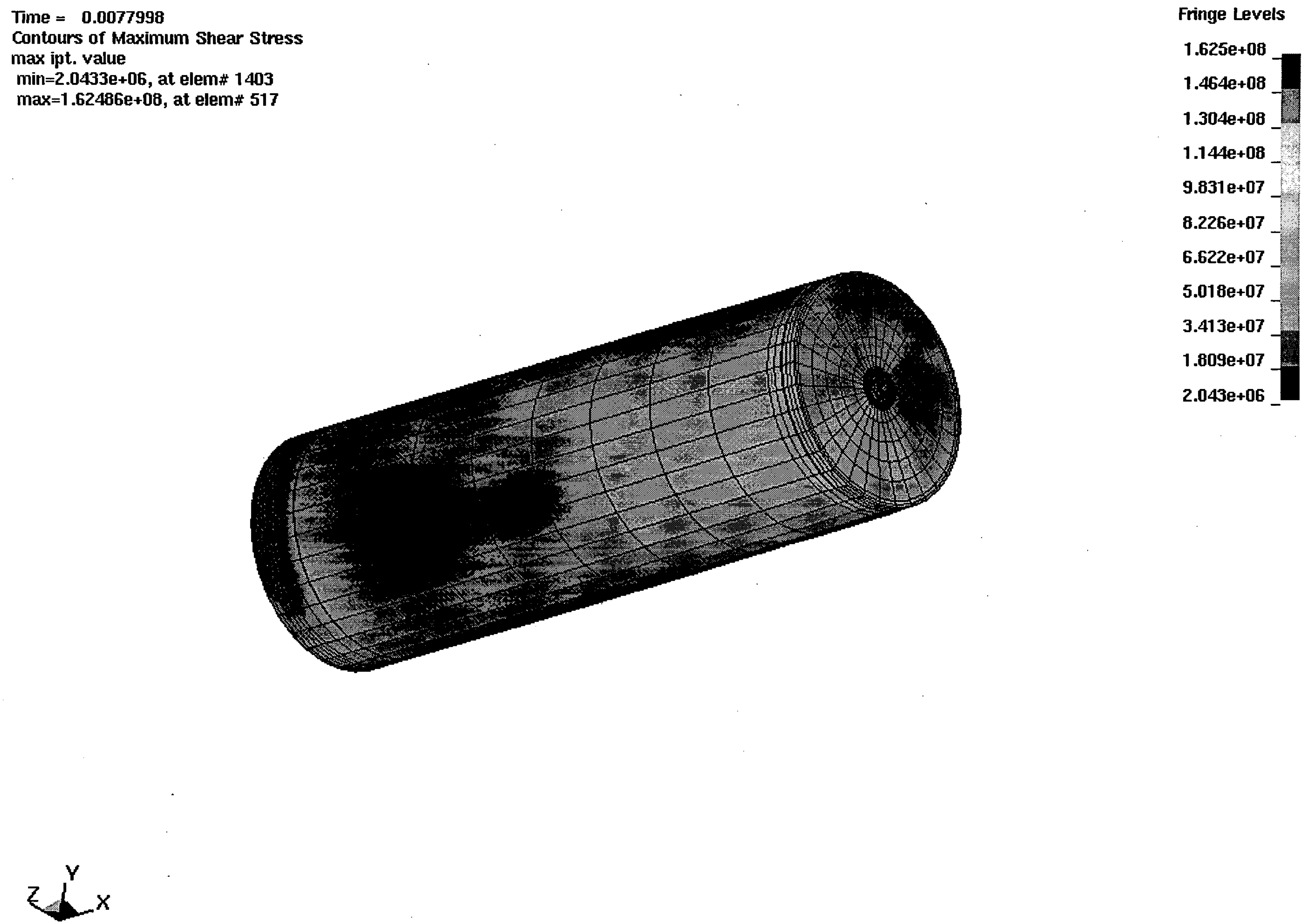


Figure III-5. Shear Stress Plot of Inner Shell and Inner Lid (Case 1)

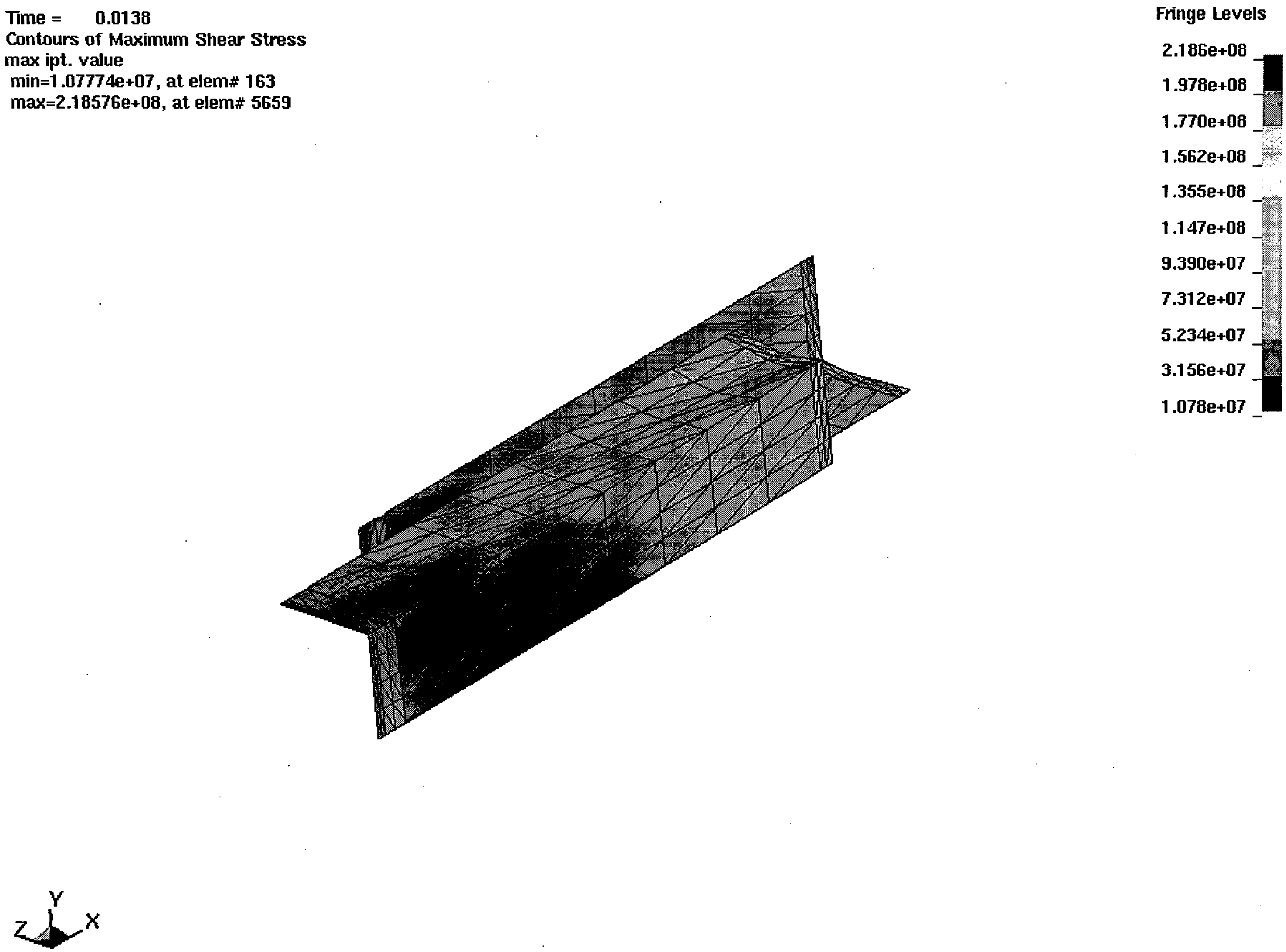


Figure III-6. Shear Stress Plot of A-Plate Dividers (Case 1)

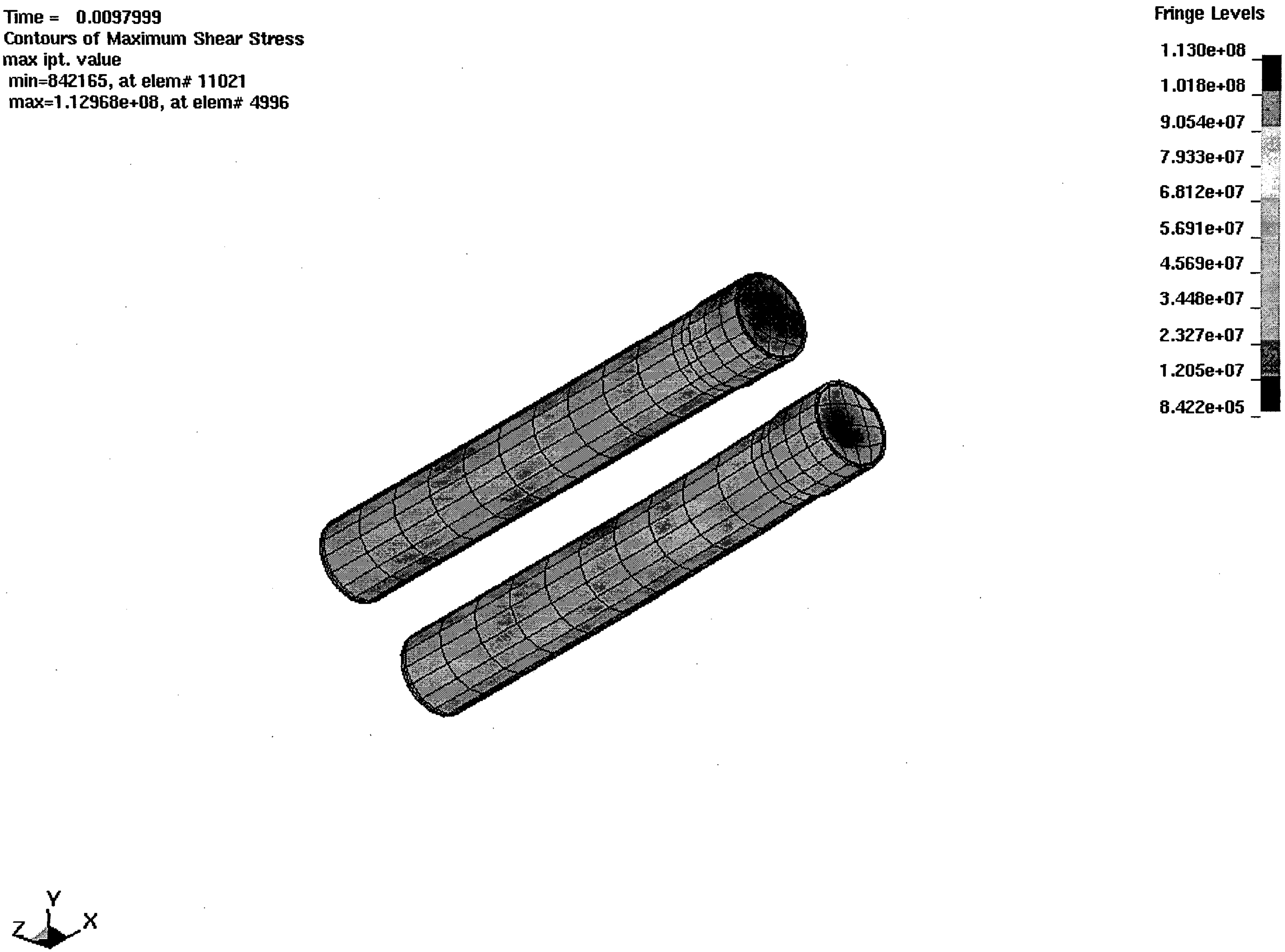


Figure III-7. Shear Stress Plot of MCOs (Case 1)

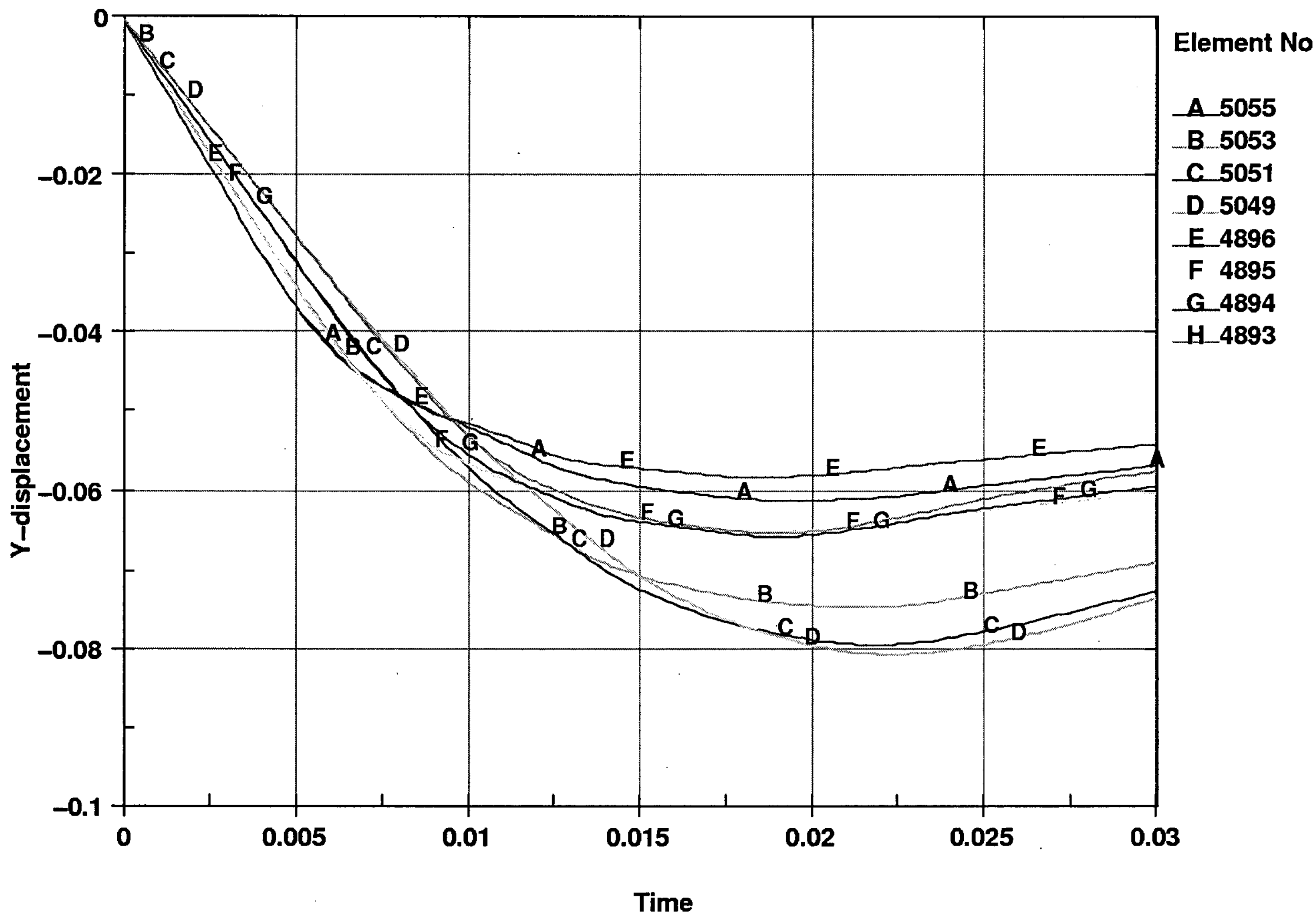


Figure III-8. Time History of MCO Deformation in Y Direction (Case 1)

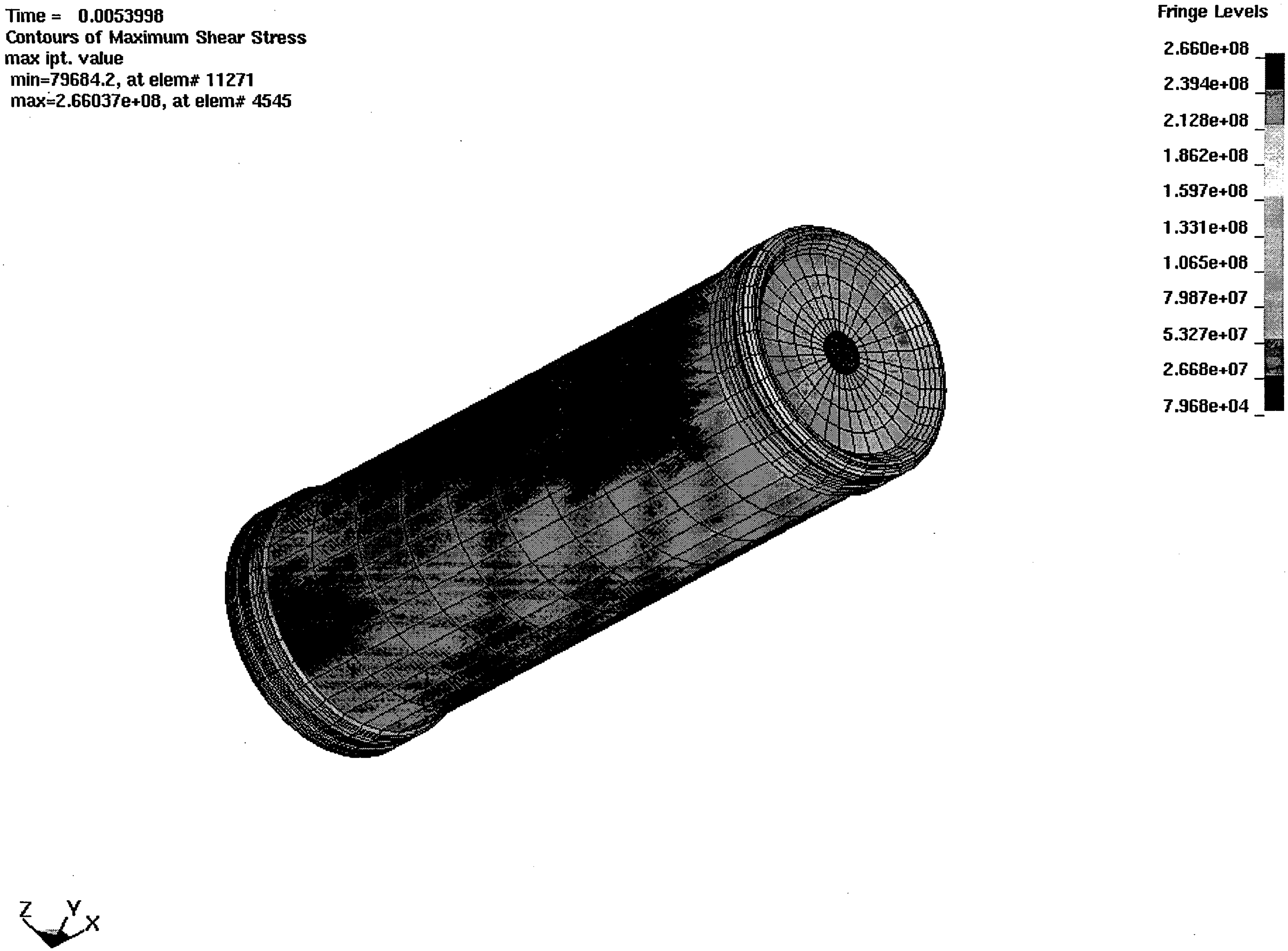


Figure III-9. Shear Stress Plot of Complete Waste Package (Case 2)

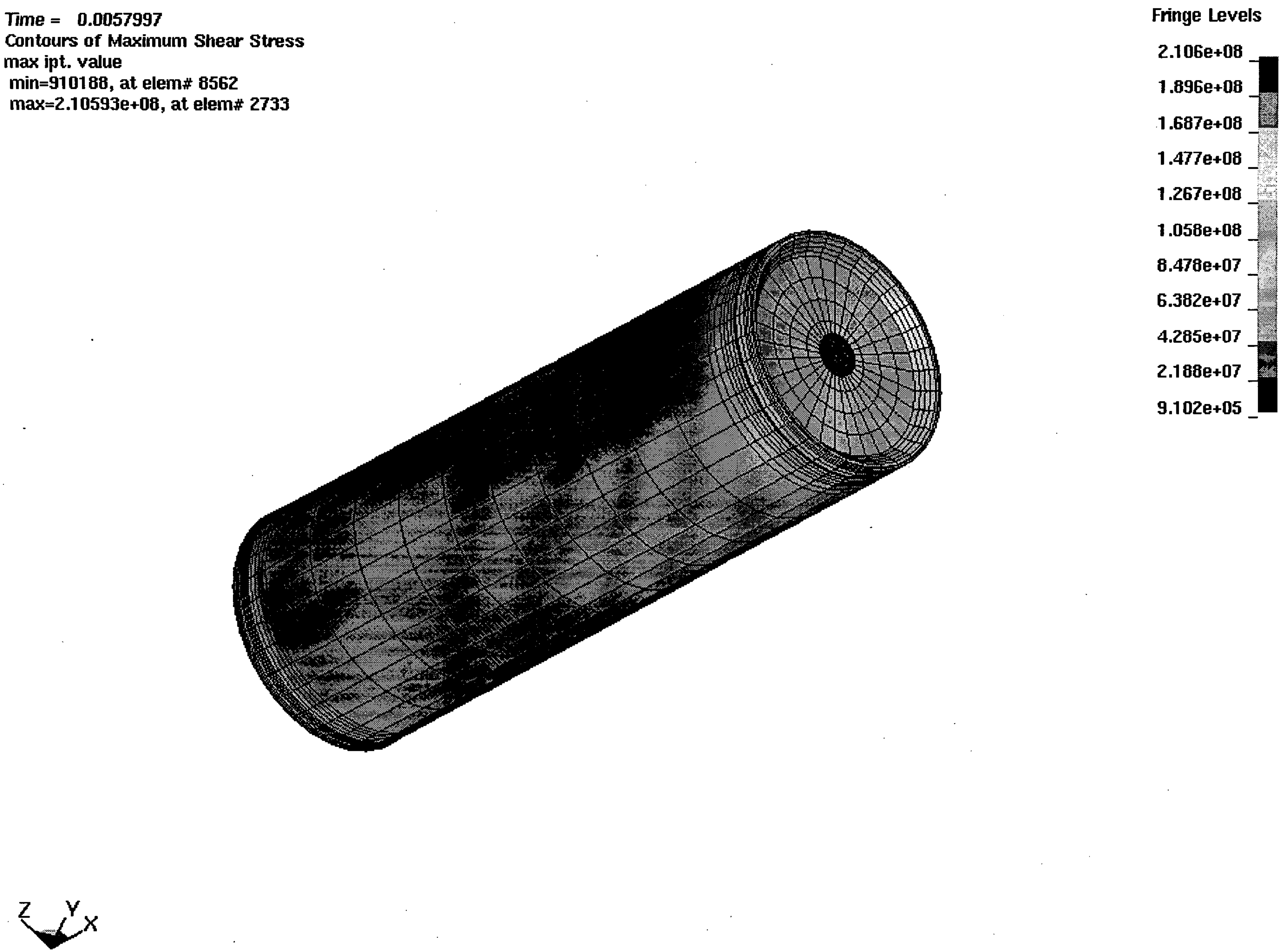


Figure III-10. Shear Stress Plot of Outer Shell and Lids (Case 2)

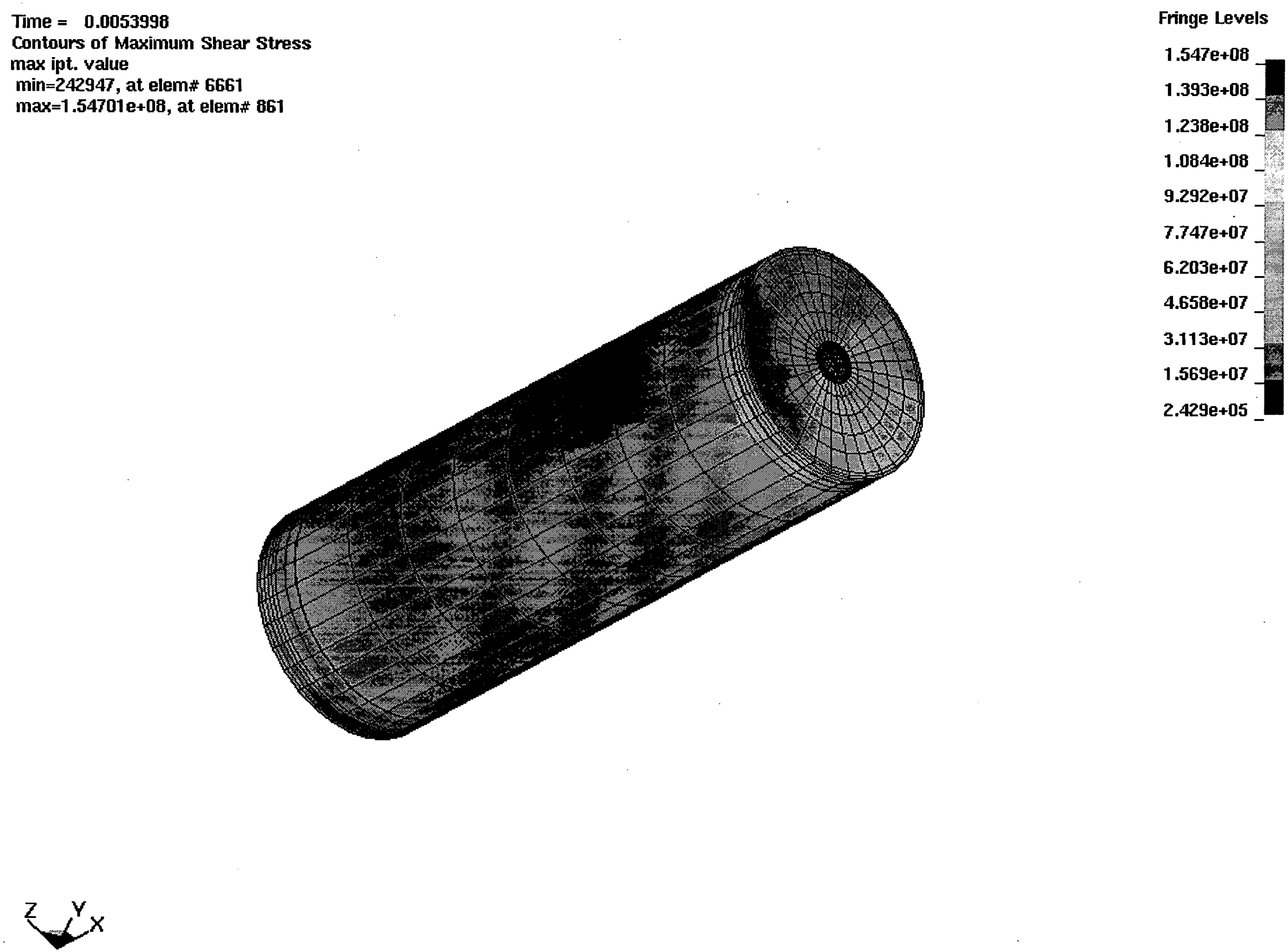


Figure III-11. Shear Stress Plot of Inner Shell and Inner Lid (Case 2)

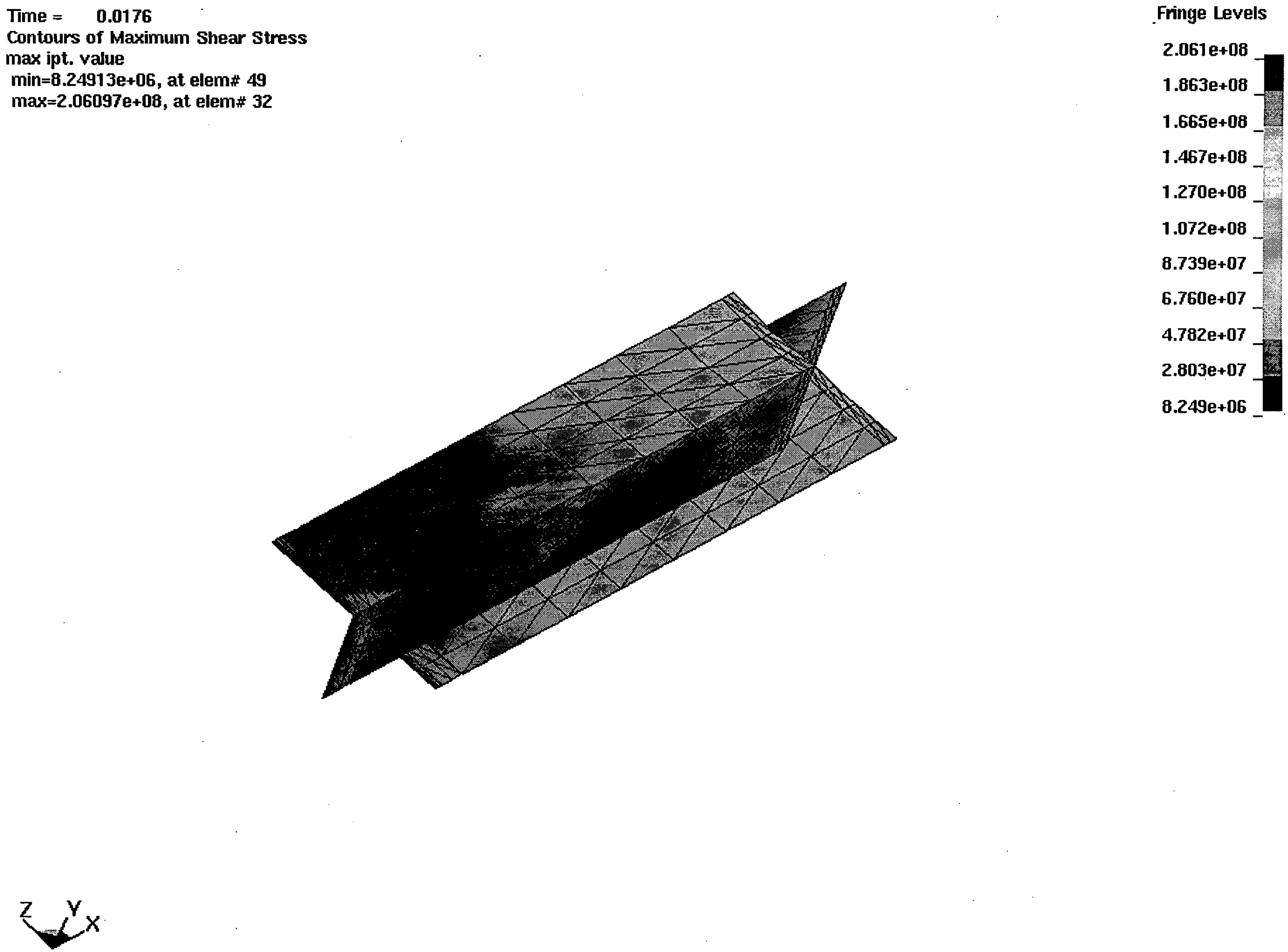


Figure III-12. Shear Stress Plot of A-Plate Dividers (Case 2)

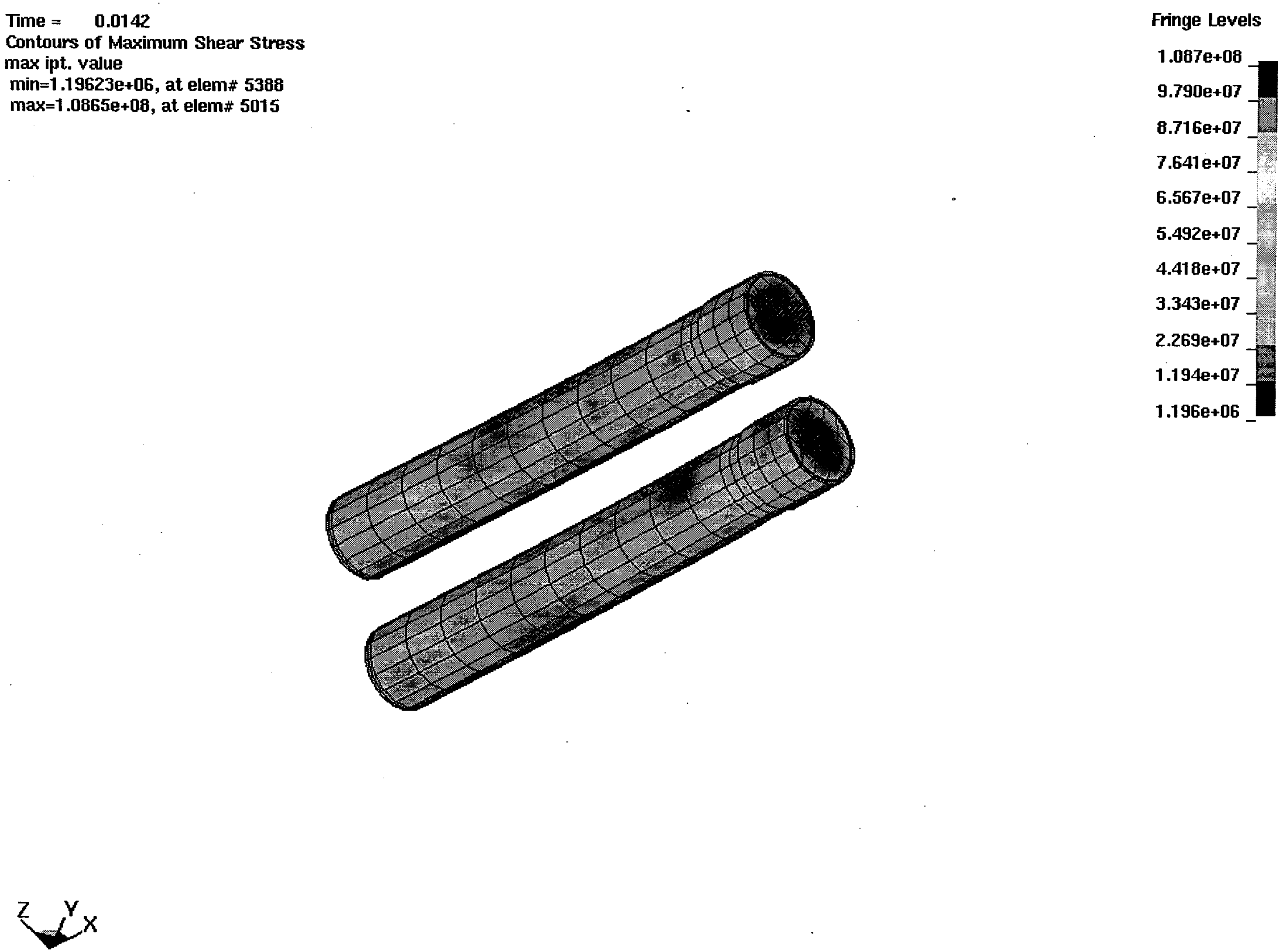


Figure III-13. Shear Stress Plot of MCOs (Case 2)

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SPECIAL INSTRUCTION SHEET

1. QA: QA

Page: 1 of: 1

Complete Only Applicable Items

This is a placeholder page for records that cannot be scanned or microfilmed

2. Record Date 07/05/2000	3. Accession Number ATT-TO MOL.20000710.0522
4. Author Name(s) TIMOTHY SCHMITT	5. Author Organization N/A

6. Title
TIP-OVER OF THE 2-MCO2/2-DHLW WASTE PACKAGE ON UNYIELDING SURFACE

7. Document Number(s) CAL-EDC-ME-000002	8. Version REV.00
9. Document Type CD-ROM	10. Medium OPTIC/DISK

11. Access Control Code
PUB

12. Traceability Designator
DC#25338

13. Comments
THIS IS A ONE-OF-A-KIND DOCUMENT DUE TO THE ATTACHMENT OF A CD-ROM, THIS CD-ROM REPRESENTS ATTACHMENTS IV, V, & VI OF CAL-EDC-ME-000002, THIS CAN BE LOCATED THROUGH THE RPC