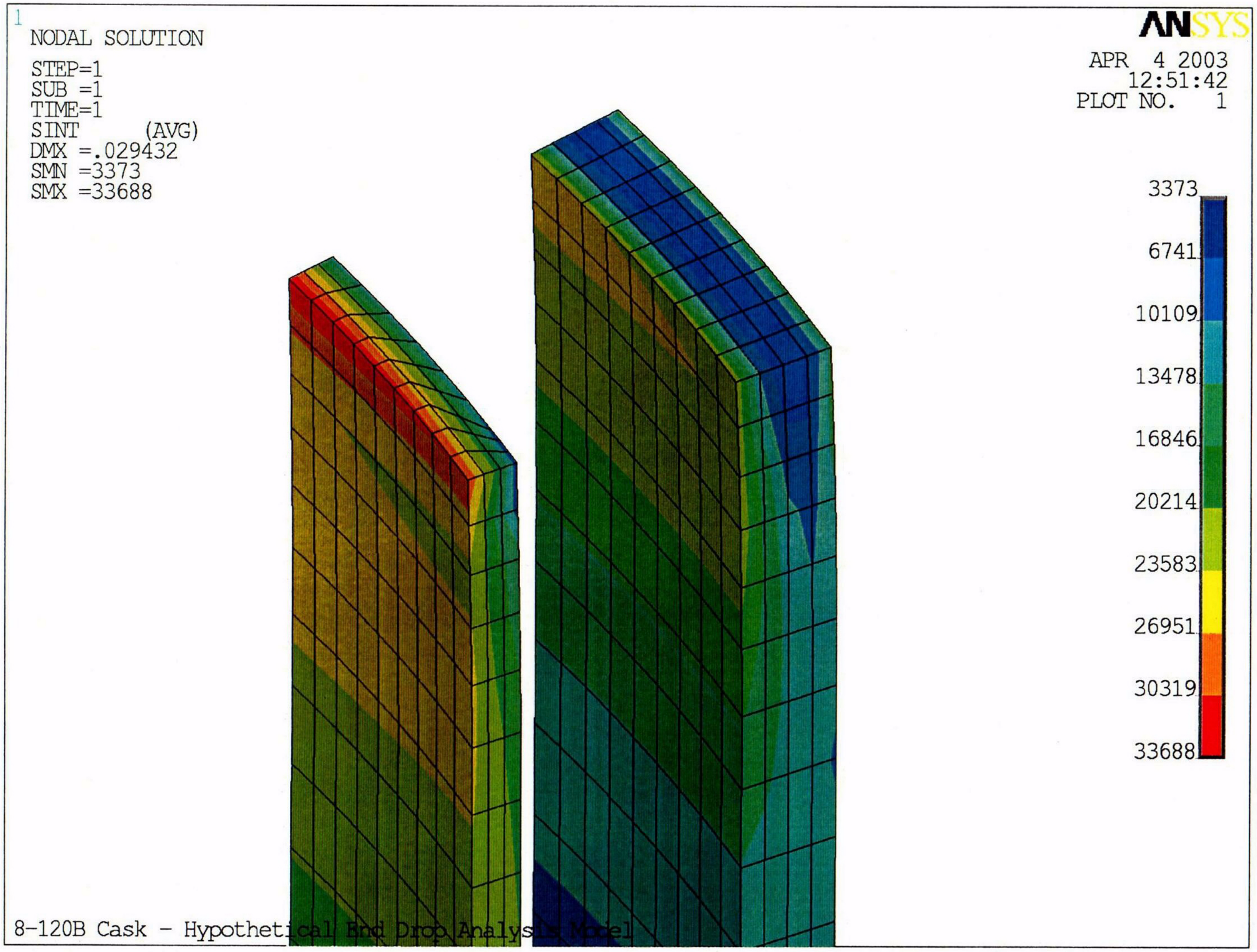


Figure 15

S.I. Distribution in the Inner & Outer Shells – Hypothetical Accident – End Drop

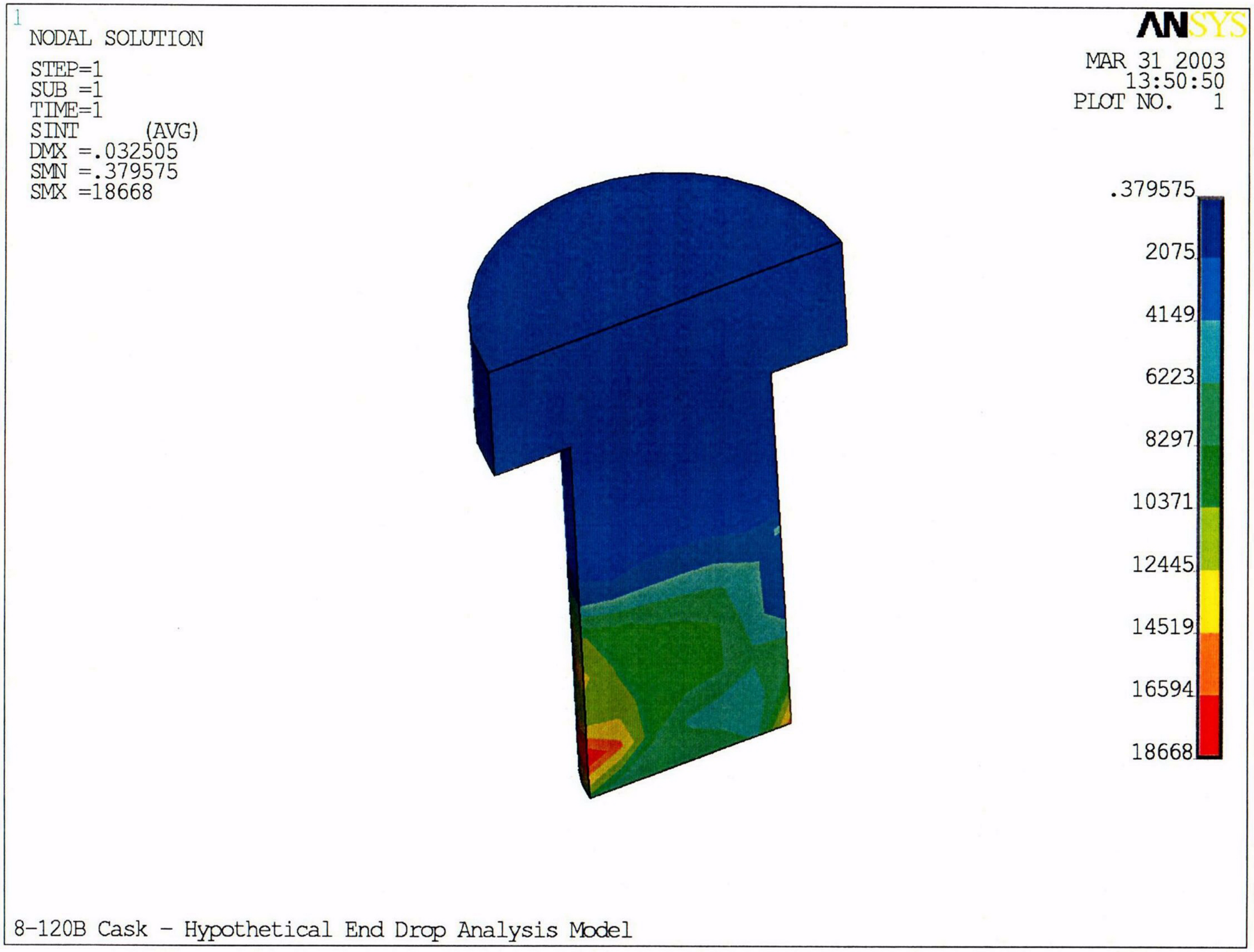


Figure 16
S.I. Distribution in the Primary Lid Bolts – Hypothetical Accident – End Drop

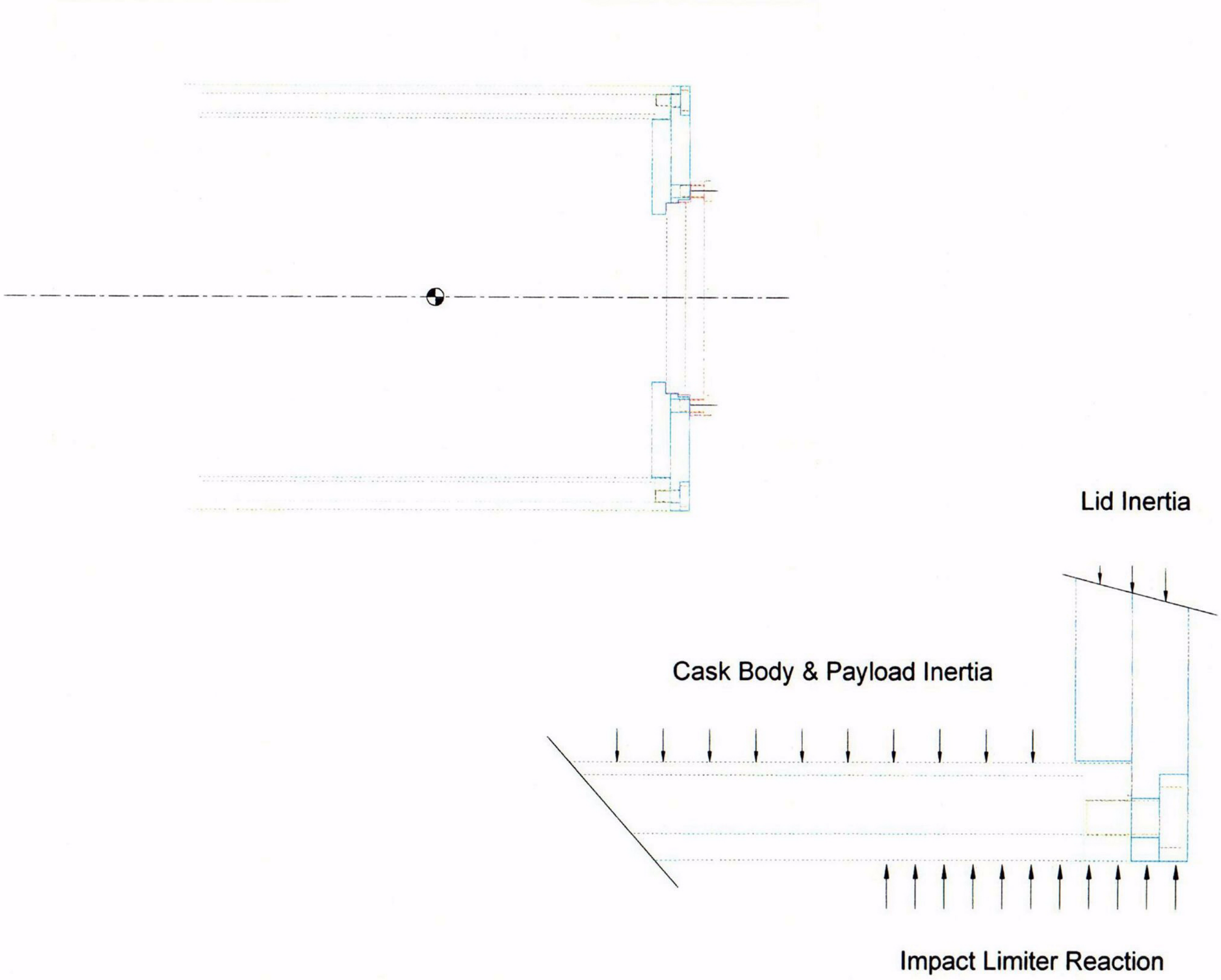


Figure 17
Inertia Load and Impact Limiter Reaction on the Cask During Side Drop

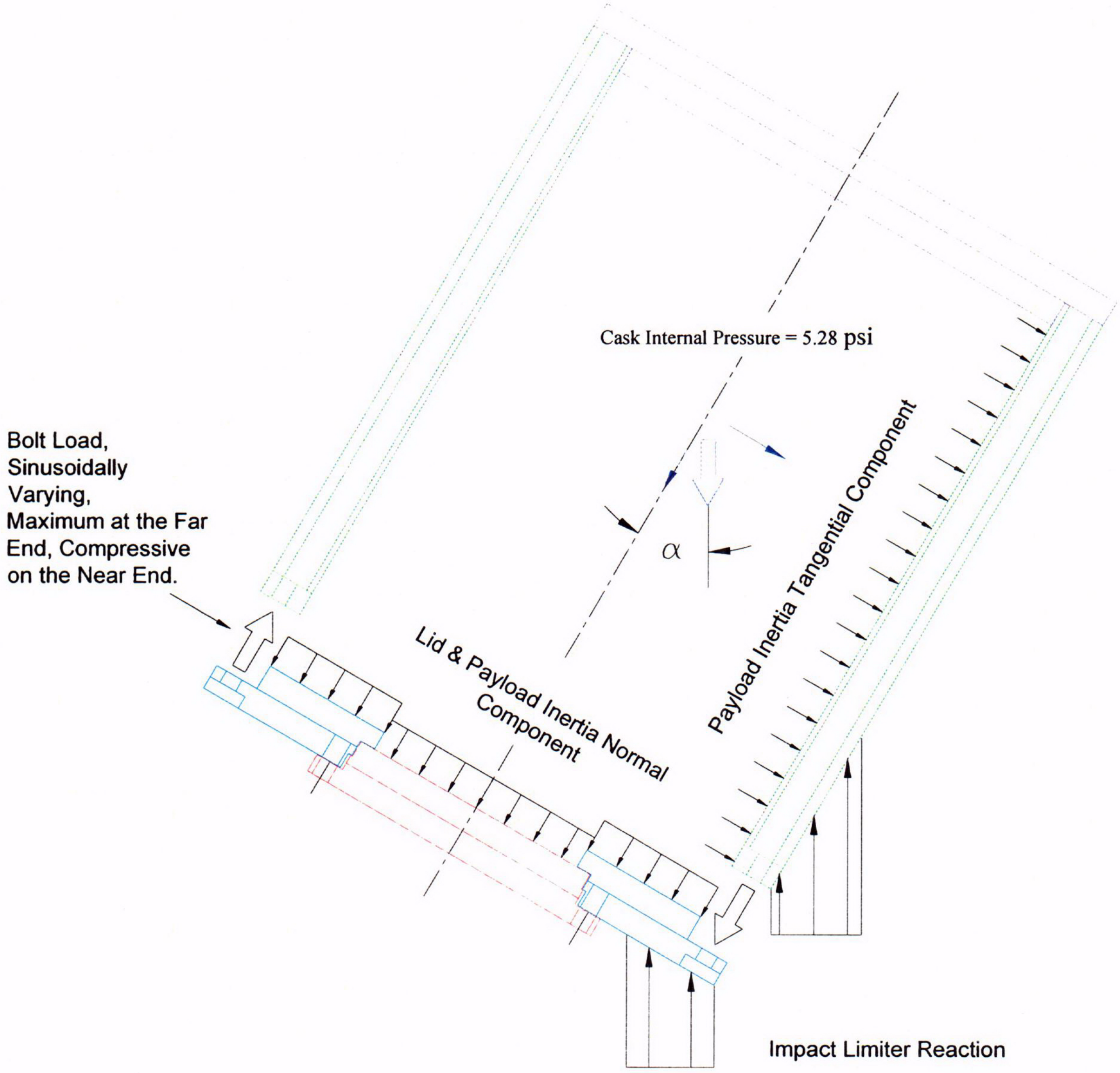


Figure 18
Inertia Load and Impact Limiter Reaction on the cask During Corner Drop

C18

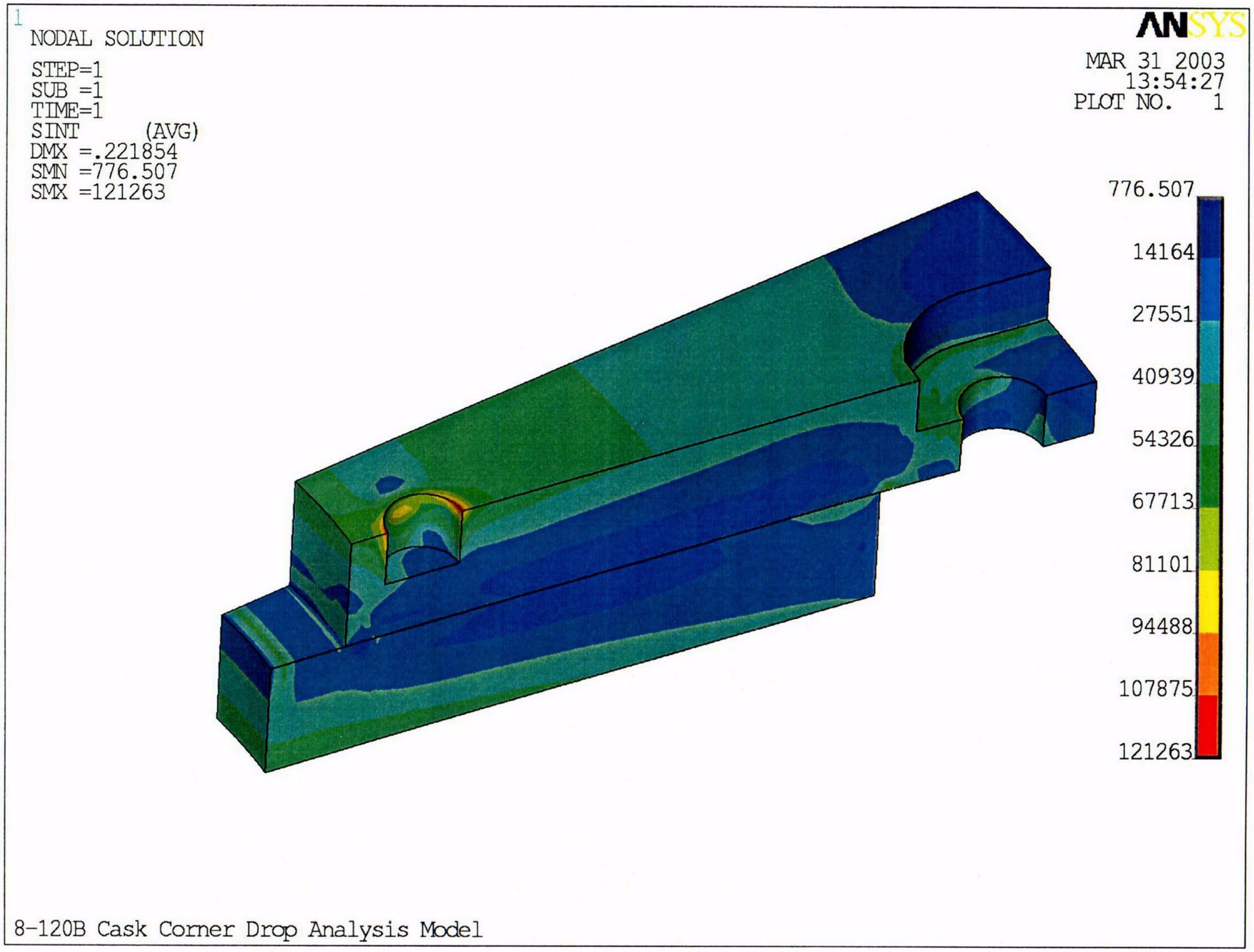
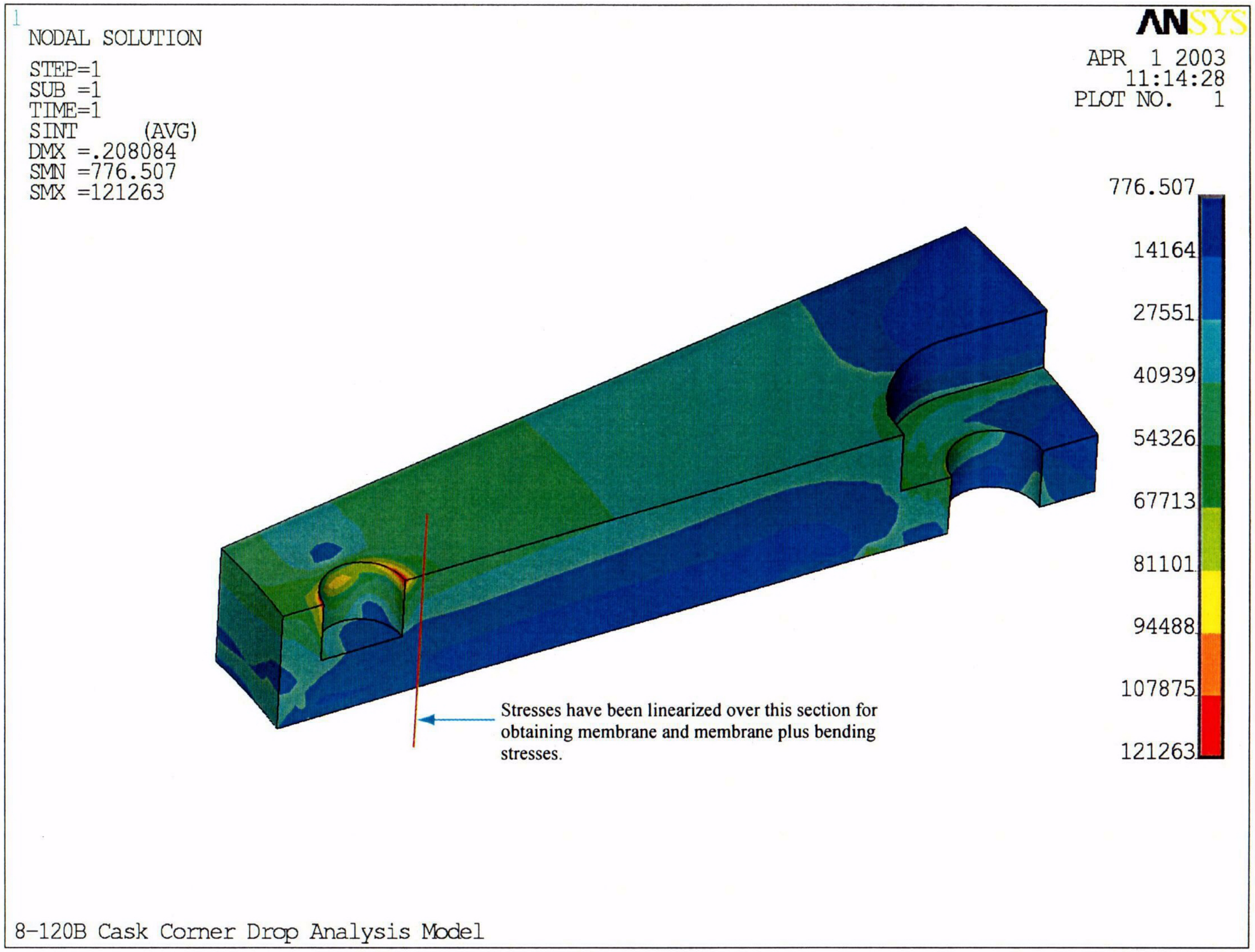


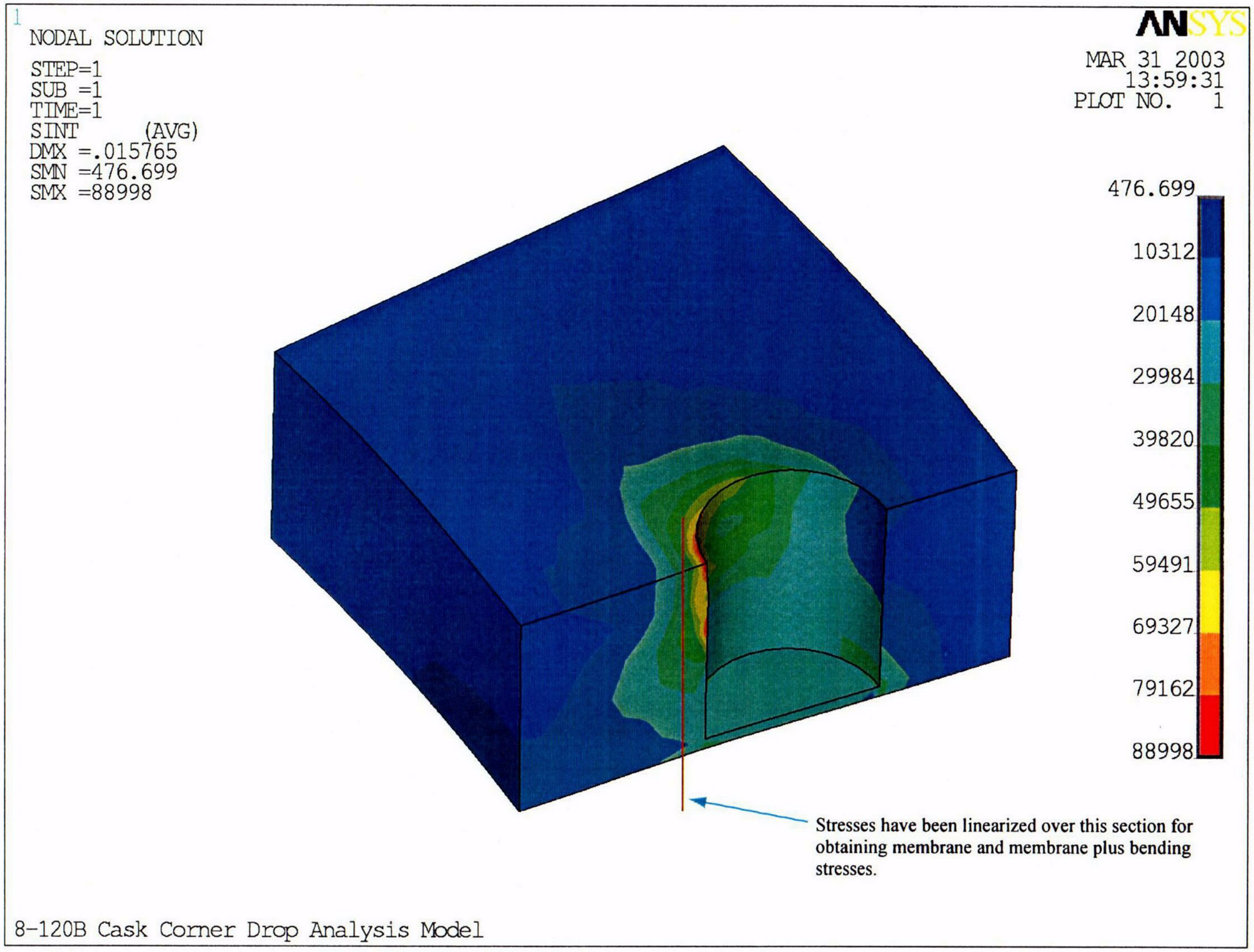
Figure 19

S.I. Distribution in the Primary Lid – Hypothetical Accident – Corner Drop



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

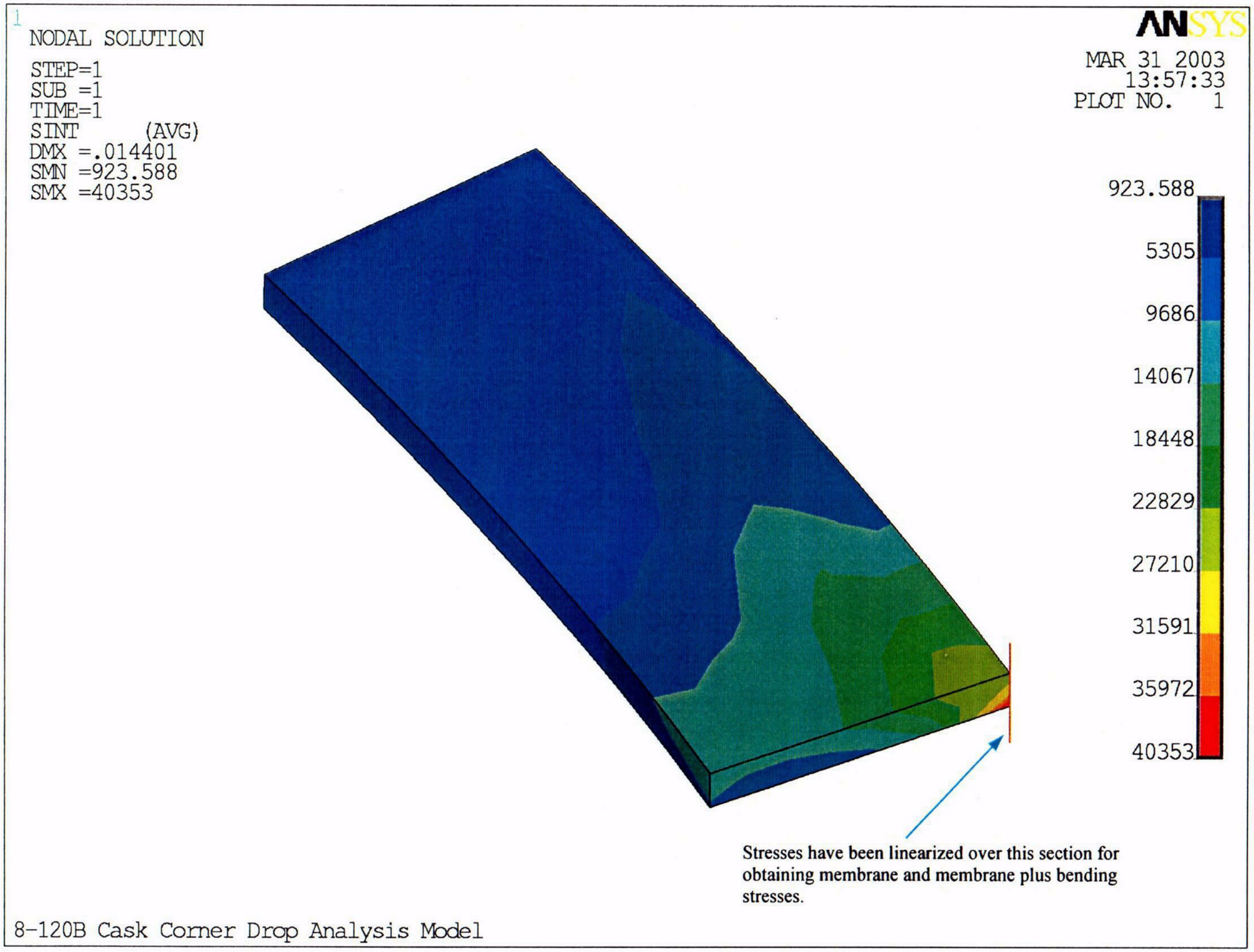
Figure 20
Location of Stress Linearization in the Primary Lid – Hypothetical Accident – Corner Drop



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 21

S.I. Distribution in the Bolting Ring – Hypothetical Accident – Corner Drop



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 22
S.I. Distribution in the Seal Plate – Hypothetical Accident – Corner Drop

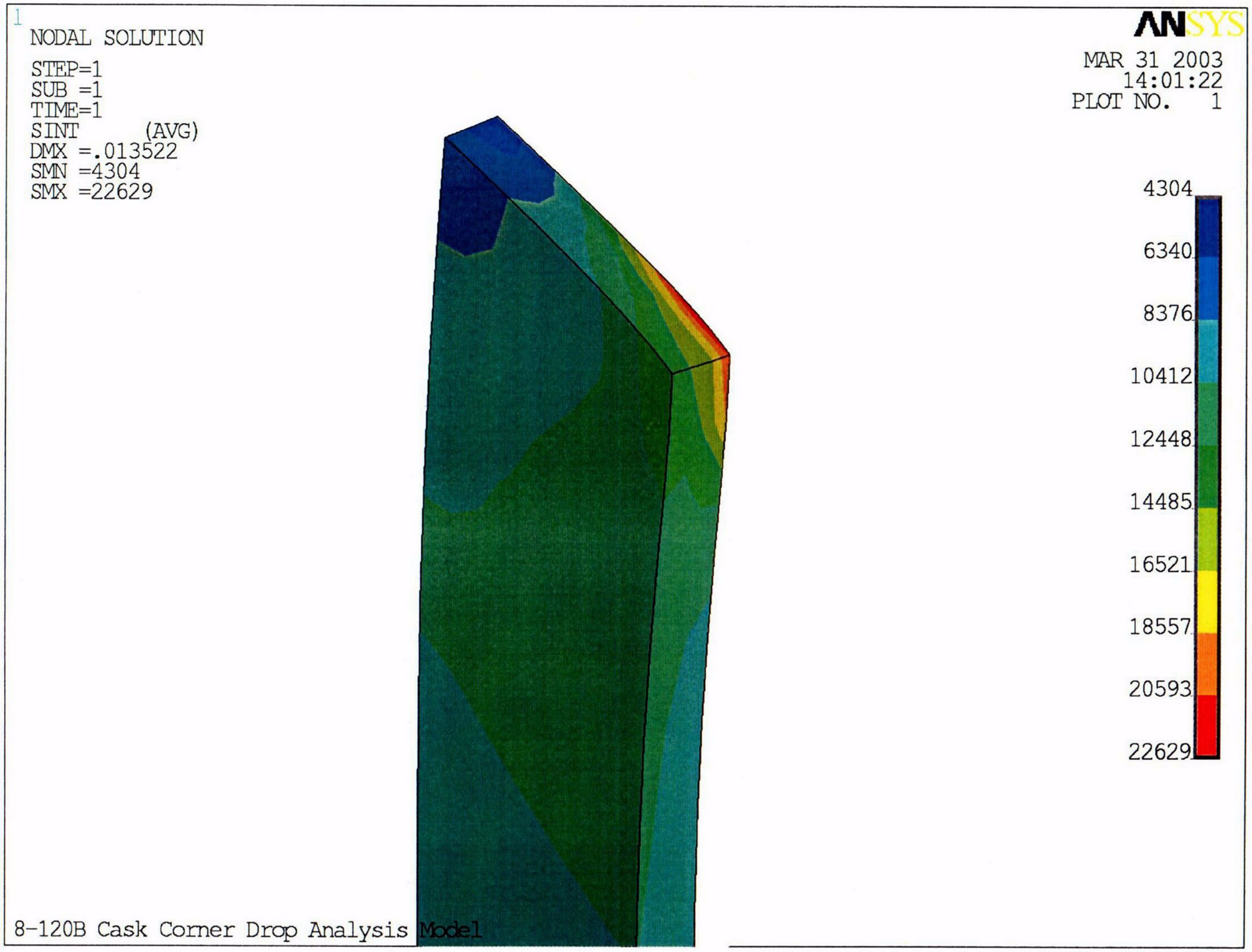


Figure 23
S.I. Distribution in the Inner Shell – Hypothetical Accident – Corner Drop

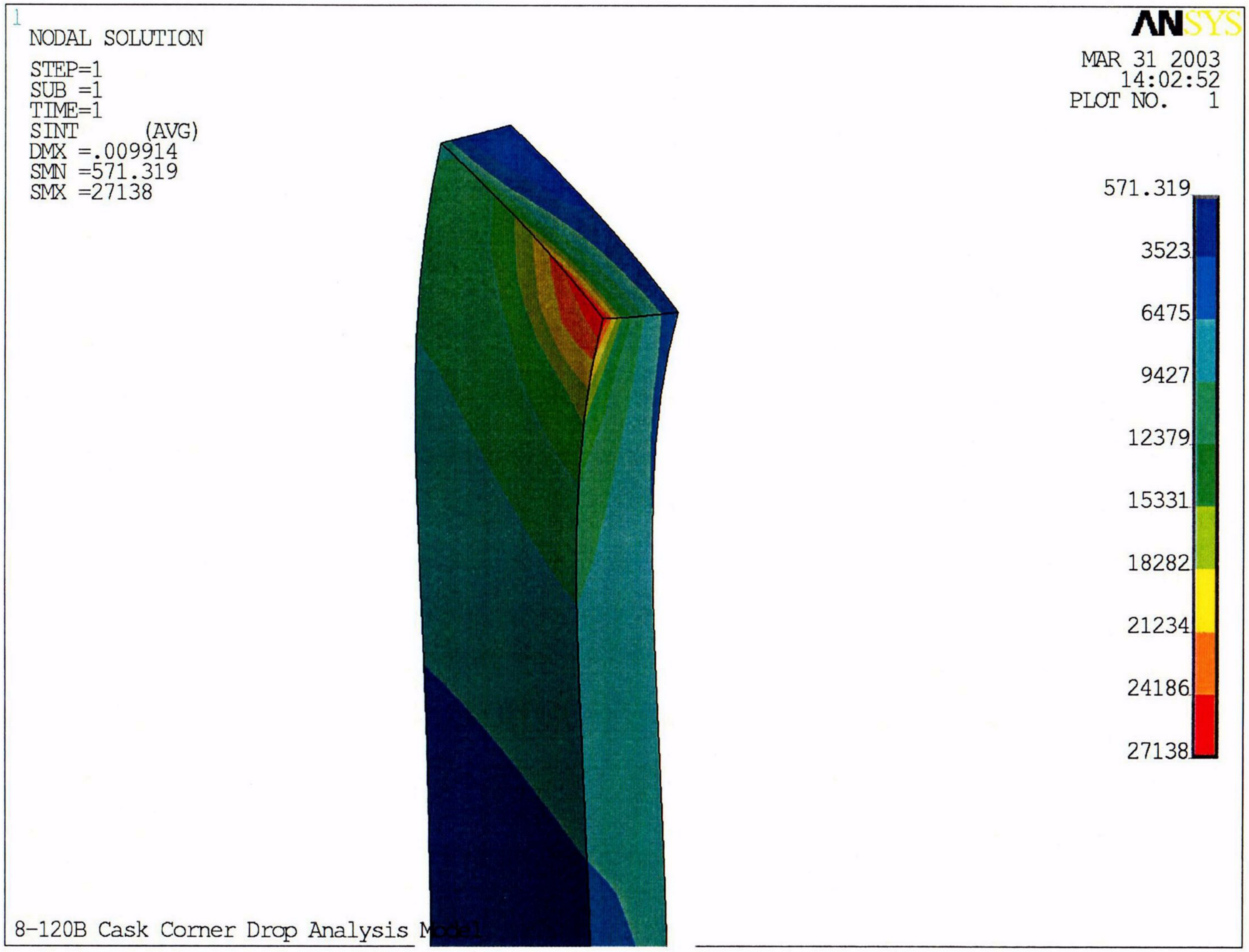
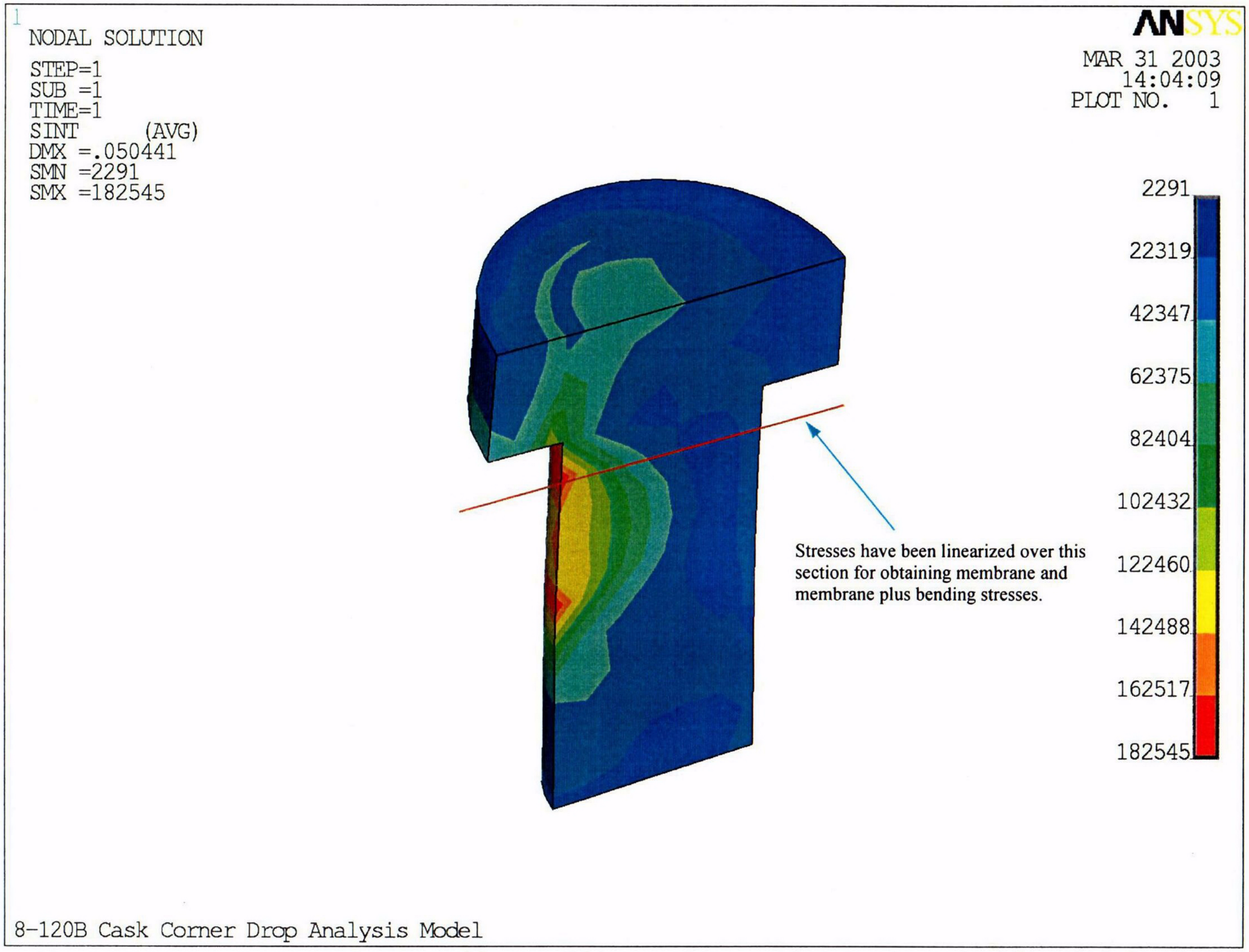


Figure 24

S.I. Distribution in the Outer Shell – Hypothetical Accident – Corner Drop

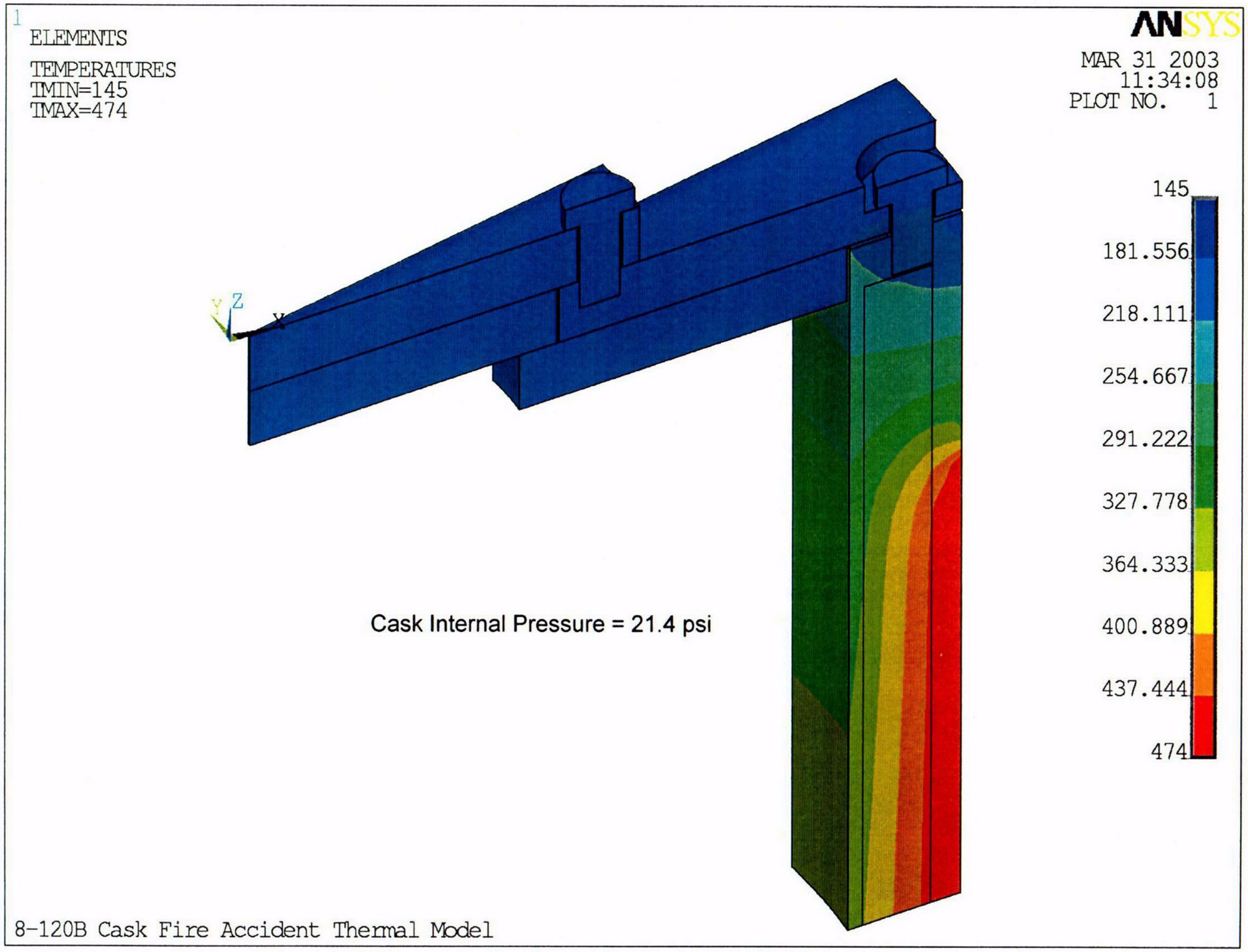


Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 25

S.I. Distribution in the Lid Bolts – Hypothetical Accident – Corner Drop

C25



Cask Internal Pressure = 21.4 psi

Figure 26
Temperature Distribution in the Cask Under Hypothetical Fire Accident

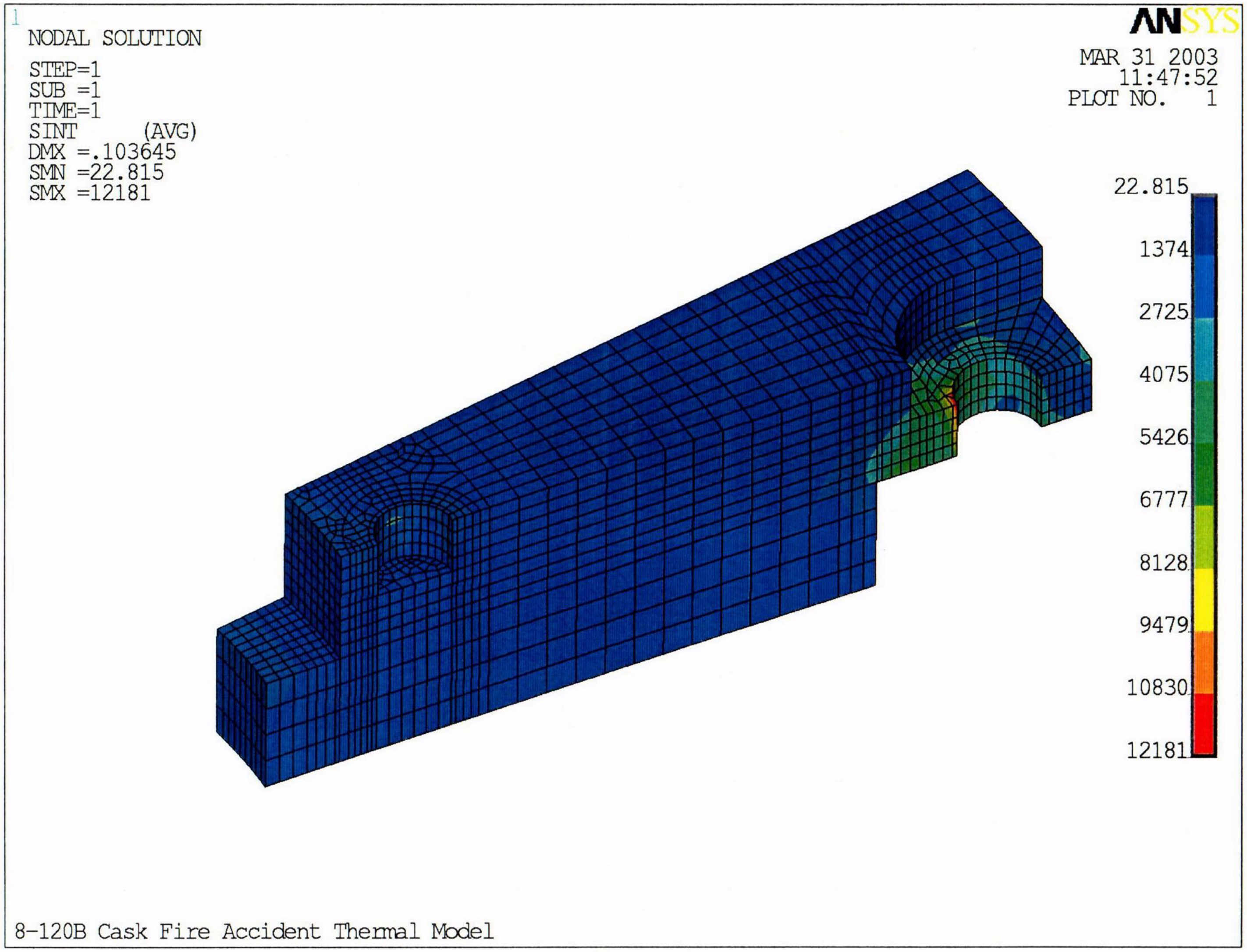


Figure 27
S.I. Distribution in the Primary Lid – Hypothetical Fire Accident

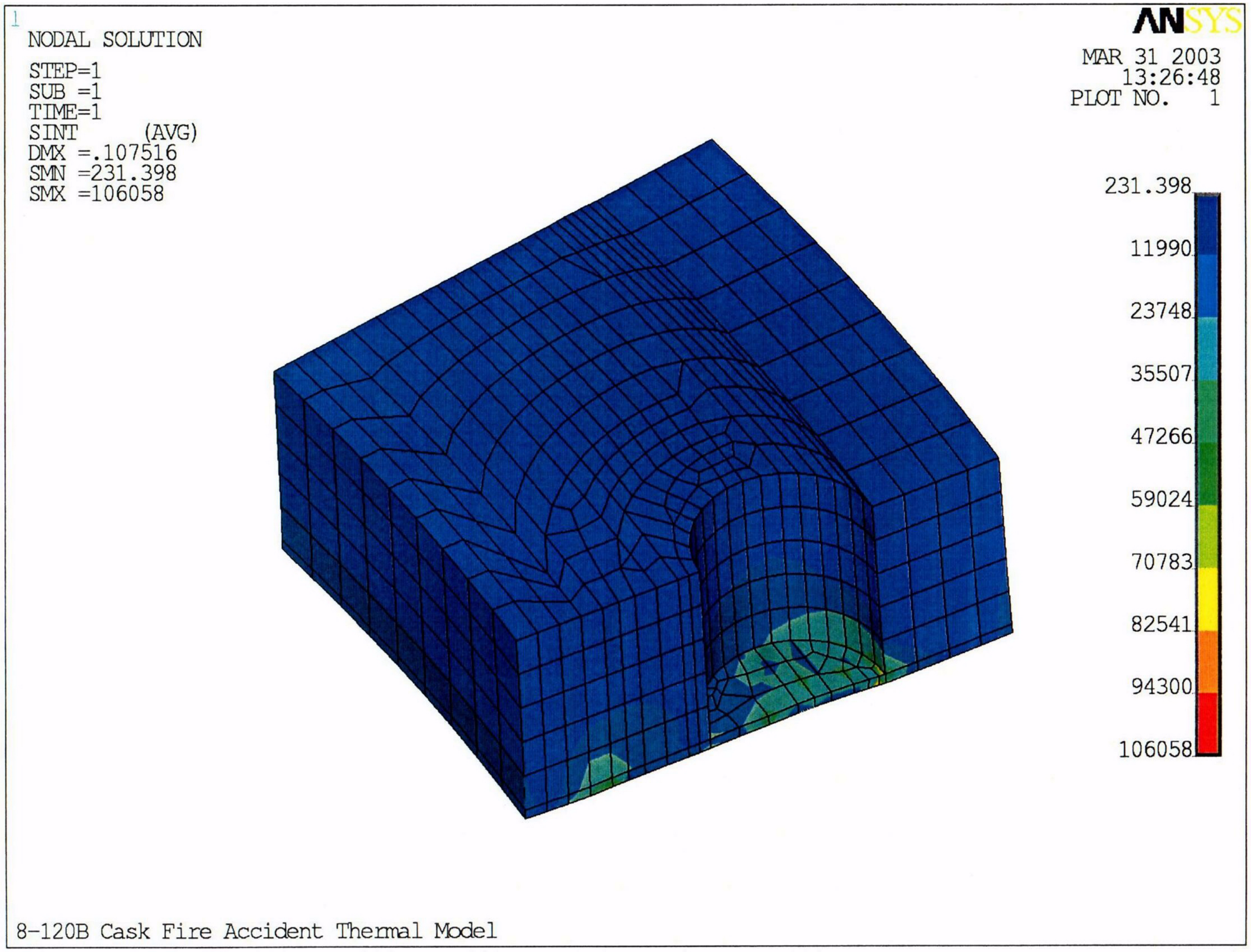
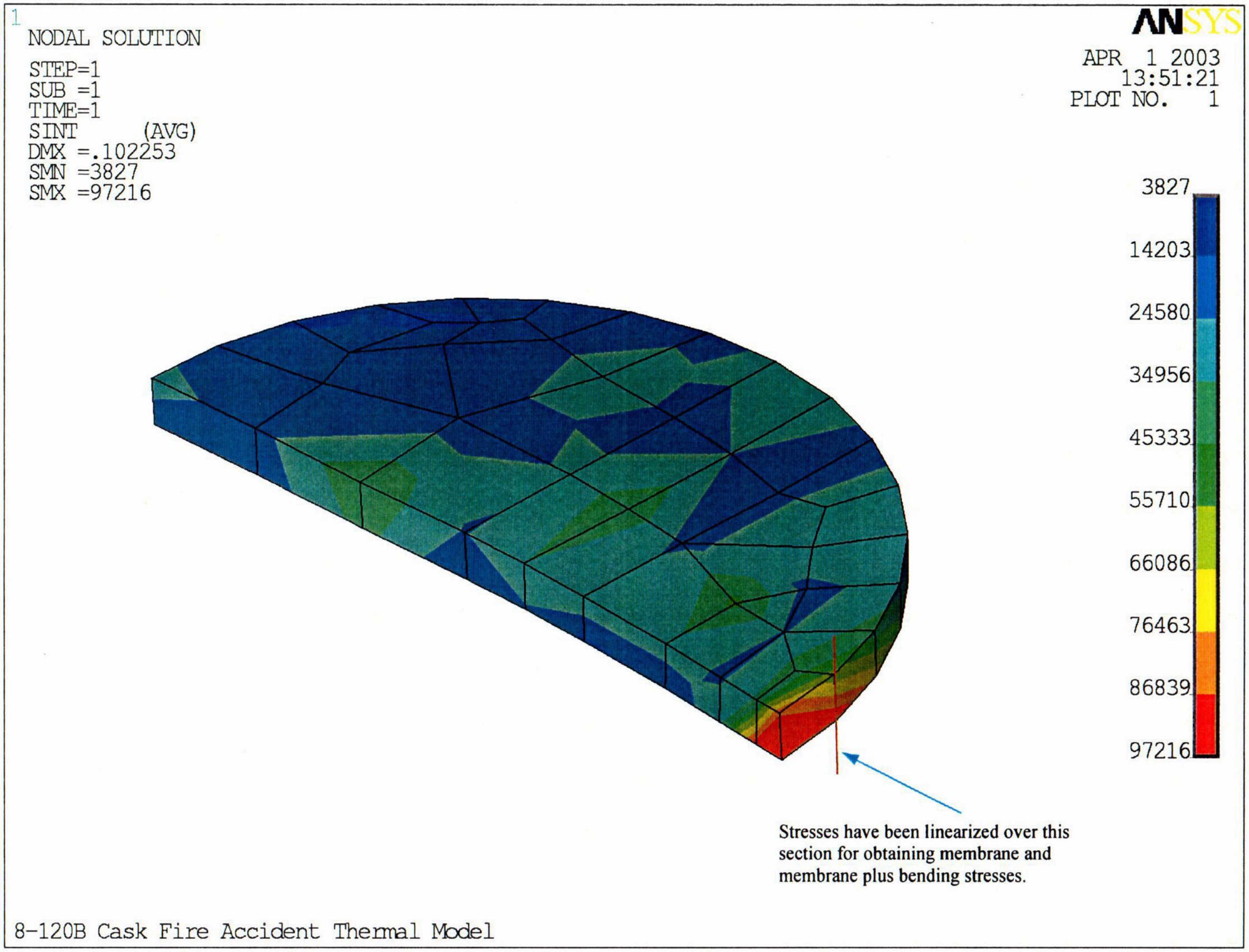


Figure 28
S.I. Distribution in the Bolting Ring – Hypothetical Fire Accident



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 29
Location of Stress Linearization in the Bolting Ring – Hypothetical Fire Accident

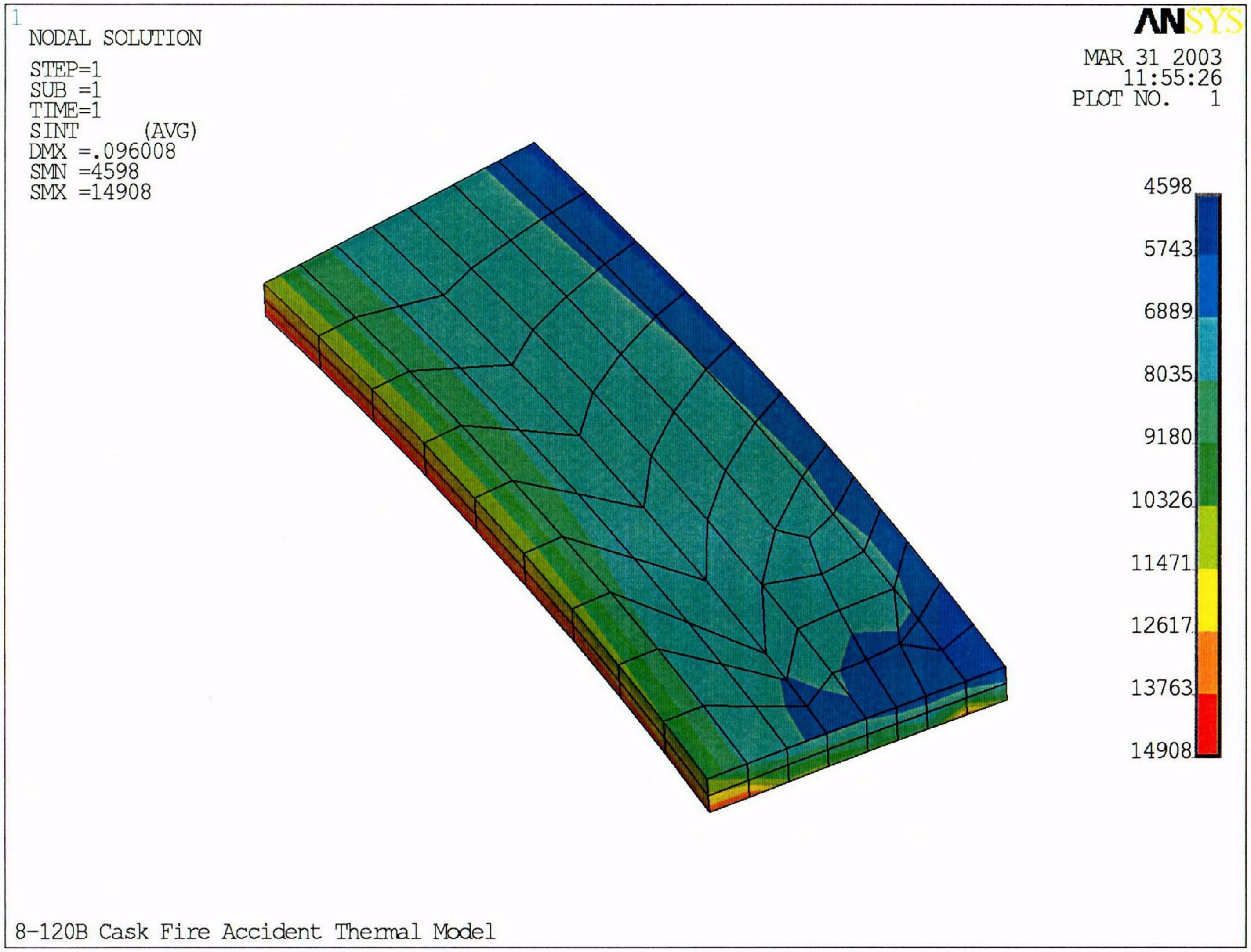
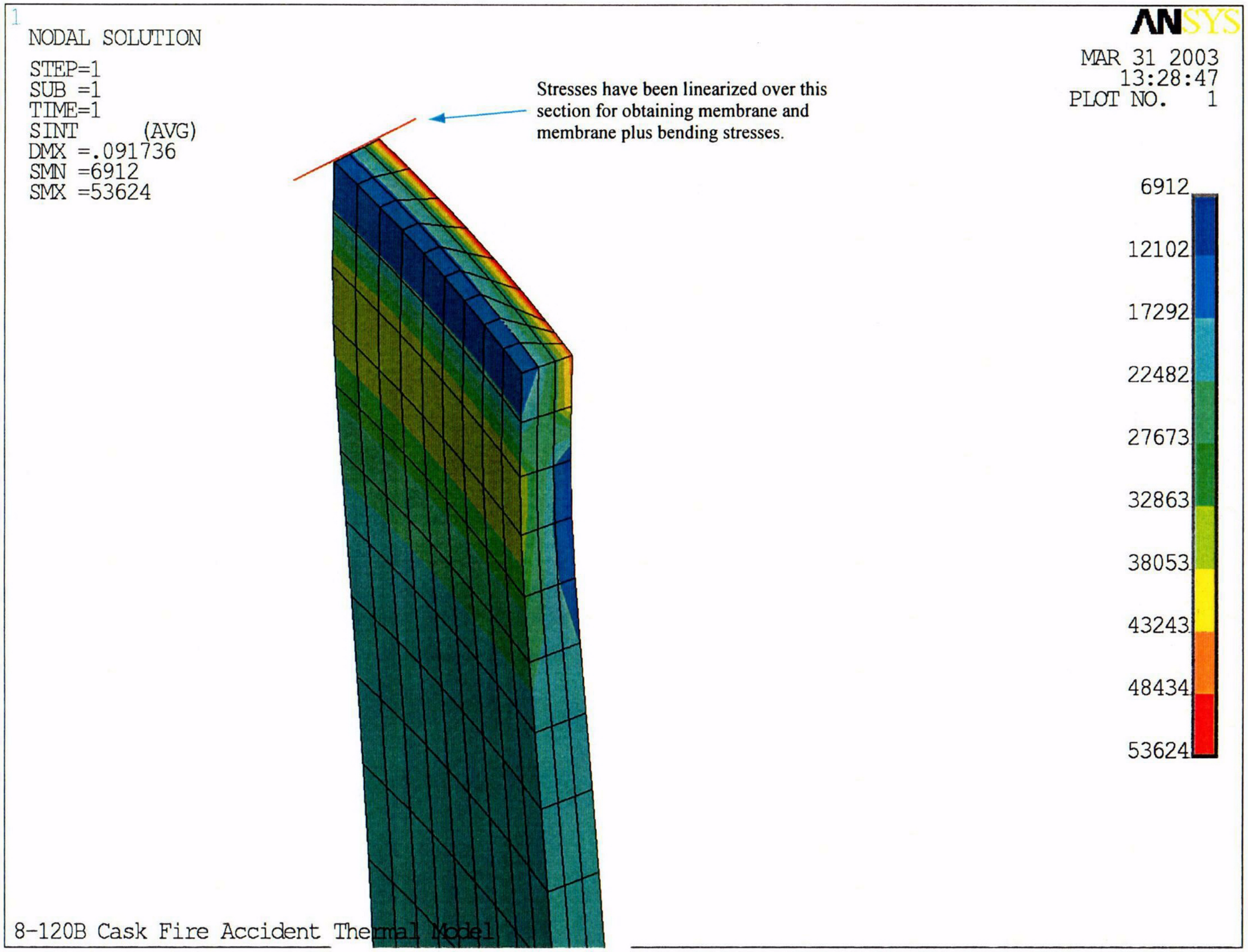


Figure 30
S.I. Distribution in the Seal Plate – Hypothetical Fire Accident

C30



Stresses have been linearized over this section for obtaining membrane and membrane plus bending stresses.

Figure 31
S.I. Distribution in the Inner Shell – Hypothetical Fire Accident

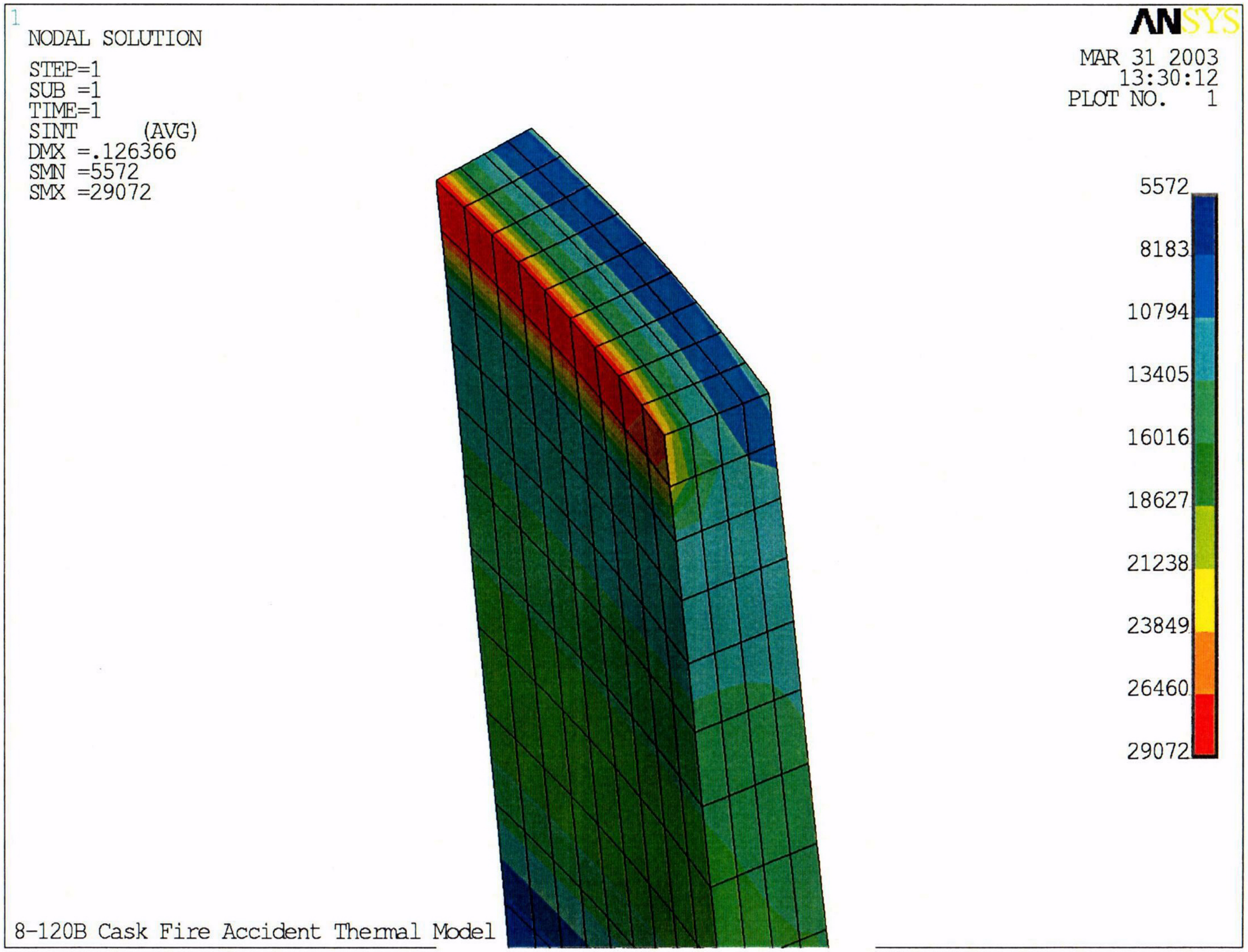


Figure 32
S.I. Distribution in the Outer Shell – Hypothetical Fire Accident

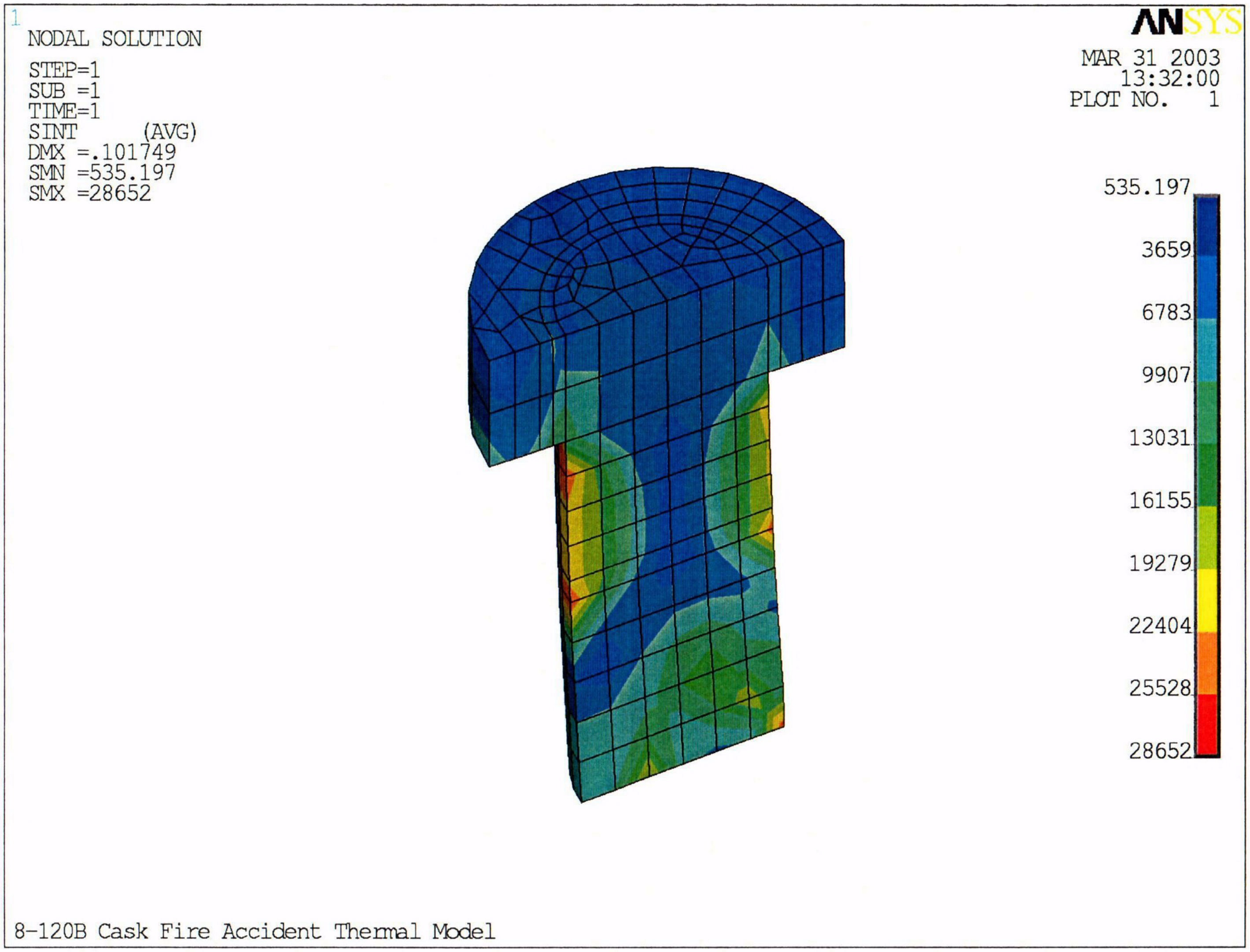


Figure 33
S.I. Distribution in the Lid Bolts – Hypothetical Fire Accident

Appendix A
CNS 8-120B Cask Analyses
ANSYS Finite Element Model Details

(8 Pages)

CNS 8-120B Cask Analyses
ANSYS Finite Element Model Details

Database Listing

```
                            G L O B A L   S T A T U S

 ANSYS - Engineering Analysis System            Apr 03, 2003          11:03
 Release 6.1                 00222442                  INTEL NT      Version

 Current working directory: E:\Ansys Analyses\8-120B\Thermal\Normal\Stress


 MENULIST File: E:\Program Files\Ansys Inc\ANSYS61\docu\english\menulist61.ans

 Product(s) enabled: ANSYS/Mechanical/Emag 3D


 Total connect time. . . . .   2 hours 47 minutes
 Total CP usage. . . . . . .   0 hours  0 minutes 12.3 seconds

 J O B   I N F O R M A T I O N ------------------------------------------

8-120B Cask Normal Conditions - Thermal Stress Analysis

 Current jobname . . . . . .file
 Initial jobname . . . . . .file

 Units . . . . . . . . . . .unknown

                                 Available                Used
 Scratch Memory Space. . .      32.000 mb              1.283 mb (   4.0%)
 Database space  . . . . . .   8191.750 mb             74.019 mb (   0.9%)
   Note! Used database space exceeds memory resident size of  32.0 mb.
         Page file is used.

 User menu file in use . . .E:\Program Files\Ansys
Inc\ANSYS61\DOCU\english\uidl\UIMENU.GRN
 User menu file in use . . .E:\Program Files\Ansys
Inc\ANSYS61\DOCU\english\uidl\UIFUNC1.GRN
 User menu file in use . . .E:\Program Files\Ansys
Inc\ANSYS61\DOCU\english\uidl\UIFUNC2.GRN
 User menu file in use . . .E:\Program Files\Ansys
Inc\ANSYS61\DOCU\english\uidl\MECHTOOL.AUI
 Beta features . . . . . . .are not shown in the user interface

 M O D E L   I N F O R M A T I O N ---------------------------------------

 Solid model summary:

                               Largest          Number          Number
                                Number         Defined        Selected
 Keypoints . . . . . . . . .     708             708              708
```

```
Lines . . . . . . . . . . .       1319          1319           1319
Areas . . . . . . . . . . .        802           802            802
Volumes . . . . . . . . . .        163           163            163

Finite element model summary:

                                 Largest       Number        Number
                                  Number       Defined       Selected
Nodes . . . . . . . . . . .       20635         20635         20635
Elements. . . . . . . . . .       16247         16247         16247

Element types . . . . . . .           3             3          n.a.
Real constant sets. . . . .          15             5          n.a.
Material property sets. . .           6             6          n.a.

Coupling. . . . . . . . . .        7072          1561          n.a.
Constraint equations. . . .           0             0          n.a.
Master DOFs . . . . . . . .           0             0          n.a.
Dynamic gap conditions. . .           0             0          n.a.

B O U N D A R Y   C O N D I T I O N   I N F O R M A T I O N ----------------

                                            Number
                                           Defined
Constraints on nodes. . . . . . . . . . .    5966
Constraints on keypoints. . . . . . . . .       0
Constraints on lines. . . . . . . . . . .       0
Constraints on areas. . . . . . . . . . .       0

Forces on nodes . . . . . . . . . . . . .       0
Forces on keypoints . . . . . . . . . . .       0

Surface loads on elements . . . . . . . .     767
Number of element flagged surfaces  . . .       0
Surface loads on lines. . . . . . . . . .       0
Surface loads on areas. . . . . . . . . .       0

Body loads on elements. . . . . . . . . .       0
Body loads on nodes . . . . . . . . . . .   20635
Body loads on keypoints . . . . . . . . .       0

Temperatures
   Uniform temperature. . . . . . . . . .     70.000
   Reference temperature. . . . . . . . .     70.000
   Offset from absolute scale . . . . . .      0.000

                                              X            Y            Z
Linear acceleration . . . . . . . . . . .  0.0000       0.0000       0.0000
Angular velocity (about global CS). . . .  0.0000       0.0000       0.0000
Angular acceleration (about global CS). .  0.0000       0.0000       0.0000
Location of reference CS. . . . . . . . .  0.0000       0.0000       0.0000
Angular velocity (about reference CS) . .  0.0000       0.0000       0.0000
Angular acceleration (about reference CS)  0.0000       0.0000       0.0000

R O U T I N E   I N F O R M A T I O N ----------------------------------

Current routine. . . . . . . . . . . .Preprocessing (PREP7)
```

```
Active coordinate system . . . . . . .  12 (Cylindrical)

Display coordinate system. . . . . . .   0 (Cartesian)

Current element attributes:
   Type number . . . . . . . . . . . .     3  (CONTAC49)
   Real number . . . . . . . . . . . .    13
   Material number . . . . . . . . . .     5
   Element coordinate system number. .     0

Current mesher type. . . . . . . . . .free mesher

Current element meshing shape 2D . . .use default element shape.

Current element meshing shape 3D . . .use hexahedra.

SmrtSize Level  . . . . . . . . . . . . OFF

Global element size. . . . . . . . .      0 divisions per line

Active coordinate system . . . . . . .  12 (Cylindrical)

Display coordinate system. . . . . . .   0 (Cartesian)

Analysis type. . . . . . . . . . . . .Static (steady-state)

Active options for this analysis type:
   Large deformation effects . . . . .Not included
   Plasticity. . . . . . . . . . . . .Not included
   Creep . . . . . . . . . . . . . . .Not included
   Equation solver to use. . . . . . .Program Chosen

Results file . . . . . . . . . . . . .file.rst

Load step number . . . . . . . . . .      2

Number of substeps:
   Starting number of substeps . . . .      1
   Maximum number of substeps. . . . .    100
   Minimum number of substeps. . . . .      1
   Step change boundary conditions . .No
```

Element Type Listing

```
LIST ELEMENT TYPES FROM      1 TO      3 BY      1

ELEMENT TYPE      1 IS SOLID45      3-D STRUCTURAL SOLID           INOPR
 KEYOPT(1-12)=    0  0  0    0  0  0    0  0  0    0  0  0        0

ELEMENT TYPE      2 IS COMBIN40     COMBINATION                    INOPR
```

```
  KEYOPT(1-12)=    0  0  3    0  0  0    0  0  0    0  0  0       0

 ELEMENT TYPE      3 IS CONTAC49      3-D POINT-TO-SURFACE CONTACT   INOPR
  KEYOPT(1-12)=    0  0  0    0  0  0    0  0  0    0  0  0       0

 CURRENT NODAL DOF SET IS  UX    UY    UZ
  THREE-DIMENSIONAL MODEL
```

Real Constant Listing

```
 LIST REAL SETS        1 TO      15 BY       1

 REAL CONSTANT SET        7  ITEMS    1 TO   6
    1.0000      0.0000       0.0000     0.10000E-03   0.0000       0.10000E+09

 REAL CONSTANT SET       12  ITEMS    1 TO   6
    0.0000      0.0000       0.0000     0.10000E-03   0.0000       0.10000E+07

 REAL CONSTANT SET       13  ITEMS    1 TO   6
   0.10000E+07  0.0000      0.10000E-02  0.0000       5.0000        0.0000

 REAL CONSTANT SET       14  ITEMS    1 TO   6
    0.0000      0.0000       0.0000      0.25000      0.0000       0.10000E+07

 REAL CONSTANT SET       15  ITEMS    1 TO   6
    0.0000      0.0000       0.0000      100.00       0.0000        0.0000

 REAL CONSTANT SET       15  ITEMS    7 TO  12
   0.10000E-01  0.0000       0.0000      0.0000       0.0000        0.0000
```

Material Properties Listing

```
 LIST MATERIALS        1 TO       6 BY       1
  PROPERTY= ALL

 PROPERTY TABLE EX    MAT=        1  NUM. POINTS=  6
   TEMPERATURE       DATA     TEMPERATURE      DATA     TEMPERATURE       DATA
     70.000     0.27900E+08  100.00      0.27800E+08  200.00      0.27700E+08
     300.00     0.27400E+08  400.00      0.27000E+08  500.00      0.26400E+08

 PROPERTY TABLE NUXY  MAT=        1  NUM. POINTS=  6
   TEMPERATURE       DATA     TEMPERATURE      DATA     TEMPERATURE       DATA
     70.000     0.30000      100.00      0.30000       200.00     0.30000
     300.00     0.30000      400.00      0.30000       500.00     0.30000

 PROPERTY TABLE ALPX  MAT=        1  NUM. POINTS=  6
   TEMPERATURE       DATA     TEMPERATURE      DATA     TEMPERATURE       DATA
```

```
    70.000     0.65000E-05  100.00     0.65000E-05  200.00     0.66700E-05
    300.00     0.68700E-05  400.00     0.70700E-05  500.00     0.72500E-05

PROPERTY TABLE DENS  MAT=       1  NUM. POINTS=  1
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    0.0000     0.28300

PROPERTY TABLE KXX   MAT=       1  NUM. POINTS= 16
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.81300E-03  100.00     0.80300E-03  200.00     0.77800E-03
    300.00     0.74800E-03  400.00     0.71500E-03  500.00     0.67700E-03
    600.00     0.64800E-03  700.00     0.61600E-03  800.00     0.58300E-03
    900.00     0.55100E-03  1000.0     0.51900E-03  1100.0     0.48400E-03
    1200.0     0.45100E-03  1300.0     0.41700E-03  1400.0     0.38000E-03
    1500.0     0.36300E-03

PROPERTY TABLE C     MAT=       1  NUM. POINTS= 16
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.10330      100.00     0.10530      200.00     0.11210
    300.00     0.11770      400.00     0.12340      500.00     0.12780
    600.00     0.13220      700.00     0.13810      800.00     0.14520
    900.00     0.15350      1000.0     0.16240      1100.0     0.17100
    1200.0     0.18290      1300.0     0.20450      1400.0     0.40100
    1500.0     0.19820

PROPERTY TABLE EX    MAT=       2  NUM. POINTS=  6
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.27900E+08  100.00     0.27800E+08  200.00     0.27700E+08
    300.00     0.27400E+08  400.00     0.27000E+08  500.00     0.26400E+08

PROPERTY TABLE NUXY  MAT=       2  NUM. POINTS=  6
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.30000      100.00     0.30000      200.00     0.30000
    300.00     0.30000      400.00     0.30000      500.00     0.30000

PROPERTY TABLE ALPX  MAT=       2  NUM. POINTS=  6
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.65000E-05  100.00     0.65000E-05  200.00     0.66700E-05
    300.00     0.68700E-05  400.00     0.70700E-05  500.00     0.72500E-05

PROPERTY TABLE DENS  MAT=       2  NUM. POINTS=  1
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    0.0000     0.28300

PROPERTY TABLE KXX   MAT=       2  NUM. POINTS= 16
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.81300E-03  100.00     0.80300E-03  200.00     0.77800E-03
    300.00     0.74800E-03  400.00     0.71500E-03  500.00     0.67700E-03
    600.00     0.64800E-03  700.00     0.61600E-03  800.00     0.58300E-03
    900.00     0.55100E-03  1000.0     0.51900E-03  1100.0     0.48400E-03
    1200.0     0.45100E-03  1300.0     0.41700E-03  1400.0     0.38000E-03
    1500.0     0.36300E-03

PROPERTY TABLE C     MAT=       2  NUM. POINTS= 16
  TEMPERATURE     DATA    TEMPERATURE     DATA   TEMPERATURE     DATA
    70.000     0.10330      100.00     0.10530      200.00     0.11210
    300.00     0.11770      400.00     0.12340      500.00     0.12780
```

```
    600.00      0.13220      700.00      0.13810      800.00      0.14520
    900.00      0.15350      1000.0      0.16240      1100.0      0.17100
    1200.0      0.18290      1300.0      0.20450      1400.0      0.40100
    1500.0      0.19820

PROPERTY TABLE EX     MAT=       3  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.29900E+08 100.00      0.29900E+08 200.00      0.29900E+08
    300.00      0.29900E+08 400.00      0.29900E+08 500.00      0.29900E+08

PROPERTY TABLE NUXY  MAT=       3  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.30000      100.00      0.30000      200.00      0.30000
    300.00      0.30000      400.00      0.30000      500.00      0.30000

PROPERTY TABLE ALPX  MAT=       3  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.65000E-05 100.00      0.65000E-05 200.00      0.65000E-05
    300.00      0.65000E-05 400.00      0.65000E-05 500.00      0.65000E-05

PROPERTY TABLE DENS  MAT=       3  NUM. POINTS=  1
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    0.0000      0.28300

PROPERTY TABLE KXX   MAT=       3  NUM. POINTS= 16
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.81300E-03 100.00      0.80300E-03 200.00      0.77800E-03
    300.00      0.74800E-03 400.00      0.71500E-03 500.00      0.67700E-03
    600.00      0.64800E-03 700.00      0.61600E-03 800.00      0.58300E-03
    900.00      0.55100E-03 1000.0      0.51900E-03 1100.0      0.48400E-03
    1200.0      0.45100E-03 1300.0      0.41700E-03 1400.0      0.38000E-03
    1500.0      0.36300E-03

PROPERTY TABLE C     MAT=       3  NUM. POINTS= 16
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.10330      100.00      0.10530      200.00      0.11210
    300.00      0.11770      400.00      0.12340      500.00      0.12780
    600.00      0.13220      700.00      0.13810      800.00      0.14520
    900.00      0.15350      1000.0      0.16240      1100.0      0.17100
    1200.0      0.18290      1300.0      0.20450      1400.0      0.40100
    1500.0      0.19820

PROPERTY TABLE EX     MAT=       4  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.27900E+08 100.00      0.27800E+08 200.00      0.27700E+08
    300.00      0.27400E+08 400.00      0.27000E+08 500.00      0.26400E+08

PROPERTY TABLE NUXY  MAT=       4  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.30000      100.00      0.30000      200.00      0.30000
    300.00      0.30000      400.00      0.30000      500.00      0.30000

PROPERTY TABLE ALPX  MAT=       4  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE     DATA     TEMPERATURE      DATA
    70.000      0.65000E-05 100.00      0.65000E-05 200.00      0.66700E-05
    300.00      0.68700E-05 400.00      0.70700E-05 500.00      0.72500E-05
```

```
PROPERTY TABLE DENS  MAT=          4  NUM. POINTS=  1
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    0.0000      0.28300

PROPERTY TABLE KXX   MAT=          4  NUM. POINTS= 16
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.81300E-03  100.00      0.80300E-03  200.00      0.77800E-03
    300.00      0.74800E-03  400.00      0.71500E-03  500.00      0.67700E-03
    600.00      0.64800E-03  700.00      0.61600E-03  800.00      0.58300E-03
    900.00      0.55100E-03  1000.0      0.51900E-03  1100.0      0.48400E-03
    1200.0      0.45100E-03  1300.0      0.41700E-03  1400.0      0.38000E-03
    1500.0      0.36300E-03

PROPERTY TABLE C     MAT=          4  NUM. POINTS= 16
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.10330      100.00      0.10530      200.00      0.11210
    300.00      0.11770      400.00      0.12340      500.00      0.12780
    600.00      0.13220      700.00      0.13810      800.00      0.14520
    900.00      0.15350      1000.0      0.16240      1100.0      0.17100
    1200.0      0.18290      1300.0      0.20450      1400.0      0.40100
    1500.0      0.19820

PROPERTY TABLE EX    MAT=          5  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.28300E+08  100.00      0.28100E+08  200.00      0.27600E+08
    300.00      0.27000E+08  400.00      0.26500E+08  500.00      0.25800E+08

PROPERTY TABLE NUXY  MAT=          5  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.30000      100.00      0.30000      200.00      0.30000
    300.00      0.30000      400.00      0.30000      500.00      0.30000

PROPERTY TABLE ALPX  MAT=          5  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.85000E-05  100.00      0.86000E-05  200.00      0.89000E-05
    300.00      0.92000E-05  400.00      0.95000E-05  500.00      0.97000E-05

PROPERTY TABLE DENS  MAT=          5  NUM. POINTS=  1
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    0.0000      0.28300

PROPERTY TABLE KXX   MAT=          5  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.19900E-03  100.00      0.20100E-03  200.00      0.21500E-03
    300.00      0.22700E-03  400.00      0.24100E-03  500.00      0.25200E-03

PROPERTY TABLE C     MAT=          5  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    70.000      0.11650      100.00      0.11700      200.00      0.12190
    300.00      0.12520      400.00      0.12890      500.00      0.13110

PROPERTY TABLE EX    MAT=          6  NUM. POINTS=  8
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
   -40.000      0.24600E+07 -20.000      0.24300E+07  70.000      0.22700E+07
    100.00      0.22100E+07  200.00      0.20100E+07  300.00      0.18500E+07
    400.00      0.17000E+07  500.00      0.15200E+07
```

```
PROPERTY TABLE NUXY  MAT=       6  NUM. POINTS=  6
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    81.000       0.40000       212.00      0.40000       302.00      0.40000
    392.00       0.40000       513.00      0.40000       621.00      0.40000

PROPERTY TABLE ALPX  MAT=       6  NUM. POINTS=  8
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
   -40.000       0.15560E-04 -20.000       0.15650E-04  70.000       0.16060E-04
    100.00       0.16220E-04  200.00       0.16700E-04  300.00       0.17330E-04
    400.00       0.18160E-04  500.00       0.19120E-04

PROPERTY TABLE DENS  MAT=       6  NUM. POINTS=  1
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    0.0000       0.41000

PROPERTY TABLE KXX   MAT=       6  NUM. POINTS=  4
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    32.000       0.47000E-03  212.00       0.44700E-03  392.00       0.42100E-03
    572.00       0.39800E-03

PROPERTY TABLE C     MAT=       6  NUM. POINTS=  5
  TEMPERATURE      DATA     TEMPERATURE      DATA     TEMPERATURE      DATA
    32.000       0.30600E-01  212.00       0.31500E-01  392.00       0.32500E-01
    572.00       0.33500E-01  752.00       0.32800E-01
```

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring			
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Appendix B

CNS 8-120B Cask Analyses
ANSYS Finite Element Analysis Result Summary

(8 Pages)

CNS 8-120B Cask Analyses
ANSYS Finite Element Analysis Result Summary

1. Normal Conditions - Thermal Stresses

Primary Lid Stresses

```
                S1          S2          S3          SINT        SEQV

 MINIMUM  VALUES
 NODE       9331        9331        4301        8777        8777
 VALUE   -2225.2     -2657.1     -3662.8      62.395      54.500

 MAXIMUM  VALUES
 NODE       9275        8859        8859        4301        4301
 VALUE    3385.7      1172.6      916.19      3514.3      3082.9
```

Seal Plate Stresses

```
                S1          S2          S3          SINT        SEQV

 MINIMUM  VALUES
 NODE      10460       10441       10453       10613       10613
 VALUE   -3028.3     -6411.6     -10382.      986.19      867.17

 MAXIMUM  VALUES
 NODE      10450       10591       10613       10457       10457
 VALUE    3214.0     -602.09     -1270.0      10191.      8869.6
```

Bolting Ring Stresses

```
                S1          S2          S3          SINT        SEQV

 MINIMUM  VALUES
 NODE      10675       11002       11002       11626       11626
 VALUE   -939.40     -6016.8     -30747.      1784.3      1546.0

 MAXIMUM  VALUES
 NODE      10924       10862       10862       10924       10924
 VALUE    56878.      21173.      15164.      60116.      52982.
```

Inner Shell Stresses

```
                S1          S2          S3          SINT        SEQV

 MINIMUM  VALUES
 NODE      14391       14239       14199       14201       14201
 VALUE    83.882     -2529.0     -5076.5      2467.6      2447.4

 MAXIMUM  VALUES
 NODE      10689       10693       10686       10689       10689
 VALUE    20285.      8892.0      2683.4      18562.      16232.
```

Outer Shell Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE       10949       12829       10941       13152       13152
 VALUE     1343.7      588.02     -4224.4      3440.4      3010.1

 MAXIMUM VALUES
 NODE       10871       10868       10871       10870       10870
 VALUE     20067.      9415.8      3766.4      16831.      14854.
```

Primary Lid Bolt Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE       20442       20434       20543       20132       20006
 VALUE    -3316.4     -4278.7     -8340.0      512.87      468.39

 MAXIMUM VALUES
 NODE       20476       20476       20472       20431       20431
 VALUE     13936.      10193.      8420.3      16701.      14949.
```

2. Result Summary - Hypothetical End Drop

Primary Lid Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE        9363        9449        9363        9226        9226
 VALUE    -33821.     -48717.     -88062.      127.45      120.93

 MAXIMUM VALUES
 NODE        4301        4271        4271        9665        9665
 VALUE     38501.      13208.      12496.      63356.      56988.
```

Seal Plate Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE       10570       10570       10565       10466       10466
 VALUE    -63686.     -67583.    -0.12704E+06  5647.5      5064.3

 MAXIMUM VALUES
 NODE       10605       10610       10617       10571       10571
 VALUE     54216.      3981.8     -439.02    0.12127E+06 0.10526E+06
```

Bolting Ring Stresses

```
             S1          S2          S3         SINT         SEQV

 MINIMUM VALUES
 NODE      11515       11515       11516       11010        11010
 VALUE    -25683.     -32826.     -55220.      1695.9       1489.3

 MAXIMUM VALUES
 NODE      10835       11304       11303       10805        10805
 VALUE     30010.      12422.      2292.6      49055.       42487.
```

Inner Shell Stresses

```
             S1          S2          S3         SINT         SEQV

 MINIMUM VALUES
 NODE      14408       10681       10674       10683        10683
 VALUE    -2019.5     -8631.5     -32103.      8439.6       7324.0

 MAXIMUM VALUES
 NODE      10690       14258       10683       10674        10674
 VALUE     3253.0      74.150     -6227.4      33688.       30153.
```

Outer Shell Stresses

```
             S1          S2          S3         SINT         SEQV

 MINIMUM VALUES
 NODE      10868       10868       10868       10939        10939
 VALUE    -4551.5     -7641.2     -28499.      3372.6       3047.2

 MAXIMUM VALUES
 NODE      12829       12831       10937       12886        12886
 VALUE     15561.      11768.      102.18      24948.       23755.
```

Primary Lid Bolt Stresses

```
             S1          S2          S3         SINT         SEQV

 MINIMUM VALUES
 NODE      20457       20584       20547       20107        20107
 VALUE    -4230.6     -10462.     -14495.     0.37957      0.33552

 MAXIMUM VALUES
 NODE      20599       20563       20469       20563        20563
 VALUE     16502.      13060.      4512.3      18668.       17260.
```

3. Hypothetical Corner Drop – Far End

Primary Lid Stresses

```
                S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE        4271        9990        4301        8777        8777
VALUE     -29865.     -54005.     -83358.      776.51      681.18

MAXIMUM VALUES
NODE        8632        8652        4458        8623        8623
VALUE    0.10072E+06  58220.      22990.     0.12126E+06 0.11227E+06
```

Seal Plate Stresses

```
                S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       10485       10458       10458       10519       10519
VALUE      63.853     -5603.2     -26687.      923.59      842.42

MAXIMUM VALUES
NODE       10592       10448       10394       10458       10458
VALUE      23076.      7810.2      365.56      40353.      34958.
```

Bolting Ring Stresses

```
                S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       10836       10806       11420       11613       11657
VALUE     -5319.5     -29138.     -68148.      476.70      427.40

MAXIMUM VALUES
NODE       12048       12063       10869       11420       11420
VALUE      68046.      14443.      3006.6      88998.      78829.
```

Inner Shell Stresses

```
                S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       14237       14329       10663       13795       13795
VALUE      5349.3     -127.30     -3622.5      4303.7      4215.3

MAXIMUM VALUES
NODE       10683       10674       14184       10685       10686
VALUE      22472.      5986.1      4863.9      22629.      20811.
```

Outer Shell Stresses

```
               S1           S2           S3           SINT         SEQV

 MINIMUM  VALUES
 NODE       12831        12830        12848        13304        13304
 VALUE     25.967      -819.64      -5198.2       571.32       495.78

 MAXIMUM  VALUES
 NODE       10870        10871        12790        10862        10862
 VALUE     26612.       5300.7       3155.9       27138.       25062.
```

Primary Lid Bolt Stresses

```
               S1           S2           S3           SINT         SEQV

 MINIMUM  VALUES
 NODE       19985        19990        20002        20285        20285
 VALUE    -7413.8      -40804.      -51227.       2290.7       1993.1

 MAXIMUM  VALUES
 NODE       20180        20182        20179        20356        20329
 VALUE    0.22397E+06  91377.       70254.      0.18254E+06 0.17227E+06
```

4. Hypothetical Corner Drop – Close End

Primary Lid Stresses

```
               S1           S2           S3           SINT         SEQV

 MINIMUM  VALUES
 NODE        9915         9915         9955         6297         6297
 VALUE    -674.77      -1267.2      -1520.7       4.9068       4.8204

 MAXIMUM  VALUES
 NODE       10080        10080        10105        10034        10034
 VALUE     1253.1       822.01       463.19       1472.0       1276.4
```

Seal Plate Stresses

```
               S1           S2           S3           SINT         SEQV

 MINIMUM  VALUES
 NODE       10616        10456        10458        10645        10471
 VALUE    -95.946      -270.14      -1335.2       240.79       215.99

 MAXIMUM  VALUES
 NODE       10453        10453        10446        10460        10460
 VALUE     1991.2       548.14       192.14       2150.8       1865.2
```

Bolting Ring Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE      10871       10871       10924       11319       11320
 VALUE   -3363.8     -4886.2     -13420.      227.86      199.38

 MAXIMUM VALUES
 NODE      10680       10677       11359       10924       10924
 VALUE    10023.      4794.9      371.73      12620.      11739.
```

Inner Shell Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE      10690       10686       10688       10698       10698
 VALUE   -1540.5     -2219.7     -9008.1      3537.2      3094.5

 MAXIMUM VALUES
 NODE      14320       13856       14246       13805       13806
 VALUE    13682.      4952.6     0.42798      14512.      13713.
```

Outer Shell Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE      10873       10871       10868       12917       12917
 VALUE   -1418.1     -2072.7     -6676.8      41.649      36.321

 MAXIMUM VALUES
 NODE      10941       12829       13210       12886       12886
 VALUE    4881.4      2708.1     0.32603      5611.6      5398.4
```

Primary Lid Bolt Stresses

```
             S1          S2          S3          SINT        SEQV

 MINIMUM VALUES
 NODE      20138       20563       20138       19935       19935
 VALUE   -2129.0     -2957.0     -7897.9      159.83      148.96

 MAXIMUM VALUES
 NODE      20179       20560       20560       20407       20407
 VALUE    9008.3      3292.6      3208.0      8800.8      8422.5
```

5. Hypothetical Fire Accident

Primary Lid Stresses

```
                S1          S2          S3           SINT         SEQV

 MINIMUM VALUES
 NODE        9915        9982        9982         8780         8780
 VALUE    -3171.0     -5593.9     -13315.       22.815       20.580

 MAXIMUM VALUES
 NODE        9471       10079        4459         9982         9982
 VALUE     4381.0      1850.5      568.55       12181.       10674.
```

Seal Plate Stresses

```
                S1          S2          S3           SINT         SEQV

 MINIMUM VALUES
 NODE       10458       10441       10404        10613        10613
 VALUE    -4522.0     -11329.     -17786.       4597.7       4019.0

 MAXIMUM VALUES
 NODE       10450       10487       10592        10403        10403
 VALUE     5316.8      593.69     -5109.7       14908.       13322.
```

Bolting Ring Stresses

```
                S1          S2          S3           SINT         SEQV

 MINIMUM VALUES
 NODE       11002       11002       11002        11533        11533
 VALUE    -3551.3     -14284.     -62936.       231.40       200.43

 MAXIMUM VALUES
 NODE       10924       10862       10862        10924        10924
 VALUE     99067.      38172.      24806.     0.10606E+06    93221.
```

Inner Shell Stresses

```
                S1          S2          S3           SINT         SEQV


 MINIMUM VALUES
 NODE       14238       10680       14199        14238        14238
 VALUE     3262.1     -1429.3     -9605.3       6911.7       6015.2

 MAXIMUM VALUES
 NODE       10689       14062       10686        10689        10689
 VALUE     59803.      22702.      8222.5       53624.       48627.
```

Outer Shell Stresses

```
            S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       13067       12838       12943       13067       12877
VALUE     5370.2     -4090.4     -7567.4      5571.6      5192.2

MAXIMUM VALUES
NODE       10871       10868       10871       10870       10870
VALUE     35029.      17510.      6479.6      29072.      25455.
```

Primary Lid Bolt Stresses

```
            S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       20469       20434       20138       19935       19935
VALUE    -7124.1     -8829.1     -24793.      535.20      483.28

MAXIMUM VALUES
NODE       20179       20476       20472       20431       20431
VALUE     29979.      19853.      14512.      28652.      25323.
```

Title 8-120B Cask Analyses - Optional Raised Seal Surface on Bolting Ring			
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Appendix C

CNS 8-120B Cask Analyses
ANSYS Stress Result Linearization

(10 Pages)

CNS 8-120B Cask Analyses
ANSYS Stress Result Linearization

1. Normal Conditions - Thermal Stresses

Bolting Ring

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION1 DSYS= 0

        ***** POST1 LINEARIZED STRESS LISTING *****
       INSIDE NODE =  10978     OUTSIDE NODE =  11000

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM  12

             ** MEMBRANE **
     SX           SY          SZ          SXY         SYZ         SXZ
 0.1387E+05   6499.       -263.0      -686.4      -1974.      -3240.
     S1           S2          S3          SINT        SEQV
 0.1458E+05   7029.       -1508.      0.1609E+05  0.1394E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I   3034.       -2064.       463.5       107.5       66.36       642.9
C   0.000        0.000       0.000       0.000       0.000       0.000
O  -3034.        2064.      -463.5      -107.5      -66.36      -642.9
     S1           S2          S3          SINT        SEQV
I   3189.        312.4      -2068.       5257.       4559.
C   0.000        0.000       0.000       0.000       0.000
O   2068.       -312.4      -3189.       5257.       4559.

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I  0.1690E+05   4435.        200.5      -578.8      -1908.      -2597.
C  0.1387E+05   6499.       -263.0      -686.4      -1974.      -3240.
O  0.1083E+05   8563.       -726.5      -793.9      -2040.      -3883.
     S1           S2          S3          SINT        SEQV
I  0.1730E+05   5156.       -921.4      0.1822E+05  0.1607E+05
C  0.1458E+05   7029.       -1508.      0.1609E+05  0.1394E+05
O  0.1202E+05   8992.       -2347.      0.1437E+05  0.1312E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I   1.318      -0.8963      0.2013      0.4669E-01  0.2881E-01  0.2792
C  0.3638E-11 -0.2092E-10 -0.8794E-10 -0.6708E-11  0.1592E-11 -0.7321E-10
O  -1.318       0.8963     -0.2013     -0.4669E-01 -0.2881E-01 -0.2792
     S1           S2          S3          SINT        SEQV
I   1.385       0.1356     -0.8978      2.282       1.980
C  0.4487E-10 -0.2156E-10 -0.1285E-09  0.1734E-09  0.1515E-09
O  0.8978      -0.1356     -1.385       2.282       1.980

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I  0.1690E+05   4434.        200.7      -578.8      -1908.      -2597.
```

```
C  0.1387E+05   6499.        -263.0       -686.4       -1974.       -3240.
O  0.1083E+05   8564.        -726.7       -793.9       -2041.       -3883.
     S1          S2           S3           SINT         SEQV         TEMP
I  0.1730E+05   5155.        -921.2       0.1822E+05   0.1607E+05   176.6
C  0.1458E+05   7029.        -1508.       0.1609E+05   0.1394E+05
O  0.1202E+05   8992.        -2347.       0.1437E+05   0.1312E+05   176.6
```

2. Hypothetical End Drop

Primary Lid

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION1 DSYS= 0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =   9363     OUTSIDE NODE =   8723

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY           SZ          SXY          SYZ          SXZ
  92.95       -6327.      -0.2645E+05  -70.30       35.31       -1571.
     S1          S2           S3          SINT         SEQV
  186.4       -6328.      -0.2654E+05  0.2673E+05   0.2414E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ           SXY          SYZ          SXZ
I  -7787.       -9231.       -0.3076E+05  -122.3       94.96        -3568.
C   0.000        0.000        0.000        0.000        0.000        0.000
O   7787.        9231.        0.3076E+05   122.3       -94.96        3568.
     S1          S2           S3           SINT         SEQV
I  -7236.       -9240.       -0.3130E+05   0.2407E+05   0.2313E+05
C   0.000        0.000        0.000        0.000        0.000
O  0.3130E+05   9240.        7236.        0.2407E+05   0.2313E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ           SXY          SYZ          SXZ
I  -7694.      -0.1556E+05  -0.5721E+05  -192.6        130.3       -5139.
C   92.95       -6327.      -0.2645E+05  -70.30        35.31       -1571.
O   7880.        2904.        4313.        51.98       -59.65        1997.
     S1          S2           S3           SINT         SEQV
I  -7161.      -0.1556E+05  -0.5774E+05   0.5058E+05   0.4694E+05
C   186.4       -6328.      -0.2654E+05   0.2673E+05   0.2414E+05
O   8774.        3429.        2893.        5881.        5632.

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY           SZ           SXY          SYZ          SXZ
I -0.3285E+05 -0.1827E+05 -0.2955E+05  -7.980        22.25       -2730.
C   3194.        3591.        0.1028E+05   32.15       -18.01        1431.
O  -5109.       -5276.      -0.1517E+05  -49.38        45.87       -1921.
     S1          S2           S3           SINT         SEQV
I -0.1827E+05 -0.2801E+05 -0.3439E+05   0.1612E+05   0.1406E+05
C  0.1056E+05   3593.        2914.        7646.        7330.
```

```
O  -4748.      -5282.      -0.1553E+05  0.1078E+05  0.1052E+05

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.4055E+05 -0.3383E+05 -0.8676E+05  -200.6       152.5       -7869.
C   3287.      -2735.      -0.1617E+05  -38.15       17.30       -140.2
O   2771.      -2372.      -0.1086E+05   2.596      -13.78        76.02
     S1          S2          S3          SINT        SEQV        TEMP
I -0.3382E+05 -0.3925E+05 -0.8806E+05  0.5424E+05  0.5174E+05   70.00
C   3288.      -2736.      -0.1617E+05  0.1946E+05  0.1725E+05
O   2771.      -2372.      -0.1086E+05  0.1363E+05  0.1192E+05   70.00
```

Bolting Ring

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION2 DSYS= 0

          ***** POST1 LINEARIZED STRESS LISTING *****
         INSIDE NODE =  10494     OUTSIDE NODE =  10571

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
-0.2113E+05 -0.2343E+05 -0.2323E+05  -83.09       21.35       269.3
     S1          S2          S3          SINT        SEQV
-0.2109E+05 -0.2326E+05 -0.2344E+05   2348.       2263.

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  0.4382E+05  0.2428E+05  0.3749E+05  -170.3      -5.415      -3595.
C   0.000       0.000       0.000       0.000       0.000       0.000
O -0.4382E+05 -0.2428E+05 -0.3749E+05   170.3       5.415       3595.
     S1          S2          S3          SINT        SEQV
I  0.4544E+05  0.3586E+05  0.2428E+05  0.2116E+05  0.1835E+05
C   0.000       0.000       0.000       0.000       0.000
O -0.2428E+05 -0.3586E+05 -0.4544E+05  0.2116E+05  0.1835E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  0.2269E+05   852.7       0.1426E+05  -253.4       15.93      -3326.
C -0.2113E+05 -0.2343E+05 -0.2323E+05  -83.09       21.35        269.3
O -0.6494E+05 -0.4771E+05 -0.6071E+05   87.24       26.76       3865.
     S1          S2          S3          SINT        SEQV
I  0.2385E+05  0.1311E+05   849.7       0.2300E+05  0.1993E+05
C -0.2109E+05 -0.2326E+05 -0.2344E+05   2348.       2263.
O -0.4771E+05 -0.5842E+05 -0.6723E+05  0.1952E+05  0.1694E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.1879E+05 -0.1023E+05 -0.1445E+05   127.5      -69.73       3300.
C  0.1205E+05   5610.       5689.      -126.1        78.40      -2018.
O  -1552.      0.3172E+05  0.1095E+06   245.4      -384.0      0.1500E+05
     S1          S2          S3          SINT        SEQV
```

```
I -0.1023E+05 -0.1267E+05 -0.2057E+05  0.1034E+05   9364.
C  0.1264E+05   5610.       5100.       7541.       7299.
O  0.1115E+06  0.3172E+05  -3545.      0.1150E+06  0.1020E+06

              ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I   3897.       -9381.      -189.6      -125.9      -53.79      -25.81
C  -9075.     -0.1782E+05 -0.1754E+05  -209.2       99.75      -1749.
O -0.6649E+05 -0.1599E+05  0.4875E+05   332.7      -357.3      0.1886E+05
     S1           S2          S3          SINT        SEQV        TEMP
I   3899.       -189.4      -9382.     0.1328E+05  0.1178E+05   70.00
C  -8722.     -0.1779E+05 -0.1792E+05   9197.       9133.
O  0.5176E+05 -0.1599E+05 -0.6951E+05  0.1213E+06  0.1053E+06   70.00
```

Seal Plate

3. Hypothetical Corner Drop

Primary Lid

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION1 DSYS= 0

        ***** POST1 LINEARIZED STRESS LISTING *****
       INSIDE NODE =   2695     OUTSIDE NODE =   4355

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM  11

              ** MEMBRANE **
     SX           SY          SZ          SXY         SYZ         SXZ
  3047.       0.3068E+05  0.1202E+05  -1592.      -573.3      -6395.
     S1           S2          S3          SINT        SEQV
 0.3077E+05   0.1534E+05  -369.5      0.3114E+05  0.2697E+05

              ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I  0.2137E+05  0.4533E+05   8347.      -2513.      -631.8      -7925.
C   0.000       0.000       0.000       0.000       0.000       0.000
O -0.2137E+05 -0.4533E+05  -8347.       2513.       631.8       7925.
     S1           S2          S3          SINT        SEQV
I  0.4559E+05  0.2492E+05   4534.      0.4106E+05  0.3556E+05
C   0.000       0.000       0.000       0.000       0.000
O  -4534.     -0.2492E+05 -0.4559E+05  0.4106E+05  0.3556E+05

              ** MEMBRANE PLUS BENDING **   I=INSIDE C=CENTER O=OUTSIDE
     SX           SY          SZ          SXY         SYZ         SXZ
I  0.2442E+05  0.7601E+05  0.2036E+05  -4106.      -1205.     -0.1432E+05
C   3047.      0.3068E+05  0.1202E+05  -1592.      -573.3      -6395.
O -0.1832E+05 -0.1465E+05   3671.       921.0       58.48       1530.
     S1           S2          S3          SINT        SEQV
I  0.7633E+05  0.3672E+05   7737.      0.6859E+05  0.5964E+05
C  0.3077E+05  0.1534E+05  -369.5      0.3114E+05  0.2697E+05
```

```
O   3778.      -0.1444E+05 -0.1864E+05  0.2242E+05  0.2064E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I -0.3094E+05   7964.      -0.1175E+05 -1679.       867.3       0.1148E+05
C   5795.      -2391.       5019.       735.5       327.2       1924.
O  -4046.       4243.      -2977.      -1025.      -136.0      -1786.
      S1          S2          S3          SINT        SEQV
I   8044.      -6386.      -0.3639E+05  0.4443E+05  0.3926E+05
C   7431.       3452.      -2460.       9890.       8620.
O   4369.      -1688.      -5461.       9830.       8589.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  -6525.       0.8397E+05  8612.      -5785.      -337.8      -2841.
C   8842.       0.2829E+05  0.1704E+05 -856.8      -246.1      -4472.
O -0.2237E+05 -0.1041E+05   693.9      -103.6      -77.48      -255.9
      S1          S2          S3          SINT        SEQV        TEMP
I  0.8434E+05   9122.      -7403.       0.9174E+05  0.8470E+05  70.00
C  0.2833E+05  0.1900E+05   6838.       0.2149E+05  0.1866E+05
O   697.3      -0.1041E+05 -0.2237E+05  0.2307E+05  0.1998E+05  70.00
```

Bolting Ring

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION4 DSYS= 0

        ***** POST1 LINEARIZED STRESS LISTING *****
       INSIDE NODE =  20263     OUTSIDE NODE =  20342

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM    1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
   1310.       1417.       0.3526E+05  -105.0       1004.       1845.
      S1          S2          S3          SINT        SEQV
 0.3539E+05    1481.       1117.       0.3427E+05  0.3409E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I   1319.       2079.      -0.7002E+05 -469.0      -87.12       2945.
C   0.000       0.000       0.000       0.000       0.000       0.000
O  -1319.      -2079.       0.7002E+05  469.0       87.12      -2945.
      S1          S2          S3          SINT        SEQV
I   2330.       1190.      -0.7014E+05  0.7247E+05  0.7190E+05
C   0.000       0.000       0.000       0.000       0.000
O  0.7014E+05  -1190.      -2330.       0.7247E+05  0.7190E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I   2629.       3496.      -0.3476E+05 -573.9       916.7       4790.
C   1310.       1417.       0.3526E+05 -105.0       1004.       1845.
O  -8.931      -662.2       0.1053E+06  364.0       1091.      -1100.
      S1          S2          S3          SINT        SEQV
```

```
I    3854.        2900.      -0.3539E+05  0.3924E+05  0.3877E+05
C  0.3539E+05    1481.         1117.      0.3427E+05  0.3409E+05
O  0.1053E+06    150.6        -844.4      0.1061E+06  0.1056E+06

            ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  -2591.       -1587.       3467.       6.177       -1392.       367.8
C   859.4       -273.8      -597.6       158.7        924.9      -913.1
O  -2521.       -4030.      -553.1       873.9       -1424.       1682.
      S1          S2          S3          SINT        SEQV
I   3845.       -1931.      -2624.       6469.        6152.
C   1351.        279.1      -1642.       2993.        2627.
O   569.1       -2356.      -5317.       5886.        5097.

            ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I   38.09        1909.     -0.3129E+05  -567.7       -475.7       5158.
C   2169.        1143.      0.3466E+05   53.69        1929.       932.1
O  -2529.       -4693.      0.1047E+06   1238.       -333.2       581.9
      S1          S2          S3          SINT        SEQV        TEMP
I   2213.        565.4     -0.3212E+05  0.3434E+05  0.3354E+05    70.00
C  0.3480E+05    2143.       1032.      0.3377E+05  0.3322E+05
O  0.1047E+06   -1969.      -5258.      0.1100E+06  0.1084E+06    70.00
```

Seal Plate

```
 PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION3   DSYS=
0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  10458     OUTSIDE NODE =  10613

  LOAD STEP     1  SUBSTEP=     1
  TIME=    1.0000         LOAD CASE=  0

 THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

            ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
  -6538.     0.1450E+05 -0.1136E+05   1839.       -3565.       5529.
      S1          S2          S3          SINT        SEQV
  0.1504E+05  -2928.     -0.1551E+05  0.3055E+05  0.2660E+05

            ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  -4634.       -2965.      -7186.       479.5       -1289.       4025.
C   0.000        0.000       0.000       0.000        0.000       0.000
O   4634.        2965.       7186.      -479.5        1289.      -4025.
      S1          S2          S3          SINT        SEQV
I  -1569.       -2845.     -0.1037E+05   8800.        8237.
C   0.000        0.000       0.000       0.000        0.000
O  0.1037E+05    2845.       1569.       8800.        8237.

            ** MEMBRANE PLUS BENDING **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I -0.1117E+05  0.1153E+05 -0.1855E+05   2318.       -4853.       9554.
```

```
C  -6538.      0.1450E+05 -0.1136E+05   1839.       -3565.        5529.
O  -1904.      0.1746E+05  -4178.       1359.       -2276.        1503.
      S1          S2          S3          SINT        SEQV
I  0.1233E+05 -4659.      -0.2586E+05 0.3819E+05  0.3314E+05
C  0.1504E+05 -2928.      -0.1551E+05 0.3055E+05  0.2660E+05
O  0.1777E+05 -1158.       -5234.     0.2301E+05  0.2126E+05

             ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  -1832.       1326.       70.07       206.6       -96.39       258.5
C   1830.      -1327.      -73.19      -206.4        95.83      -256.7
O  -1828.       1328.       76.31       206.2       -95.27       255.0
      S1          S2          S3          SINT        SEQV
I   1344.       100.8      -1882.       3226.       2818.
C   1879.      -103.5      -1345.       3224.       2817.
O   1346.       106.2      -1876.       3223.       2816.

             ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I -0.1300E+05  0.1286E+05 -0.1848E+05   2525.       -4950.        9813.
C  -4708.      0.1317E+05 -0.1144E+05   1632.       -3469.        5272.
O  -3732.      0.1879E+05  -4102.       1566.       -2372.        1758.
      S1          S2          S3          SINT        SEQV        TEMP
I  0.1367E+05 -5603.      -0.2669E+05 0.4035E+05  0.3496E+05   70.00
C  0.1370E+05 -1822.      -0.1485E+05 0.2855E+05  0.2475E+05
O  0.1912E+05 -2157.       -6004.     0.2512E+05  0.2344E+05   70.00
```

Lid Bolts

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION2 DSYS= 0

        ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =  11421     OUTSIDE NODE =  10836

 LOAD STEP     1  SUBSTEP=      1
 TIME=    1.0000         LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM  11

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
   1493.       845.6       9852.      -78.11       -2906.     0.1495E+05
      S1          S2          S3          SINT        SEQV
 0.2147E+05   840.0     -0.1012E+05  0.3158E+05  0.2777E+05

             ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  0.1911E+05  0.2378E+05   7476.       974.0       -1908.       9912.
C   0.000       0.000       0.000       0.000        0.000       0.000
O -0.1911E+05 -0.2378E+05  -7476.      -974.0        1908.      -9912.
      S1          S2          S3          SINT        SEQV
I  0.2480E+05  0.2397E+05   1594.     0.2321E+05  0.2280E+05
C   0.000       0.000       0.000       0.000        0.000
O  -1594.     -0.2397E+05 -0.2480E+05 0.2321E+05  0.2280E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
```

```
     SX          SY          SZ          SXY         SYZ         SXZ
I  0.2061E+05  0.2462E+05  0.1733E+05   895.9       -4814.      0.2486E+05
C   1493.       845.6       9852.       -78.11      -2906.      0.1495E+05
O -0.1762E+05 -0.2293E+05   2376.       -1052.      -998.0       5036.
     S1          S2          S3          SINT        SEQV
I  0.4424E+05  0.2481E+05  -6498.      0.5074E+05  0.4434E+05
C  0.2147E+05   840.0     -0.1012E+05  0.3158E+05  0.2777E+05
O   3628.     -0.1867E+05 -0.2313E+05  0.2676E+05  0.2483E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.3910E+05   6080.       -9432.      4424.       1808.      -0.1949E+05
C  -1091.      -442.2       9049.      -175.3      -492.7       2999.
O  -6619.      -8074.      -9205.      -583.0       29.06       166.7
     S1          S2          S3          SINT        SEQV
I   6510.       204.5     -0.4917E+05  0.5568E+05  0.5281E+05
C   9896.      -467.4      -1913.      0.1181E+05  0.1116E+05
O  -6407.      -8272.      -9220.       2813.       2479.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I -0.1849E+05  0.3071E+05   7895.       5319.      -3006.       5376.
C   401.7       403.5      0.1890E+05  -253.4      -3399.      0.1795E+05
O -0.2424E+05 -0.3101E+05  -6829.      -1635.      -968.9       5203.
     S1          S2          S3          SINT        SEQV        TEMP
I  0.3153E+05   8787.     -0.2021E+05  0.5173E+05  0.4491E+05   70.00
C  0.3015E+05   313.9     -0.1076E+05  0.4091E+05  0.3665E+05
O  -5320.     -0.2537E+05 -0.3138E+05  0.2606E+05  0.2364E+05   70.00
```

4. Hypothetical Fire Accident

Bolting Ring

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION1 DSYS= 0

        ***** POST1 LINEARIZED STRESS LISTING *****
       INSIDE NODE =  10867     OUTSIDE NODE =  11002

 LOAD STEP     1  SUBSTEP=     1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM   1

             ** MEMBRANE **
     SX          SY          SZ          SXY         SYZ         SXZ
 0.1720E+05  0.1400E+05  -6088.      -2691.       5020.     -0.1504E+05
     S1          S2          S3          SINT        SEQV
 0.2635E+05  0.1263E+05 -0.1386E+05  0.4021E+05  0.3540E+05

             ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  0.7480E+05  0.2450E+05   6537.       3867.       1520.       391.0
C   0.000       0.000       0.000       0.000       0.000       0.000
O -0.7480E+05 -0.2450E+05  -6537.      -3867.      -1520.      -391.0
     S1          S2          S3          SINT        SEQV
```

```
I  0.7510E+05  0.2433E+05   6409.       0.6869E+05  0.6171E+05
C   0.000       0.000       0.000       0.000       0.000
O  -6409.     -0.2433E+05 -0.7510E+05  0.6869E+05  0.6171E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  0.9200E+05  0.3849E+05   449.0       1176.       6541.      -0.1464E+05
C  0.1720E+05  0.1400E+05  -6088.      -2691.       5020.      -0.1504E+05
O -0.5760E+05 -0.1050E+05 -0.1262E+05  -6558.       3500.      -0.1543E+05
      S1          S2          S3          SINT        SEQV
I  0.9428E+05  0.3956E+05  -2903.       0.9719E+05  0.8439E+05
C  0.2635E+05  0.1263E+05 -0.1386E+05  0.4021E+05  0.3540E+05
O  -3543.     -0.1428E+05 -0.6291E+05  0.5936E+05  0.5479E+05

             ** PEAK **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I   32.48       10.64       2.838       1.679       0.6602      0.1698
C  0.1721E-08  0.8949E-09  0.8822E-09 -0.2638E-10  0.9995E-09 -0.1583E-09
O  -32.48      -10.64      -2.838      -1.679      -0.6602     -0.1698
      S1          S2          S3          SINT        SEQV
I   32.61       10.56       2.783       29.83       26.80
C  0.1960E-08  0.1653E-08 -0.1158E-09  0.2076E-08  0.1941E-08
O  -2.783      -10.56      -32.61       29.83       26.80

             ** TOTAL **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I  0.9203E+05  0.3851E+05   451.8       1177.       6541.      -0.1464E+05
C  0.1720E+05  0.1400E+05  -6088.      -2691.       5020.      -0.1504E+05
O -0.5763E+05 -0.1051E+05 -0.1263E+05  -6559.       3499.      -0.1543E+05
      S1          S2          S3          SINT        SEQV        TEMP
I  0.9432E+05  0.3957E+05  -2899.       0.9722E+05  0.8441E+05   203.2
C  0.2635E+05  0.1263E+05 -0.1386E+05  0.4021E+05  0.3540E+05
O  -3551.     -0.1428E+05 -0.6294E+05  0.5938E+05  0.5481E+05   201.5
```

Inner Shell

```
PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY PATH= SECTION2 DSYS= 0

         ***** POST1 LINEARIZED STRESS LISTING *****
        INSIDE NODE =   10688      OUTSIDE NODE =   10674

 LOAD STEP     1  SUBSTEP=      1
 TIME=    1.0000          LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN COORDINATE SYSTEM    1

             ** MEMBRANE **
      SX          SY          SZ          SXY         SYZ         SXZ
   8164.       7095.      0.2013E+05   16.43       -112.8       8905.
      S1          S2          S3          SINT        SEQV
 0.2488E+05   7095.       3419.       0.2146E+05  0.1988E+05

             ** BENDING **   I=INSIDE C=CENTER O=OUTSIDE
      SX          SY          SZ          SXY         SYZ         SXZ
I   2036.       9335.      0.2688E+05   71.35       -50.24       3558.
C   0.000       0.000       0.000       0.000       0.000       0.000
```

```
O  -2036.      -9335.      -0.2688E+05  -71.35      50.24       -3558.
     S1          S2          S3          SINT        SEQV
I  0.2738E+05   9336.       1535.      0.2585E+05  0.2296E+05
C   0.000       0.000       0.000       0.000       0.000
O  -1535.      -9336.      -0.2738E+05 0.2585E+05  0.2296E+05

             ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  0.1020E+05  0.1643E+05  0.4702E+05   87.78      -163.0      0.1246E+05
C   8164.       7095.      0.2013E+05   16.43      -112.8       8905.
O   6129.      -2241.      -6748.      -54.92      -62.54       5346.
     S1          S2          S3          SINT        SEQV
I  0.5084E+05  0.1643E+05   6376.      0.4446E+05  0.4039E+05
C  0.2488E+05   7095.       3419.      0.2146E+05  0.1988E+05
O   8060.      -2241.      -8679.      0.1674E+05  0.1462E+05

             ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I  -986.2       2517.       9520.       39.32       2.382      -460.6
C   401.1      -861.8      -3337.      -14.17      0.1347E-01   180.0
O  -618.0       929.9       3829.       17.35      -2.436      -259.2
     S1          S2          S3          SINT        SEQV
I   9540.       2518.      -1007.      0.1055E+05   9300.
C   409.9      -862.0      -3346.       3756.       3309.
O   3844.       930.1      -633.3       4477.       3936.

             ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
     SX          SY          SZ          SXY         SYZ         SXZ
I   9214.      0.1895E+05  0.5654E+05   127.1      -160.6      0.1200E+05
C   8565.       6233.      0.1680E+05   2.263      -112.8       9085.
O   5511.      -1311.      -2919.      -37.57      -64.98       5087.
     S1          S2          S3          SINT        SEQV        TEMP
I  0.5941E+05  0.1895E+05   6341.      0.5307E+05  0.4802E+05   227.5
C  0.2266E+05   6233.       2706.      0.1995E+05  0.1844E+05
O   7903.      -1311.      -5311.      0.1321E+05  0.1174E+05   234.0
```

4.0 Containment

This chapter describes the containment configuration of the Model CNS 8-120B Package for Normal Transport and Hypothetical Accident Conditions.

4.1 Containment Boundary

4.1.1 Containment Vessel

The package containment vessel is defined as the inner shell of the shielded transport cask, together with the associated lid, o-ring seals and lid closure bolts. The inner shell of the cask or containment vessel consists of a right circular cylinder of 62 inches inner diameter and 75 inches inside height. The shell is fabricated of ¾" thick carbon steel plate, ASTM A516-70. At the base, the cylindrical shell is attached to a circular end plate with full penetration welds. The primary lid is attached to the cask body with twenty (20) equally spaced 2-8 UN bolts. A secondary lid covers an opening in the primary lid and is attached to the primary lid using twelve (12) equally spaced 2-8 UN bolts. See Section 4.1.4 for closure details.

4.1.2 Containment Penetration

There are four penetrations of the containment vessel. These are (1) the optional drain line; (2) the primary lid with the containment boundary of the primary lid's inner o-ring; (3) the secondary lid with the containment boundary of the secondary lid's inner o-ring; and (4) the cask vent port located in the primary lid. Located at the cask base, the drain line consists of a 2" diameter steel rod drilled to 0.75 inches diameter penetrating into the second 3-1/4" layer of steel that forms the cask bottom. A 0.63" DIA. hole, drilled at a right angle, opens on the side of the outer shell near the cask bottom. A vent port penetrates the primary lid into the main cask cavity. The vent and drain penetrations are sealed with Parker Stat-O-Seals or equivalent. The primary and secondary lids are sealed with Parker silicone o-rings or equivalent.

4.1.3 Welds and Seals

The containment vessel is fabricated using full penetration groove welds. Seals are described in Sections 4.1.2 and 4.1.4.

4.1.4 Closure

The primary lid closure consists of two 3-1/4" thick laminated plates, stepped to fit over and within the top edge of the cylindrical body. The lid is supported at the perimeter of the cylindrical body by a thick plate (bolt ring) welded to the top of the inner and outer cylindrical body walls. This plate contains a 14-gauge stainless steel ring at a location, which corresponds to the sealing surface for the o-rings mounted in the lid. The lid is attached to the cask body by twenty (20) equally spaced 2-8 UN bolts. These bolts are torqued to 500 ft-lbs ± 10 % (lubricated). Two (2) solid, high temperature silicone o-rings are retained in machined grooves at the lid perimeter. Groove dimensions prevent over-compression of the o-rings by the closure bolt pre-load forces and hypothetical accident impact forces. The cask is fitted with a secondary lid of similar construction attached to the primary lid with twelve (12) equally spaced identical bolts. The secondary lid is also sealed with two (2) solid, high temperature silicone o-rings in machined grooves.

The vent and drain penetrations are sealed with Parker Stat-O-Seals (or equivalent), which are used beneath the heads of the hex head cap screws. Table 4.1.4 gives the torque values for the cap screws.

Location	Size (in.)	Torque Values (in-lbs, ± 10% lubricated)	Torque Values (ft-lbs, ± 10% lubricated)
Test Ports (2)	3/8	144	12
Vent	1/2	240	20
Drain	3/4	960	80
Primary Lid	2-8UN	---	500
Secondary Lid	2-8UN	---	500

TABLE 4.1.4 Bolt and Cap Screw Torque Requirements

4.2 Containment Requirements for Normal Conditions of Transport

4.2.1 Leak Test Requirements

The CNS 8-120B cask is designed, fabricated, and leak tested to preclude a release of radioactive material in excess of the limits prescribed in NRC Regulatory Guide 7.4, paragraph C and 10CFR71.51(a)(1). The limits on leakage during normal conditions of transport are defined by 10CFR71.51(a)(1).

The leak test procedure must be able to detect leaks of 4.94 x 10^{-6} ref-cm^3/sec (based on dry air at 25°C with a pressure differential of one atmosphere) to assure compliance with 10CFR71.51(a)(1). A description of the calculational procedure used to determine this value follows.

10CFR71.51(a)(1) states the containment requirements for normal conditions of transport as:

...no loss or dispersal of radioactive contents, as demonstrated to a sensitivity of 10^{-6} A_2 *per hour, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging;*

ANSI N14.5-1997 (Reference 4) states that the permissible leak rate shall be determined by:

$$L := \frac{R}{C}$$

Where:

L = permissible volumetric leak rate (cm^3/sec)
R = package containment requirements (Ci/sec)
C = activity per unit volume of the medium that could escape from the containment system (Ci/cm3)

$$R_N := A_2 \cdot \frac{10^{-6}}{hr} \qquad \Rightarrow \qquad R_N = 2.78 \times 10^{-10} \frac{A_2}{sec}$$

In Section 3.4.4, it is noted that the saturated water vapor in equilibrium at 168 degrees-F and 8.95 psig could exist within the internal shipping containers (liners or drains). It is assumed that these conditions exist within the cask cavity. The containment must limit the leakage of this water vapor to that prescribed in ANSI N14.5. It is very conservative to assume that the concentration of nuclides in the free liquid is equal to that of the solids, which comprise the vast majority of material being transported in the cask. This value is determined below:

Curies = Total Curie Content of Vapor
Void = Minimum Void Volume of Cavity

$$C_N := \frac{Curies}{V_{Void}}$$

- Cask curie content is limited to 2000*A2 or less (Chapter 1).
- Free water is limited to the restriction of one-percent of solid volume

$\Rightarrow$ $Curies := 1\% \cdot 2000 \cdot A_2$

Vapor Curie Content

$\Rightarrow$ $Curies = 20 A_2$

The minimum void volume occurs when the largest liner is shipped.

$V_{Cavity} := \frac{\pi \cdot 61.8^2 \cdot 74.9}{4} \cdot in^3$ See Chapter 1 for Cask Dimensions

$\Rightarrow \quad V_{Cavity} = 224672 in^3$

$V_{Liner} := \frac{\pi \cdot 60^2 \cdot 73}{4} \cdot in^3 \quad \Rightarrow \quad V_{Liner} = 206403 in^3$

$V_{Void} := V_{Cavity} - V_{Liner} \quad \Rightarrow \quad V_{Void} = 18269 in^3$

$\Rightarrow \quad V_{Void} = 299379 cm^3$

$C_N := \frac{Curies}{V_{Void}} \quad \Rightarrow \quad C_N = 6.68 \times 10^{-5} \frac{A_2 \cdot C_i}{cm^3}$

$L_N := \frac{R_N}{C_N}$

$L_N = 4.16 \times 10^{-6} \frac{cm^3}{sec}$

A leak rate at standard conditions will be calculated which is equivalent to a volumetric leak rate of 4.16×10^{-6} cm^3/sec using Equations B.3, B.4, and B.5 from ANSI N14.5-1997 (Ref. 4).

First, determine the diameter of the leakage hole, D_{max}, that would allow a leakage of 4.16×10^{-6} cm^3/sec.

$M_{air} := 29 \cdot \frac{gm}{mole}$

$T := 350 \cdot K$

$L_u := (F_c + F_m) \cdot (P_u - P_d) \cdot \left(\frac{P_a}{P_u}\right) \cdot \frac{cm^3}{sec}$ Equation B.5, ANSI N14.5-1997

$$F_m := \frac{3.8 \cdot 10^3 \cdot D^3 \cdot \sqrt{\frac{T}{M_{air}}}}{a \cdot P_a}$$ Equation B.4, ANSI N14.5-1997

$$F_c := \frac{2.49 \cdot 10^6 \cdot D^4}{a \cdot \mu_{air}}$$

Where:

L_u = upstream leakage rate, cm^3/sec

$\mu_{air} := 0.0185 \cdot cP$

$T := 350 \cdot K$ Section 3.4.4

$P_u := 23.65 \cdot psi$

Pu = 8.95 psig = 1.61 atm

$P_u = 1.61 atm$

$P_d := 1 \cdot atm$

$$P_a := \frac{P_u + P_d}{2}$$

$P_a = 1.30 atm$

$$M_{air} := 29 \cdot \frac{gm}{mole}$$

$a := 0.6 \cdot cm$ assumption for length of hole leaking the air

Substitute these parameters into equations B.3, B.4, and B.5 respectively:

$$F_m(D) := \frac{3.81 \cdot 10^3 \cdot D^3 \cdot \sqrt{\frac{350}{29}}}{(0.6) \cdot (1.30)} \qquad F_m(D) = 1.70 \times 10^4 D^3$$

$$F_c(D) := \frac{2.49 \cdot 10^6 \cdot D^4}{(.6) \cdot (.0185)} \qquad F_c(D) = 2.24 \times 10^8 D^4$$

$$F(D) := \left[\left[\left(2.24\cdot 10^{8}\cdot D^{4}\right)+\left(1.70\cdot 10^{4}\cdot D^{3}\right)\right]\cdot(1.61-1)\cdot\frac{1.30}{1.61}\right]-4.16\cdot 10^{-6}$$

Solve this equation iteratively.

$D := 4.23\cdot 10^{-4}\cdot \mathrm{cm}$

Next, using Equation B.5 of Ref. 4, determine the flow of air at standard conditions through a hole of this diameter:

$a := 0.6\cdot \mathrm{cm}$

$M_{air} := 29\cdot\frac{\mathrm{gm}}{\mathrm{mole}}$

$\mu_{air} := 0.0185\cdot \mathrm{cP}$

$P_u := 1.0\cdot \mathrm{atm}$

$P_d := 0.1\cdot \mathrm{atm}$

$P_a := \frac{P_u+P_d}{2}$ $\qquad P_a = 0.55\mathrm{atm}$

$T := 298\cdot \mathrm{K}$

$$F_m := \frac{3.81\cdot 10^{3}\cdot D^{3}\cdot\sqrt{\frac{T}{M_{air}}}\cdot \mathrm{cm}\cdot \mathrm{gm}^{.5}}{a\cdot P_a\cdot \mathrm{mole}^{.5}\cdot \mathrm{sec}\cdot \mathrm{K}^{.5}} \qquad F_m = 2.801\times 10^{-6}\,\frac{\mathrm{cm}^{3}}{\mathrm{atm}\cdot \mathrm{sec}}$$

$$F_c := \frac{2.49\,10^{6}\cdot D^{4}\cdot \mathrm{cP}}{a\cdot\mu_{air}\cdot \mathrm{sec}\cdot \mathrm{atm}} \qquad F_c = 7.182\times 10^{-6}\,\frac{\mathrm{cm}^{3}}{\mathrm{sec}\cdot \mathrm{atm}}$$

Substitute these values into Equation B.5 of Ref. 4:

$$L_{STD} := \left(F_c+F_m\right)\cdot\left(P_u-P_d\right)\cdot\frac{P_a}{P_u}$$

$$L_{STD} = 4.94\times 10^{-6}\,\frac{\mathrm{refcm}^{3}}{\mathrm{sec}}$$

4.2.2 Pressurization of the Containment Vessel

Section 2.4.4 summarizes normal condition temperatures and pressures within the containment vessel. These pressures and associated temperatures are used to evaluate the integrity of the CNS 8-120B package. None of these conditions reduce the effectiveness of the package containment.

4.2.3 Coolant Containment

Not applicable; there are no coolants in the CNS 8-120B package.

4.2.4 Coolant Loss

Not applicable; there are no coolants in the CNS 8-120B package.

4.3 Containment Requirements for the Hypothetical Accident Conditions

4.3.1 Fission Gas Products

There are no fission gas products present.

4.3.2 Leak Test Requirements

Section 2.7 demonstrates that the CNS 8-120B cask will maintain its containment capability throughout the hypothetical accident conditions. Fission gas products will not be carried within the cask so there can be no release of fission gases. The CNS 8-120B cask is designed, fabricated, and leak tested to preclude a release of radioactive material in excess of the limits prescribed in NRC Regulatory Guide 7.4, paragraph C and 10CFR71.51(a)(2). The limits on leakage during hypothetical accident conditions are defined by 10CFR71.51(a)(2).

The leak test procedure which assures compliance with leakage during normal conditions of transport will also be sufficient to assure compliance during hypothetical accident conditions. A description follows of the calculational procedure which demonstrates that the maximum leakage requirement during normal conditions of transport is more stringent than the maximum leakage requirement during the hypothetical accident.

10CFR71.51(a)(2) states the containment requirements for the hypothetical accident conditions as:

> ...no escape of krypton-85 exceeding 10,000 curies in one week, no escape of other radioactive material exceeding a total amount of A_2 in one week, and no external radiation dose rate exceeding one rem per hour at one meter from the external surface of the package.

Since the cask does not carry fission products or radioactive gases, only the A_2 per week requirement is limiting. A release of A_2 in one week is equivalent to the activity release rate, R_a, given by the following equation.

$$\begin{aligned} Ra &= (A2/\text{week})(1\ \text{week}/168\ \text{hr}) \\ &= 5.952 \times 10^{-3}\ A2/\text{hr} \end{aligned}$$

Next, determine L_A for hypothetical accident conditions:

$$R_A := 1.65\,10^{-6} \cdot \frac{A_2}{\text{sec}}$$

$C_A := C_N$ Section 4.2.1

$$L_A := \frac{R_A}{C_A} \quad \Rightarrow \quad L_A = 0.025\frac{\text{cm}^3}{\text{sec}}$$

Since L_N is more restrictive than L_A, the standard leak rate is calculated in Section 4.2.1 based on the permissible leak rate of $L_N = 4.94 \times 10^{-6}\ \text{cm}^3/\text{sec}$.

4.4 Determination of Test Conditions for Assembly Verification Leak Test

This test will be performed by pressurizing the annulus between the o-ring seals of the primary and secondary lids with air using a pressure gauge, readable without estimation, and calibrated to a maximum error of 1% of full scale.

The test pressure shall be 18 psig and the test shall last for 1 hour with an allowable pressure drop of 1 psi. Any condition which results in a pressure drop of more than 1 psi shall be corrected.

The following sections demonstrate that the sensitivity at the test conditions is equivalent to the required procedure sensitivity of $5\times10^{-4}\,\frac{\text{atm}\cdot\text{cm}^{-3}}{\text{s}}$ based on dry air at standard conditions as defined in ANSI N14.5-1977.

4.4.1 Maximum Permissible Leak Rates at Standard Condtions

The sensitivity of the assembly verification leak test must demonstrate that not more than an A_2 quantity of the radioactive contents is released in 10 days. The sensitivity of the leakage test need not be more sensitive than $1\times10^{-3}\,\frac{\text{atm}\cdot\text{cm}^3}{\text{s}}$ of dry air at standard conditions. Furthermore, ANSI N14.5 requires that the leakage test procedure have a sensitivity of one-half the maximum permissible leakage rate, unless otherwise justified. Thus, a procedure sensitivity of $5\times10^{-4}\,\frac{\text{atm}\cdot\text{cm}^3}{\text{s}}$ of dry air at standard conditions is required.

4.4.2 Detector Sensitivity – Test Conditions

This test will be performed by the pressure drop test described in Section A3.1 of ANSI N14.5 – 1977 by pressurizing the annulus between the o-ring seals with air. The annulus is a ¼" deep groove, 1/8" in width, centered between the o-rings, with an inner diameter of 64.0 inches. The volume of the annulus is 103.2 cm^3. The leakage rate at test conditions determined from Equation B.11 of ANSI N14.5-1977 as given below in slightly different terms:

$$L_t = \frac{VT_s\Delta P}{T_t}\left(\frac{atm \cdot cm^3}{s}\right) \qquad (1)$$

where:

L_t = equivalent leakage rate of air at the test pressure converted to the standard temperature of 298K.
V = test volume (cm^3)
T_s = 298K
ΔP = allowable change in pressure (atm)
T = test temperature (K)
t = test time (s)

4.4.3 Equivalent Leakage Rate at Standard Conditions

Leakage rates are normally expressed as an equivalent leakage rate of dry air at the standard conditions of 298K (25°C) and a 1 atm pressure against a vacuum of 0.1 atm or less. In the case of laminar flow, leakage rates at test conditions, with upstream and downstream pressures different from standard conditions, are proportional to the equivalent leakage rate at standard conditions in the manner described by Equation B.5 of ANSI N14.5-1977 as given below:

$$L_s = \frac{L_t n_t}{n_S[(P_u)^2 - (P_o)^2]}\,\frac{atm \cdot cm^3}{s} \qquad (2)$$

where:

L_s = equivalent leakage rate of dry air at standard conditions.
$n_s = 0.0184$ cP
L_t = equivalent leakage rate of air at the test pressure converted to the standard temperature of 298K
n_t = viscosity of air at test conditions (cP).
P_u = upstream test pressure (atm).
P_o = downstream test pressure (atm).

Substituting equation (1) into equation (2) yields:

$$L_S = \frac{VT_S n_t P}{Ttn_S\left[(P_u)^2 - (P_O)^2\right]} \quad \frac{\text{atm}\cdot\text{cm}^3}{\text{s}} \quad (3)$$

Where each of the above terms has been described previously.

4.4.4 Required Charge Pressure at Test Temperature

In the specific case of performing a pressure drop leak test on the 8-120B cask the annulus between the o-ring seals will be pressurized with air and the allowable change in pressure will be fixed at 1 psi (0.068 atm). The downstream test pressure in this instance is 1 atm and the test time will be fixed at 1 hour (3600 sec). Insertion of the various constants into equation (3) reduces it to:

$$L_S = \frac{31.43 n_t}{\left[(P_t)^2 - 1\right]T} \quad \frac{\text{atm}\cdot\text{cm}^3}{\text{s}} \quad (4)$$

Where: $P_t = P_u$, the upstream test pressure (atm).

In the above equation "n_t" is a function of the test temperature. Since the variation in the test air viscosity with the test temperature is nearly linear over the temperature range for which the cask will be leak tested, the test air viscosity will be interpolated between n = 0.01708 cP at 273 K (32°F) and N = 0.02102 cP at 347 K (165°F) (ref. 1, p. F-47). Functionally this is expressed as:

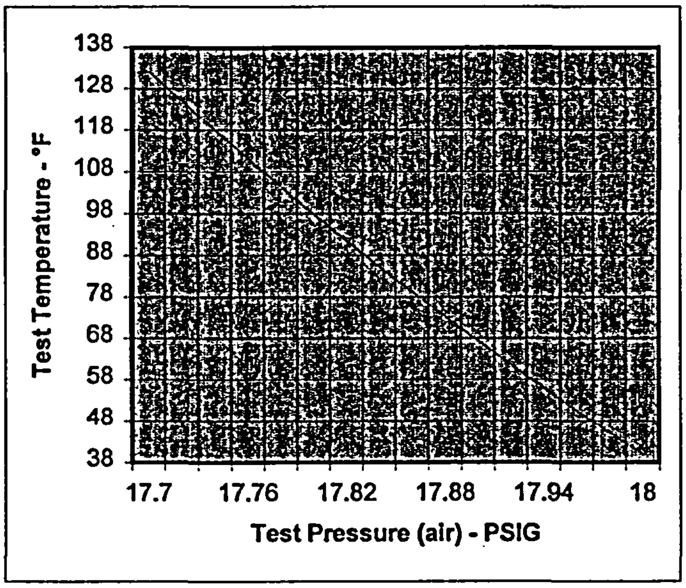
$n_t = 5.324 \times 10^{-5} T + 2.545 \times 10^{-3}$ (cP) (5)

Substitution of equation (5) into equation (4) yields:

$$L_S = \frac{1.673\times10^{-3}T + 0.080}{\left[(P_t)^2 - 1\right]T} \quad \frac{atm\cdot cm^3}{s} \quad (6)$$

When "L_S" of equation (6) is equated to the required procedure sensitivity for leaktightness of 5 X 10^{-4} $\frac{atm\cdot cm^3}{s}$ of dry air at standard conditions then a functional relationship between the test temperature T and the required test pressure remains.

This relationship is shown on the figure below with temperature converted to a Fahrenheit scale and pressure converted to a psig scale. From the figure, it is clear that a charge pressure of 18 psig (2.22 atm) is sufficient for leak testing the cask at temperatures above 40°F (278K).



Allowable Pressure Drop = 1 psi

Test Time = 1 Hour (3600 s)

$L_S = 5.0 \times 10^{-4}$ atm-cm^3/s (dry air & stand. conditions)

4.5 Periodic Verification Leak Rate Determination Using R-12 Test Gas

Calculation of Permitted R-12 Leak Rate

The purpose of this calculation is to determine the allowable leak rate using the R-12 halogen gas that may be used to perform the annual verification leak tests on the CNS 8-120B cask.

The text of this document is prepared using Mathcad, Version 2000i, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. As a courtesy, several conversion factors are presented within the text, and the important final calculated values are listed in tabular form at the end of this document for use in checking the calculations, so that the calculations can be documented as hand calculations, eliminating the need for full verification of the Mathcad software.

This calculation uses formulas presented in ANSI N14.5 – 1997 (Ref. 4).

This test is performed using an R-12 leak detector. A leak standard, traceable to NIST, is used to calibrate the leak detector to detect the maximum allowable leak rates specified in Figure 4.3.

First, using the Standard Allowable Leak Rate from Section 4.3.2 of the SAR, determine the maximum possible diameter hole in the cask o-ring that would permit this leak rate at standard conditions.

$$L_{std} := 4.94 \cdot 10^{-6} \cdot \text{ref} \cdot \frac{\text{cm}^3}{\text{sec}}$$

See Section 4.2.1

Where, for air at standard conditions:

$P_a := .505 \cdot \text{atm}$

$T := 298 \cdot K$

$P_u := 1.0 \cdot \text{atm}$

$M_{air} := 29 \cdot \frac{\text{gm}}{\text{mole}}$

$P_d := .01 \cdot \text{atm}$

$\mu_{air} := 0.0185 \cdot \text{cP}$

Assume a, which is the length of the hole in the o-ring, is:

$a := 0.6 \cdot \text{cm}$

$D_{max} := 4.23 \cdot 10^{-4} \cdot \text{cm}$ From Section 4.2.1

$$F_c(D) := \frac{2.49 \cdot 10^6 \cdot D^4 \cdot \text{cP} \cdot \text{ref}}{a \cdot \mu_{air} \cdot \text{sec} \cdot \text{atm}}$$ Eqn. B3 - ANSI N14.5

$$F_m(D) := \frac{3.81 \cdot 10^3 \cdot D^3 \cdot \sqrt{\frac{T}{M_{air}}} \cdot \text{cm} \cdot \text{gm}^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot \text{mole}^{0.5} \cdot \text{sec}}$$ Eqn. B4 - ANSI N14.5

$$L_{std}(D) := \left(F_c(D) + F_m(D)\right) \cdot \left(P_u - P_d\right) \cdot \frac{P_a}{P_u}$$ Eqn. B5 - ANSI N14.5

Next, determine the equivalent air/R12 mixture (Lmix) that would leak from Dmax during a leak test. Assume the O-ring void is first evacuated to 20"Hg vacuum (9.92"Hg abs) and then pressurized to 25 psig (2.7 atm) with an air/R12 mixture.

$P_{mix} := 2.7 \cdot atm$

$P_{air} := 9.92 \cdot in\_Hg$ $P_{air} = 0.33 atm$

$P_{R12} := P_{mix} - P_{air}$ $P_{R12} = 2.37 atm$

$P_d := 1.0 \cdot atm$

$P_a := \frac{P_{mix} + P_d}{2}$ $P_a = 1.85 atm$

$M_{R12} := 121 \cdot \frac{gm}{mole}$ ANSI N14.5 - 1997

$\mu_{R12} := 0.0124 \cdot cP$ ANSI N14.5 - 1997

$M_{mix} := \frac{M_{R12} \cdot P_{R12} + M_{air} \cdot P_{air}}{P_{mix}}$ Eqn. B.7 - ANSI N14.5

$M_{mix} = 109.7 \frac{gm}{mole}$

$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R12} \cdot P_{R12}}{P_{mix}}$ Eqn. B.8 - ANSI N14.5

$\mu_{mix} = 0.013 cP$

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R12 do not change significantly over the range of temperatures evaluated:

$T := 273 \cdot K, 278 \cdot K .. 318 \cdot K$ Temperature range for test: 32°F to 113°F

$$F_c := \frac{2.49 \cdot 10^6 \cdot D_{max}^{\ 4} \cdot cP \cdot ref}{a \cdot \mu_{mix} \cdot sec \cdot atm}$$

then,

$$F_c = 1.01 \times 10^{-5} \frac{cm^3}{sec \cdot atm}$$

$$F_m(T) := \frac{3.81 \cdot 10^3 \cdot D_{max}^{\ 3} \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left[\left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_d\right) \cdot \frac{P_a}{P_{mix}} \right]$$

$$T_F(T) := \left[(T \cdot F - 273 \cdot K) \cdot \frac{9}{5 \cdot K} + 32 \right]$$

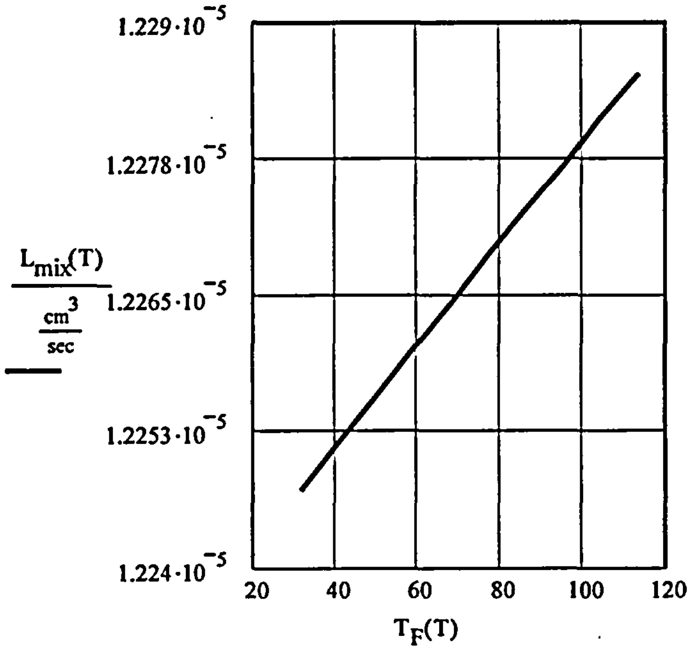


Fig. 4.1 - Allowable R-12/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

The R-12 component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-12 partial pressure to the total pressure of the mix, as follows.

$$L_{R12}(T) := L_{mix}(T)\cdot\frac{P_{R12}}{P_{mix}}$$

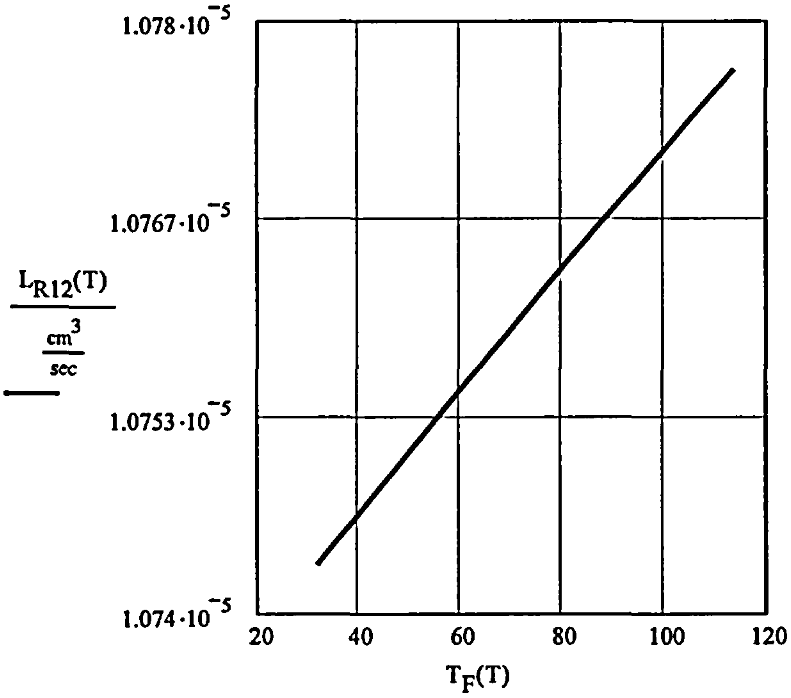


Fig. 4.2 - Allowable R-12 test leakage, cm3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{R12} in oz/yr:

$$N(T) := \frac{P_{R12} \cdot V}{R_o \cdot T}$$

Ideal Gas Law

where,

$$R_o := \frac{82.05 \cdot cm^3 \cdot atm}{mole \cdot K}$$

This data can then be used to convert the volumetric leak rate for R-12 calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$L(T) := L_{R12}(T) \cdot \frac{N(T)}{V} \cdot M_{R12} \cdot \frac{yr}{oz}$$

$$\frac{gm}{sec} = 1.113 \times 10^{6} \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

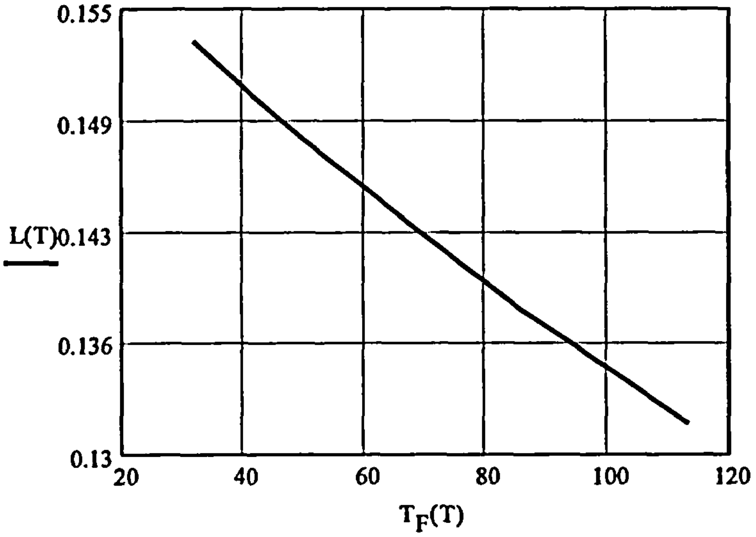


Fig. 4.3 - Allowable R12 test leakage, oz/yr, versus test temperature, deg.F

The graph above can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

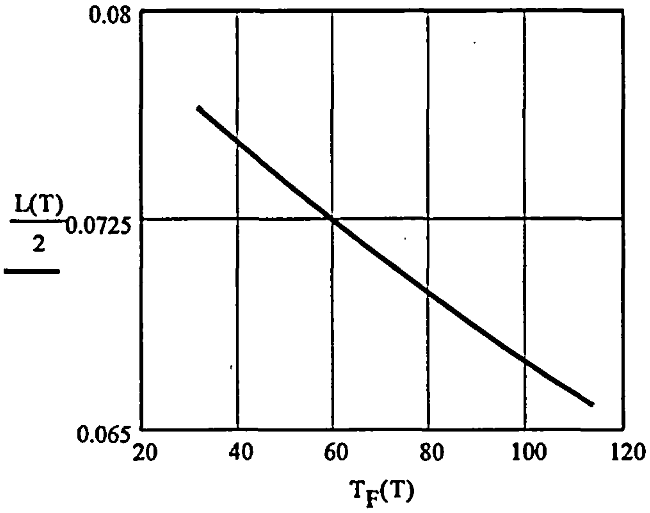


Fig. 4.4 - Allowable R12 test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.4 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.6 Periodic Verification Leak Rate Determination Using R-134A Test Gas

Calculation of Permitted R-134a Leak Rate

The purpose of this calculation is to determine the allowable leak rate using the R-134a halogen gas that will be used as an alternative to perform the annual verification leak tests on the CNS 8-120B cask. This halogen gas is now in widespread use as a replacement gas for R-12 in many industrial applications. Properties for R134a are attached in Appendix 4.1.

The text of this document is prepared using Mathcad, Version 2001i, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. As a courtesy, several conversion factors are presented within the text, and the important final calculated values are listed in tabular form at the end of this document for use in checking the calculations, so that the calculations can be documented as hand calculations, eliminating the need for full verification of the Mathcad software.

This calculation uses formulas presented in ANSI N14.5 - 1997.

This test is performed using an R-134a leak detector. A leak standard, traceable to NIST, is used to calibrate the leak detector to detect the maximum allowable leak rates specified in Figure 4.7.

First, using the Standard Allowable Leak Rate from Section 4.3.2 of the SAR, determine the maximum possible diameter hole in the cask o-ring that would permit this leak rate at standard conditions.

$L_{std} := 4.94 \cdot 10^{-6} \cdot ref \cdot \frac{cm^3}{sec}$ See Section 4.2.1.

Where, for air at standard conditions:

$P_a := .505 \cdot atm$

$T := 298 \cdot K$

$P_u := 1.0 \cdot atm$

$M_{air} := 29 \cdot \frac{gm}{mole}$

$P_d := .01 \cdot atm$

$\mu_{air} := 0.0185 cP$

Assume a, which is the length of the hole in the o-ring is:

$a := 0.6 \cdot cm$

The maximum possible diameter of hole in the o-ring is:

$D_{max} := 4.23 \cdot 10^{-4} \cdot cm$ From 4.2.1

$$F_c(D) := \frac{2.49 \cdot 10^6 \cdot D^4 \cdot cP \cdot ref}{a \cdot \mu_{air} \cdot sec \cdot atm}$$ Eqn. B3 - ANSI N14.5

$$F_m(D) := \frac{3.81 \cdot 10^3 \cdot D^3 \cdot \sqrt{\frac{T}{M_{air}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$ Eqn. B4 - ANSI N14.5

$$L_{std}(D) := \left(F_c(D) + F_m(D)\right) \cdot \left(P_u - P_d\right) \cdot \frac{P_a}{P_u}$$ Eqn. B5 - ANSI N14.5

Next, determine the equivalent air/R134a mixture (Lmix) that would leak from Dmax during a leak test. Assume the O-ring void is first evacuated to 20"Hg vacuum (9.92"Hg abs) and then pressurized to 25 psig (2.7 atm) with an air/R134a mixture.

$P_{mix} := 2.7 \cdot atm$

$P_{air} := 9.92 \cdot in\_Hg$

$P_{air} = 0.33 atm$

$P_{R134a} := P_{mix} - P_{air}$

$P_{R134a} = 2.37\text{atm}$

$P_d := 1 \cdot \text{atm}$

$$P_a := \frac{P_{mix} + P_d}{2}$$

$P_a = 1.85\text{atm}$

The properties of R134a are given in the attached literature:

$$M_{R134a} := 102 \cdot \frac{\text{gm}}{\text{mole}}$$

$\mu_{R134a} := 0.012 \cdot \text{cP}$

$$M_{mix} := \frac{M_{R134a} \cdot P_{R134a} + M_{air} \cdot P_{air}}{P_{mix}}$$

$$M_{mix} = 93.04 \frac{\text{gm}}{\text{mole}}$$

$$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R134a} \cdot P_{R134}}{P_{mix}}$$ Eqn. B.7 - ANSI N14.5

$\mu_{mix} = 0.013\text{cP}$ Eqn. B.8 - ANSI N14.5

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R134a do not change significantly over the range of temperatures evaluated:

$T := 273\cdot K, 278\cdot K .. 318\cdot K$ Temperature range for test: 32°F to 113°F

$$F_c := \frac{2.49\cdot 10^6\cdot D_{max}^{\ 4}\cdot cP\cdot ref}{a\cdot \mu_{mix} sec\cdot atm}$$

then,

$$F_c = 1.038\times 10^{-5}\,\frac{cm^3}{sec\cdot atm}$$

$$F_m(T) := \frac{3.81\cdot 10^3\cdot D_{max}^{\ 3}\cdot\sqrt{\frac{T}{M_{mix}}}\cdot cm\cdot gm^{0.5}}{a\cdot P_a\cdot K^{0.5}\cdot mole^{0.5}\cdot sec}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right)\cdot\left(P_{mix} - P_d\right)\cdot\frac{P_a}{P_{mix}}$$

$$T_F(T) := \left[(T\cdot F - 273\cdot K)\cdot\frac{9}{5\cdot K} + 32\right]$$

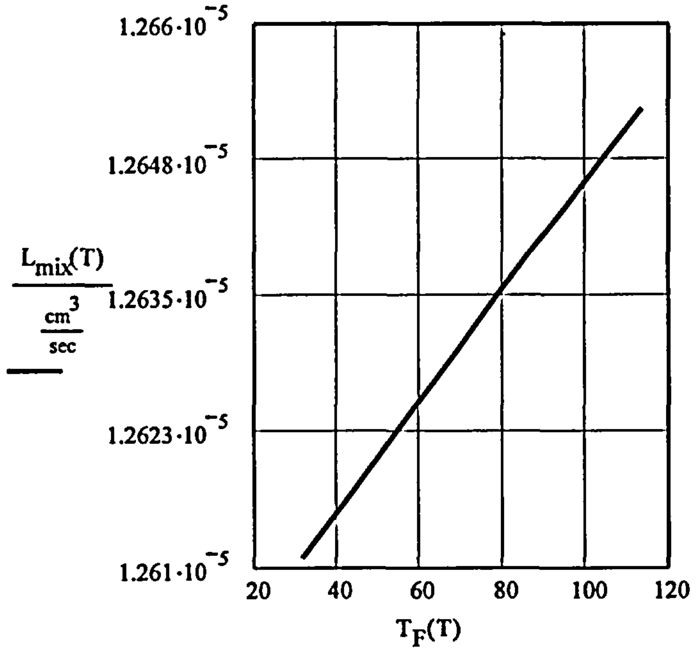


Fig. 4.5 - Allowable R-134a/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

The R-134a component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-134a partial pressure to the total pressure of the mix, as follows.

$$R134a(T) := L_{mix}(T) \cdot \frac{P_{R134a}}{P_{mix}}$$

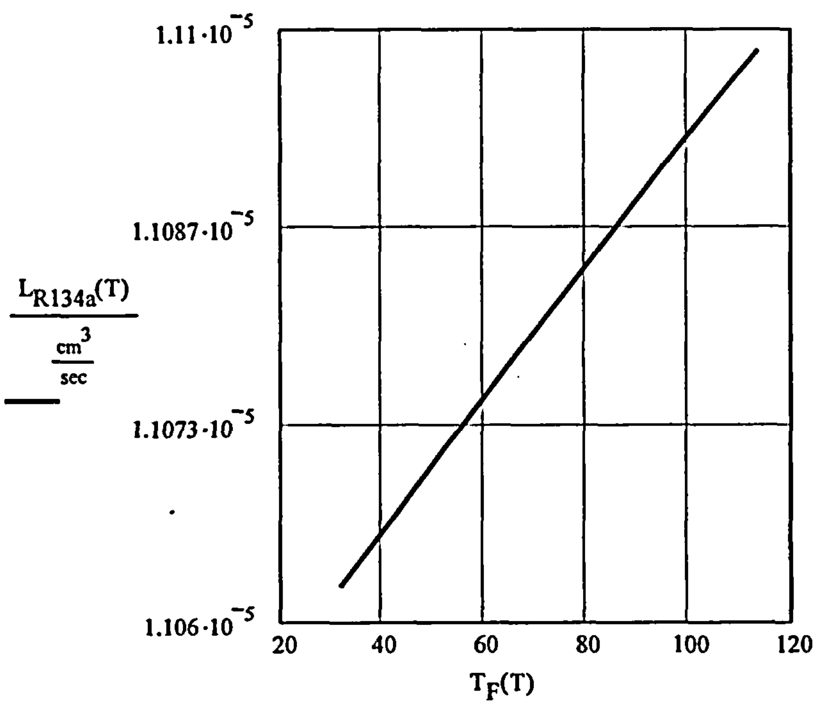


Fig. 4.6 - Allowable R-134a test leakage, cm3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{R134a} in oz/yr:

Ideal Gas Law

$$N(T) := \frac{P_{R134a} \cdot V}{R_o \cdot T}$$

where,

$$R_o := \frac{82.05 \cdot cm^3 \cdot atm}{mole \cdot K}$$

This data can then be used to convert the volumetric leak rate for R-134a calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$L(T) := L_{R134a}(T) \cdot \frac{N(T)}{V} \cdot M_{R134a} \cdot \frac{yr}{oz}$$

$$\frac{gm}{sec} = 1.113 \times 10^{6} \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

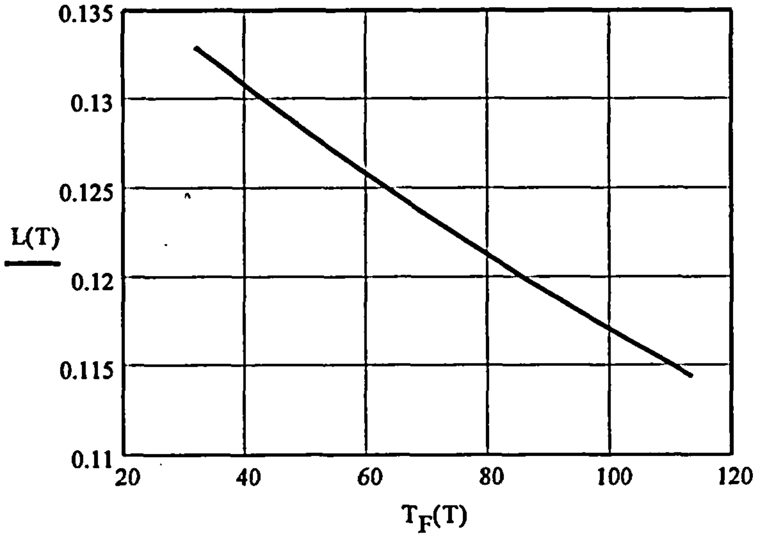


Fig. 4.7 - Allowable R-134a test leakage, oz/yr, versus test temperature, deg.F

The graph above can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

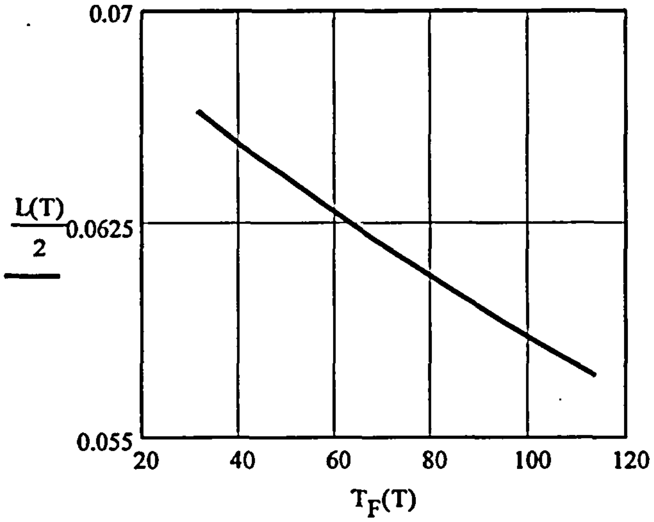


Fig. 4.8 - Allowable R-134a test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Fig. 4.8 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.7 References

1. Weast, Robert C. and Astle, Melvin J., Handbook of Chemistry and Physics, 63rd Edition, CRC Press, 1982.
2. Van Wylen, Gordon J. and Sonntag, Richard E., Fundamentals of Classical Thermodynamics. Second Edition, John Wiley and Sons, Inc., 1973.
3. Thomas, Lindon C., Heat Transfer – Professional Version, Prentice-Hall, Inc., 1993.
4. American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, American National Standards Institute, Inc., New York, ANSI N14.5-1997, 1997.

Appendix 4.1

Properties of R-134a

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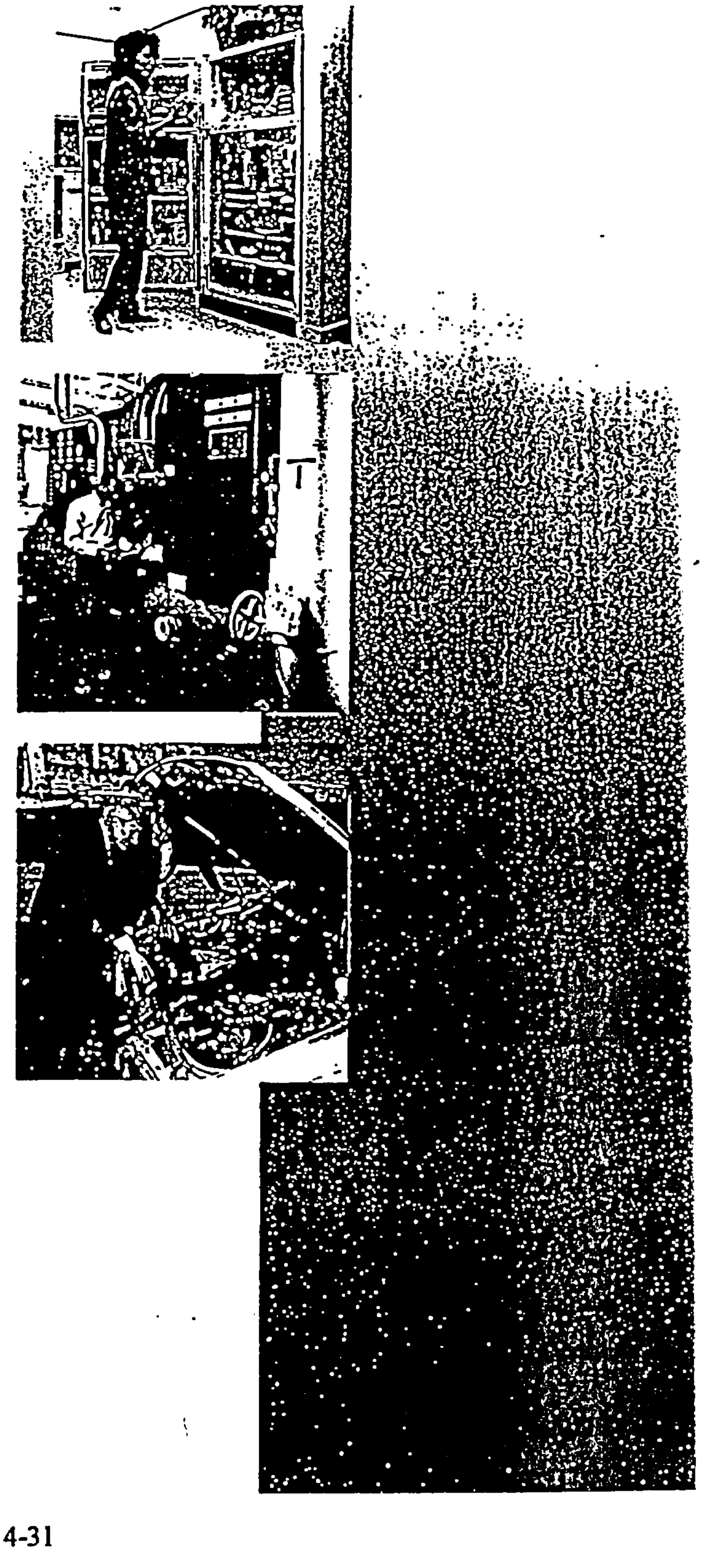
Suva
refrigerants

DuPont HFC-134a

Properties, Uses, Storage and Handling



Suva 134a refrigerant
Suva 134a (Auto) refrigerant
Formacel* Z-4 foam expansion agent
Dymel* 134a aerosol propellant
Dymel 134a/P aerosol propellant

Table 2
Physical Properties of HFC-134a

Physical Properties	Units	HFC-134a
Chemical Name	—	Ethane, 1,1,1,2-Tetrafluoro
Chemical Formula	—	CH_2FCF_3
Molecular Weight	—	102.03
Boiling Point at 1 atm (101.3 kPa or 1.013 bar)	°C	–26.1
	°F	–14.9
Freezing Point	°C	–103.3
	°F	–153.9
Critical Temperature	°C	101.1
	°F	213.9
Critical Pressure	kPa	4060
	lb/in.^{2} abs	588.9
Critical Volume	m^3/kg	1.94×10^{-3}
	ft^3/lb	0.031
Critical Density	kg/m^3	515.3
	lb/ft^3	32.17
Density (Liquid) at 25°C (77°F)	kg/m^3	1206
	lb/ft^3	75.28
Density (Saturated Vapor) at Boiling Point	kg/m^3	5.25
	lb/ft^3	0.328
Heat Capacity (Liquid) at 25°C (77°F)	kJ/kg·K	1.44
	or Btu/(lb) (°F)	0.339
Heat Capacity (Vapor at Constant Pressure) at 25°C (77°F) and 1 atm (101.3 kPa or 1.013 bar)	kJ/kg·K	0.852
	or Btu/(lb) (°F)	0.204
Vapor Pressure at 25°C (77°F)	kPa	666.1
	bar	6.661
	psia	96.61
Heat of Vaporization at Boiling Point	kJ/kg	217.2
	Btu/lb	93.4
Thermal Conductivity at 25°C (77°F)		
Liquid	W/m·K	0.0824
	Btu/hr·ft°F	0.0478
Vapor at 1 atm (101.3 kPa or 1.013 bar)	W/m·K	0.0145
	Btu/hr·ft°F	0.00836
Viscosity at 25°C (77°F)		
Liquid	mPa·S (cP)	0.202
Vapor at 1 atm (101.3 kPa or 1.013 bar)	mPa·S (cP)	0.012
Solubility of HFC-134a in Water at 25°C (77°F) and 1 atm (101.3 kPa or 1.013 bar)	wt %	0.15
Solubility of Water in HFC-134a at 25°C (77°F)	wt %	0.11
Flammability Limits in Air at 1 atm (101.3 kPa or 1.013 bar)	vol %	None
Autoignition Temperature	°C	770
	°F	1418
Ozone Depletion Potential	—	0
Halocarbon Global Warming Potential (HGWP) (For CFC-11, HGWP = 1)	—	0.28
Global Warming Potential (GWP) (100 yr. ITH. For CO_2, GWP = 1)	—	1200
TSCA Inventory Status	—	Reported/Included
Toxicity AEL(a) (8- and 12-hr TWA)	ppm (v/v)	1000

(a) AEL (Acceptable Exposure Limit) is an airborne inhalation exposure limit established by DuPont that specifies time-weighted average concentrations to which nearly all workers may be repeatedly exposed without adverse effects.

Note: kPa is absolute pressure.

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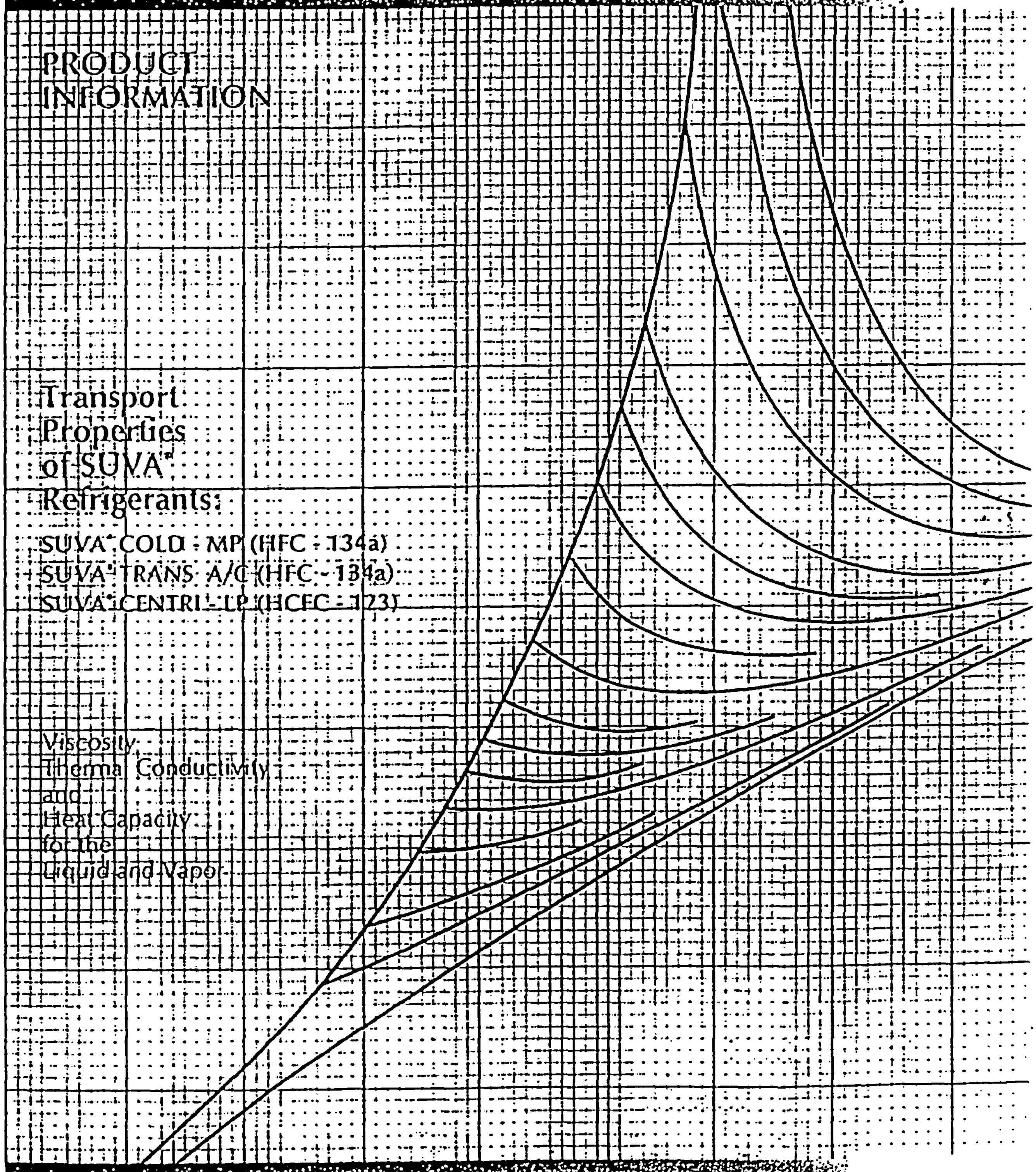
SUVA

REFRIGERANTS

ART - 1



PRODUCT INFORMATION

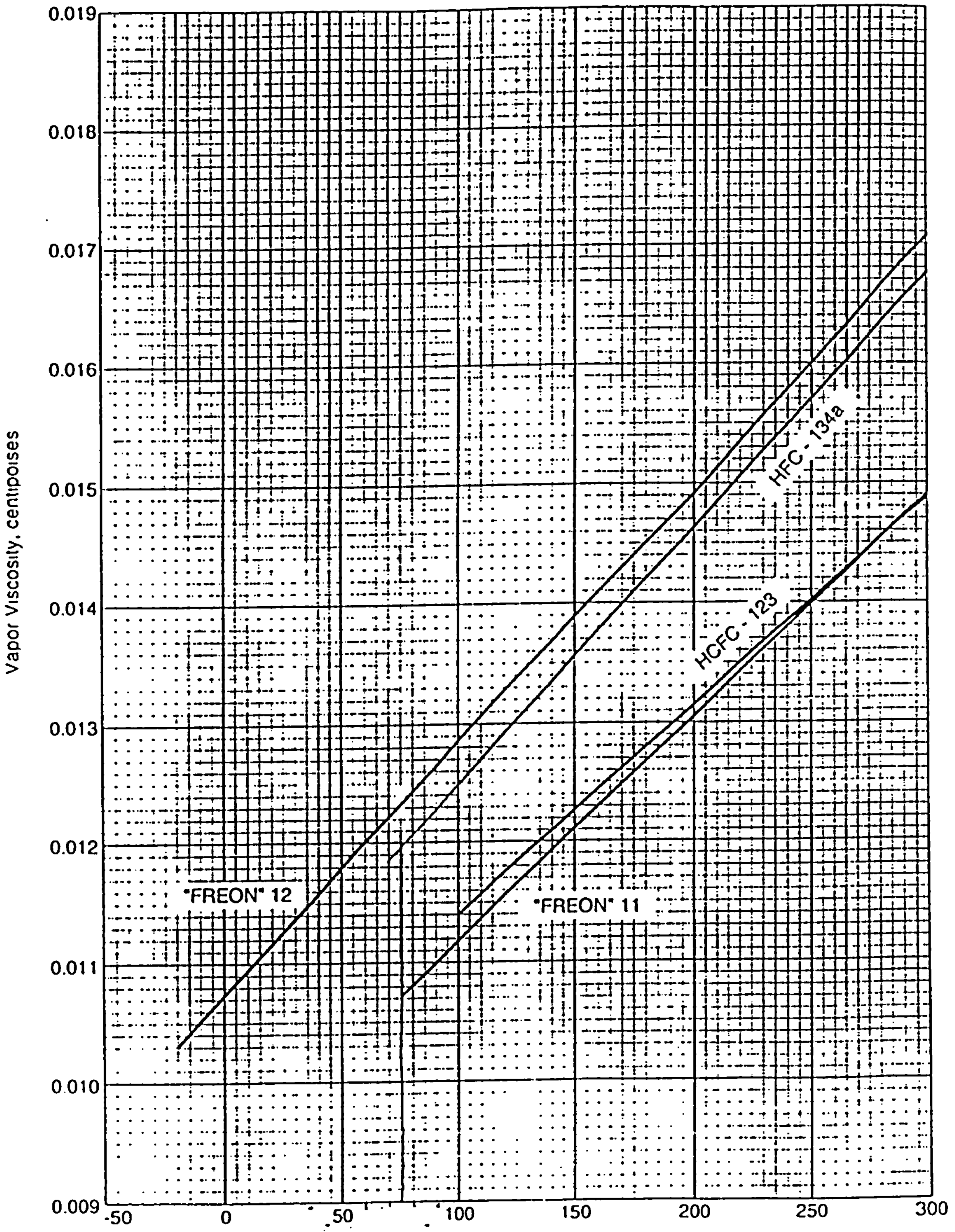
Transport Properties of SUVA® Refrigerants:

SUVA® COLD - MP (HFC - 134a)
SUVA® TRANS A/C (HFC - 134a)
SUVA® CENTRI - LP (HCFC - 123)

Viscosity,
Thermal Conductivity
and
Heat Capacity
for the
Liquid and Vapor

DUPONT

Vapor Viscosity at Atmospheric Pressure



8.0 ACCEPTANCE TESTS AND MAINTENANCE

8.1 Acceptance Tests

Prior to the first use of the CNS 8-120B package, the following tests and evaluations will be performed.

8.1.1 Visual Examination

The package will be examined visually for any adverse conditions in materials or fabrication. Welds shall be examined for compliance to the drawings. Weld integrity shall be verified by visual examination and magnetic particle or dye penetrant. NDE examinations shall be performed by an ASME Certified inspector. Acceptance criteria for NDE shall be according to ASME Code Section III, Div. 1-Section NB5342 or NB5352 as applicable.

8.1.2 Structural Tests

No structural testing is required.

8.1.3 Leak Tests

This test shall be performed prior to acceptance and operation of a newly fabricated package in accordance with ASTM E-427 using a leak detector capable of detecting the applicable leak rates specified in Figures 4.3 and 4.7 in Chapter 4. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST. The standard's setting shall correspond to the approved leak rates specified in Figures 4.3 and 4.7 in Chapter 4.

All four containment boundary penetrations must be tested.

- The volume above the vent port Stat-O-Seal
- The volume between the drain line plug and interior of the cask
- The annulus between the o-ring seals of the primary lid
- The annulus between the o-ring seals of the secondary lid

All four of these volumes must be evacuated to a minimum vacuum of 20" Hg, and then be pressurized to a minimum pressure of 25 psig with pure dichlorodifluoromethane (R-12) or 1,1,1,2 – tetrafluoroethane (R-134a). Use the detector probe to "sniff" the following areas:

- The vent port penetration on the underside of the primary lid
- Around the head of the cap screw that plugs the drain line

- Interior side of the inner o-ring for the primary lid
- Interior side of the inner o-ring for the secondary lid

Leak detection shall be in accordance with the specifications of ASTM E-427.

Any condition, which results in leakage in excess of the applicable values specified in Figures 4.3 and 4.7 in Chapter 4 shall be corrected.

8.1.4 Component Tests

Gaskets and seals will be procured and examined in accordance with the Duratek Quality Assurance Program.

8.1.5 Test for Shielding Integrity

Shielding integrity of the package will be verified by gamma scan or gamma probe methods to assure the package is free of significant voids in the poured lead shield annulus. All gamma scanning will be performed on a 4-inch square or less grid system. The acceptance criteria will be that voids resulting in shield loss in excess of 10 % of the normal lead thickness in the direction measured shall not be acceptable.

8.1.6 Thermal Acceptance Tests

No thermal acceptance testing will be performed on the CNS 8-120B package. Refer to the Thermal Evaluation, Chapter 3.0 of the report.

8.2 Maintenance Program

Duratek is committed to an ongoing preventative maintenance program for all shipping packages. The 8-120B package will be subjected to routine and periodic inspections and tests as outlined in this Chapter and Duratek approved procedures.

8.2.1 Routine Maintenance

Unless noted otherwise, for loaded packages containing material greater than "Type A" quantities, each of the following safety related items and functional features shall be visually examined for defects or replacement. Corrective action for defects shall be as noted.

8.2.1.1 Fasteners

The primary and secondary lid bolts shall be visually inspected for defects whenever it is necessary to remove them. Obtain replacement bolts as specified on Drawing No. C-110-E-0007 (current revision) for any bolts that show cracking or other visual signs of distress.

The cap screws for the vent port, test ports and drain shall be visually inspected for defects whenever it is necessary to remove them. Obtain replacement cap screws as specified on Drawing No. C-110-E-0007 (current revision) for any cap screws that show cracking or other visual signs of distress.

8.2.1.2 Gaskets and Seals

(A) Primary Lid Seals

The primary lid o-ring seals shall be visually inspected (at any time it is necessary to remove the primary lid) for serviceability ensuring that they are in the proper position and free of cracks, tears, cuts, or discontinuities which may prevent them from sealing properly. The seal seating surfaces shall be visually inspected to ensure that they are free of damage, dirt, gravel, or any foreign matter which might damage the seals. If any significant defects are detected, the seals shall be replaced and/or the seal seating surfaces shall be reworked as necessary to ensure that the lid will seal properly.

(B) Secondary Lid Seals

The secondary lid o-ring seals and seating surfaces shall be inspected as specified in Section 8.2.1.2(a) at any time it is necessary to remove the secondary lid. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2(a) if any defects are detected.

(C) Vent and Drain Seals

The above seals and seating surfaces shall be inspected as specified in Section 8.2.1.2(a) at any time it is necessary to remove them. Seal replacement and/or seating surface repair shall be as specified in Section 8.2.1.2(a) if any defects are detected.

8.2.1.3 Painted Surfaces, Identification Markings, and Match Marks Used for Closure Orientation.

The above items shall be visually inspected to ensure that painted surfaces are in good condition, identification markings are legible, and that match marks used for closure orientation remain legible and are easy to identify.

8.2.2 Periodic Maintenance

The following inspections and/or tests shall be performed as specified.

8.2.2.1 Periodic Leak Tests

The package will be leak tested as described in Section 8.1.3 after its third use. In addition, the containment system, before actual use for shipment, shall have been leak tested according to Section 8.1.3 within the preceding 12-month period.

Also, before actual use for shipment, all seals shall have been replaced within the preceding 12-month period.

8.2.2.2 Assembly Verification Leak Test

This test is required for any shipment of material that is greater than a "Type A" quantity of radioactive material. For content exemptions of these tests, refer to the current Certificate of Compliance No. 9168. The test will verify that the containment system has been assembled properly.

The test will be performed by pressurizing the annulus between the o-ring seals of the primary and secondary lids with air.

In addition, prior to shipment, the vent and drain ports shall be tested by pressurizing the volume above the respective plug and stat-o-seal, anytime they have been removed during the cask loading operation.

The test shall be performed using a pressure gauge, readable without estimation and calibrated to a maximum error of ± 1 % of full scale.

The test pressure shall normally be 18 psig (up to 20 psig) and the test shall last for 1 hour. The allowable pressure drop shall be 1 psi. Any condition which results in a pressure drop of more than 1 psi will be corrected.

Sensitivity at the test conditions is equivalent to the prescribed procedure sensitivity of $5\times10^{-4}\frac{\text{atm}\cdot\text{cm}^3}{\text{sec}}$ based on dry air at standard conditions as defined in ANSI N14.5-1987 (see Section 4.4 for the determination of the test conditions).

8.2.3 Subsystem Maintenance

The CNS 8-120B package contains no subsystem assemblies.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

As a minimum, all seals will be replaced prior to the annual leak test specified in 8.2.2.1.

8.2.5 Shielding

No shielding tests will be performed after acceptance testing unless damage has required repairs affecting shield integrity. Any shield testing which might be required would be in accordance with the original criteria specified in Section 8.1.5.