Appendix A29

ANSYS Analysis Run Summary and Input Listings for B24PGP3

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01

Run ID: B24PGP3 (analysis) (1) PB24PGP3 (postprocessing) (1)

Date/Time: 3/21/00 4:35 AM 4/13/20 3:38 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ❋PREP7 ❋SOLUTION ❋POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end w/o grapple

Loads Considered: Grapple pull load (2)

Analysis Type: ❋Static _Thermal _Other: _____

Materials: ❋Linear _Non-Linear

Geometry: ❋Linear _Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: [signature] Michael E. Cohen Date: 6/19/00

Checked By: [signature] Steven R. Streutker Date: 6/19/00

B24PGP3.inp

```
/batch,list
/filname,b24pgp3
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Refined Model)
/com refined model in region of grapple ring assy, grapple ring assy excluded
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
! et,5,solid45         ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
! et,6,solid45         ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
! et,7,solid45         ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

! et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
! r,202,1.0E+07         ! normal stiffness of gap elem btwn plug & outer plate
! r,203,1.0E+07         ! normal stiffness of gap elem btwn plug & inner plate
! keyopt,20,7,1         ! keyopt (7)=1

tref,410              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) *******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
IR_gr=5.0                 ! inner radius of the grapple ring
T_gr=1.00                 ! thickness of the grapple ring
H_gr=3.75                 ! height of the grapple ring
T_grs=0.75                ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs        ! inner radius of the grapple ring support
```

```
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-height of DSC
k,7,OR,,H_dsc/2             ! mid-height of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ***************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
```

```
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
a,22,23,31,32
a,23,24,30,31
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
lsel,r,loc,x,IR_grs,OR_gr     ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru pl thickness & at grapple suppt
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.875                   ! 0.875" element width for unmeshed lines
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,24,kp(0,IR_grs,0),kp(0,IR_grs,0),28,30,kp(0,IR_grs,T_obc),kp(0,IR_grs,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
```

```
cm,aoutbot,area
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

! /com weld of outer bottom cover plate
! lsel,none
! asel,none
! vsel,none
! type,5
! mat,1
! a,2,21,3,3
! lsel,r,loc,z,0
! lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! vmesh,all
! cm,abotweld,area
! cm,vbotweld,volume

! /com grapple support elements
! lsel,none
! asel,none
! vsel,none
! type,6
! mat,1
! a,23,60,67,24
! lsel,r,loc,z,-H_gr+T_gr       ! select lines for dividing
! lesize,all,,,2                ! 2 divisions thru support ring thickness
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! esize,T_grs                   ! element height for unmeshed lines
! vmesh,all
! cm,agrapsup,area
! cm,vgrapsup,volume

! /com grapple ring elements
```

```
! lsel,none
! asel,none
! vsel,none
! type,7
! mat,1
! a,60,61,68,67
! a,67,68,65,66
! a,61,62,63,68
! a,68,63,64,65
! lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
! lesize,all,,,1                  ! 1 line division
! vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
! esize,0.75                    ! 0.75 element size for unmeshed lines
! vmesh,all
! cm,agraprng,area
! cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
! esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                   ! lower shell to outer bottom cover plate

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                        ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                   ! upper & lower welds of inner bottom cover plate

csys,0                        ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max    ! get maximum node number
nsym,x,maxnode,all            ! reflect all nodes
esym,,maxnode,all             ! reflect all elements

*do,i,1,7,1                   ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com define contact elements
/com bottom end plates

esel,s,type,,1
allsel,below,elem
cm,cont1,node                 ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
```

```
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
! type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
! real,202
! gcgen,cont2,targ32,1          ! generate contact elem btwn plug & outer plate
! gcgen,cont2a,targ32a,1        ! gen contact btwn plug & outer pl (outer ring)
! real,203
! gcgen,cont4,targ34,1          ! generate contact elem btwn plug & inner plate
! gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com compress node and element numbering
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
```

```
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2          ! shell now ends at mid-height
d,all,uz
allsel

/com restrain center nodes for stability
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
d,all,ux,0
allsel

/com uz couple two shield plug nodes to inner cover plate for stability
/com ***** valid for grapple pull w/o contact elements *******
nsel,s,loc,z,L_bplug-.01,L_bplug+.01
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0
cp,next,uz,all
! cp,next,ux,all
nsel,s,loc,z,L_bplug-.01,L_bplug+.01
nsel,r,loc,x,-IR-.01,-IR+.01
nsel,r,loc,y,0
cp,next,uz,all
allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
! nropt,auto
! pred,on,,on
! autots,on
! nlgeom,on
! neqit,500

/com load step 1 - 60 kip tens. load at grap.ring suppt w/axisymmetric reststraint
/title,24P-s DSC (Bot.End) 60k at grap.ring suppt (outer cover pinned)
! nsubst,1,8
csys,1                        ! cylindrical coordinates
load=-60000/2
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,IR_grs-.1,OR_gr+.1  ! select 3 rows under grapple ring support
f,all,fz,load/53/3            ! force for 3*53 nodes
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

fini

/exit
```

/eof

PB24PGP3.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  grapple tension load (w/o grapple assembly)
resume,b24pgp3,db
/post1
file,b24pgp3,rst

/com element plots ------------------------------------------------------------
/show,pb24pgp3,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,1,1                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com shell adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,1
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,1
nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
/com shell at mid-height
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
```

```
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,2
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,2
nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Bottom Shield Plug Post1 Results ---------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results ------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel;r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
```

```
    *get,yt,node,inode,loc,y
    *get,zt,node,inode,loc,z
    cmsel,s,outer              ! select outer surface nodes
    onode=node(xt,yt,L_bplug)
    nsel,s,node,,inode
    nsel,a,node,,onode
    esln
    esel,r,type,,4
    nsle
    nlist,inode,onode,onode-inode
    lpath,inode,onode
    prsect
    cmsel,s,reminner           ! select remaining inner surface nodes
    nsel,u,node,,inode         ! unselect lpath nodes
    cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate -------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate -------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                         ! numbers and colors
/device,vector,0               ! raster plots
ernorm,off
```

```
dsys,0
/show,file,,0                  ! plot to file
! /edge,,1,10                    ! edge plot

/dscale,,auto                  ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20                ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/auto,1                        ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-1.02,0.71,-0.07,-0.77
/auto,1                        ! zoom - fit

/dscale,,1                     ! displacement scale

/com shell elements
esel,s,type,,1
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,5
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                 ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                         ! end load step loop

allsel
```

```
fini

exit,nosave
```

Appendix A27

ANSYS Analysis Run Summary and Input Listings for B24PTHG

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTHG (analysis) [1] PB24PTHG (postprocessing) [1]

Date/Time: 6/14/00 8:47 PM 6/15/00 1:15 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Grapple pull load + thermal load cases [2]

Analysis Type: ☒Static ☒Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: ☒Linear _Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: MEC Date: 6/19/00
Michael E. Cohen

Checked By: SRS Date: 6/19/00
Steven R. Streutker

B24PTHG.inp

```
/batch,list
/filname,b24pthg
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Refined Model)
/com refined model in region of grapple ring assembly
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

!et,20,contac49        ! 3-D point to surface contact elements
!r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
!r,202,1.0E+06         ! norm stiffness of gap elem btwn plug & outer plate
!r,203,1.0E+06         ! norm stiffness of gap elem btwn plug & inner plate
!keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)
```

```
OR_gr=8.0                   ! outer radius of the grapple ring & support
IR_gr=5.0                   ! inner radius of the grapple ring
T_gr=1.00                   ! thickness of the grapple ring
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-height of DSC
k,7,OR,,H_dsc/2             ! mid-height of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ***************************************************************
```

```
/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
a,22,23,31,32
a,23,24,30,31
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
lsel,r,loc,x,IR_grs,OR_gr     ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru pl thickness & at grapple suppt
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.875                   ! 0.875" element width for unmeshed lines
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
```

```
v,26,24,kp(0,IR_grs,0),kp(0,IR_grs,0),28,30,kp(0,IR_grs,T_obc),kp(0,IR_grs,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2             ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3               ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                 ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr       ! select lines for dividing
lesize,all,,,2                ! 2 divisions thru support ring thickness
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
```

```
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
esize,0.75                     ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                    ! lower shell to weld to outer bottom cover plate
                        ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                         ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                    ! upper & lower welds of inner bottom cover plate

csys,0                         ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,1,7,1                    ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com define contact elements
/com bottom end plates
```

```
esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
!type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
!real,202
! gcgen,cont2,targ32,1          ! generate contact elem btwn plug & outer plate
!gcgen,cont2a,targ32a,1        ! gen contact btwn plug & outer pl (outer ring)
!real,203
!gcgen,cont4,targ34,1          ! generate contact elem btwn plug & inner plate
```

```
!gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com Define soft springs to stabilize shield plug (connect to inner cover plate)
/com Valid for thermal + grapple
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,L_bplug)
node2i=node(-IR,0,L_bplug)
esel,s,type,,4
nsle
node1j=node(IR,0,L_bplug)
node2j=node(-IR,0,L_bplug)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

!/com compress node and element numbering
!allsel
!numcmp,node
!numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                     ! symmetry about x-z plane
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2           ! shell ends at mid-height
d,all,uz
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & grapple loading **********

esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
!nropt,auto
!pred,on,,on
!autots,on
!nlgeom,on
!neqit,50
```

```
/com load step 1, 60 kip grapple load
/title, 24P-FO DSC (Bottom End) 60k Grapple
!nsubst,1,8
pload=-60000/2
csys,1                              ! cylindrical
nsel,s,loc,z,-H_gr+T_gr
nsel,r,loc,x,IR_gr+0.7,IR_gr+1.6    ! select 2 rows of 19 mid-outer row nodes
nsel,r,loc,y,90-32,90+32
f,all,fz,pload/2/19

allsel
csys,0

lswrite                         ! end of load step 1
save
solve
save

/com load step 2, 60 kip grapple load + Temperature Case 15, -40 deg Ambient
/title, 24P-FO DSC (Bottom End) 60k Grapple + Temp Case 15, -40 deg Ambient
!nsubst,1,8
csys,1                              ! cylindrical

/com read input from thermal results file
ldread,temp,1,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

lswrite                         ! end of load step 2
save
solve
save

/com load step 3, Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Bottom End) 60k Grapple + Temp Case 16, 104 deg Ambient
!nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,2,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 3
save
solve
save

/com load step 4, Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Bottom End) 60k Grapple + Temp Case 26, 117 deg Ambient
!nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,3,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 4
save
solve
save

fini
```

```
/exit

/eof
```

PB24PTHG.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  grapple + thermal load
resume,b24pthg,db
/post1
file,b24pthg,rst

/com element plots ------------------------------------------------------------
/show,pb24pthg,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,1,4                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com shell adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,1
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,1
nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
/com shell at mid-height
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
```

```
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,2
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,2
nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,5
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,5
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Bottom Shield Plug Post1 Results ---------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
```

```
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results ---------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results -----------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate -------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate -------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
```

```
nlist
nforce

/com Reaction Forces at Shell Mid-Height ----------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots ---------------------------------------------------------------
/num,0                        ! numbers and colors
/device,vector,0              ! raster plots
ernorm,off
dsys,0
/show,file,,0                 ! plot to file
! /edge,,1,10                   ! edge plot

/dscale,,auto                 ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20               ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/auto,1                       ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-1.02,0.71,-0.07,-0.77
/auto,1                       ! zoom - fit

/dscale,,1                    ! displacement scale

/com shell elements
esel,s,type,,1
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,5
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot
```

```
/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                        ! end load step loop

allsel

fini

exit,nosave
```

Appendix A28

ANSYS Analysis Run Summary and Input Listings for B24PT-G

TRANSNUCLEAR, INC.
TN WEST

PROJECT NO:	SCE-01	REVISION:	0
CALCULATION NO:	SCE-01.0204	PAGE:	A28-2 of A28-17

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PT-G (analysis) [1] PB24PT-G (postprocessing) [1]

Date/Time: 6/14/00 9:27 PM 6/15/00 3:54 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: -(Grapple pull load) + thermal load cases [2]

Analysis Type: ☒Static ☒Thermal ☐Other: ____

Materials: ☒Linear ☐Non-Linear

Geometry: ☒Linear ☐Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: MEC Date: 6/19/00
Michael E. Cohen

Checked By: SR Streutker Date: 6/19/00
Steven R. Streutker

B24PT-G.inp

```
/batch,list
/filname,b24pt-g
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Refined Model)
/com refined model in region of grapple ring assembly
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

!et,20,contac49        ! 3-D point to surface contact elements
!r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
!r,202,1.0E+06         ! norm stiffness of gap elem btwn plug & outer plate
!r,203,1.0E+06         ! norm stiffness of gap elem btwn plug & inner plate
!keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) *************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)
```

```
OR_gr=8.0                  ! outer radius of the grapple ring & support
IR_gr=5.0                  ! inner radius of the grapple ring
T_gr=1.00                  ! thickness of the grapple ring
H_gr=3.75                  ! height of the grapple ring
T_grs=0.75                 ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs         ! inner radius of the grapple ring support
OR_load=8.74/2             ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                  ! shell outer bottom
k,2,IR+0.21                  ! shell inner bottom
k,3,IR,,T_bw                 ! root of outer bottom cover plate weld
k,4,IR,,L_bplug              ! bottom of inner bottom cover plate
k,5,IR,,L_ibc                ! top of inner bottom cover plate
k,6,IR,,H_dsc/2              ! mid-heght of DSC
k,7,OR,,H_dsc/2              ! mid-heght of DSC
k,8,OR,,L_ibc                ! line up with KP5
k,9,OR,,L_bplug              ! line up with KP4
k,10,OR,,0.75                ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                 ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                   ! outer radius of grapple ring
k,24,IR_grs                  ! inner radius of grapple ring
k,26,0,0,0                   ! center at bottom surface
k,28,0,,T_obc                ! center at top surface
k,30,IR_grs,,T_obc           ! line up with KP24
k,31,OR_gr,,T_obc            ! line up with KP23
k,32,IR-0.93,,T_obc          ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc               ! outer radius at bottom surface
k,41,0,,T_obc                ! center at bottom surface
k,42,0,,L_bplug              ! center at top surface
k,43,IR,,L_bplug             ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug             ! outer radius at bottom surface
k,51,0,,L_bplug              ! center radius at bottom surface
k,52,0,,L_ibc                ! center radius at top surface
k,53,IR,,L_ibc               ! outer radius at top surface
k,54,IR-0.25,,L_bplug        ! radius of shield plug contact
k,55,IR-0.25,,L_ibc          ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr       ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75       ! outer chamfer
k,62,OR_gr-0.25,,-H_gr       ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr       ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75       ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr       ! inner top surface
k,67,IR_grs,,-H_gr+T_gr      ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc               ! shell inner top
k,77,OR,,L_otc               ! shell outer top

klist

/com meshing ***************************************************************
```

```
/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
a,22,23,31,32
a,23,24,30,31
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
lsel,r,loc,x,IR_grs,OR_gr     ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru pl thickness & at grapple suppt
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.875                   ! 0.875" element width for unmeshed lines
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
```

```
v,26,24,kp(0,IR_grs,0),kp(0,IR_grs,0),28,30,kp(0,IR_grs,T_obc),kp(0,IR_grs,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2             ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3               ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                 ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr       ! select lines for dividing
lesize,all,,,2                ! 2 divisions thru support ring thickness
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
```

```
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                   ! 1 line division
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
esize,0.75                     ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                    ! lower shell to weld to outer bottom cover plate
                         ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                         ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                    ! upper & lower welds of inner bottom cover plate

csys,0                         ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,1,7,1                    ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com define contact elements
/com bottom end plates
```

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TN WEST

PROJECT NO:	SCE-01	REVISION:	0
CALCULATION NO:	SCE-01.0204	PAGE:	A28-8 of A28-17

```
esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
!type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
!real,202
! gcgen,cont2,targ32,1          ! generate contact elem btwn plug & outer plate
!gcgen,cont2a,targ32a,1        ! gen contact btwn plug & outer pl (outer ring)
!real,203
!gcgen,cont4,targ34,1          ! generate contact elem btwn plug & inner plate
```

```
!gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com Define soft springs to stabilize shield plug (connect to inner cover plate)
/com Valid for thermal + grapple
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,L_bplug)
node2i=node(-IR,0,L_bplug)
esel,s,type,,4
nsle
node1j=node(IR,0,L_bplug)
node2j=node(-IR,0,L_bplug)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

!/com compress node and element numbering
!allsel
!numcmp,node
!numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                     ! symmetry about x-z plane
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2           ! shell ends at mid-height
d,all,uz
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & grapple loading **********

esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
!nropt,auto
!pred,on,,on
!autots,on
!nlgeom,on
!neqit,50
```

```
/com load step 1, -60 kip grapple load + Temperature Case 15, -40 deg Ambient
/title, 24P-FO DSC (Bottom End) -60k Grapple + Temp Case 15, -40 deg Ambient
!nsubst,1,8
pload=60000/2
csys,1                              ! cyclindrical
nsel,s,loc,z,-H_gr+T_gr
nsel,r,loc,x,IR_gr+0.7,IR_gr+1.6    ! select 2 rows of 19 mid-outer row nodes
nsel,r,loc,y,90-32,90+32
f,all,fz,pload/2/19

/com read input from thermal results file
ldread,temp,1,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 1
save
solve
save

/com load step 2, -60k Grapple + Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Bottom End) -60k Grapple + Temp Case 16, 104 deg Ambient
!nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,2,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 2
save
solve
save

/com load step 3, -60k Grapple + Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Bottom End) -60k Grapple + Temp Case 26, 117 deg Ambient
!nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,3,,,,b24ther2,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 3
save
solve
save

fini

/exit

/eof
```

PB24PT-G.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  negative grapple pull + thermal (for stress range)
resume,b24pt-g,db
/post1
file,b24pt-g,rst

/com element plots ------------------------------------------------------------
/show,pb24pt-g,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,1,3                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com shell adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,1
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,1
nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
/com shell at mid-height
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
/com outer cover plate adjacent to DSC end components
```

```
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,2
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,2
nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,5
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,5
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Bottom Shield Plug Post1 Results ------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
```

```
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results -----------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate ------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate ------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
```

```
nlist
nforce

/com Reaction Forces at Shell Mid-Height ------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots ----------------------------------------------------------
/num,0                        ! numbers and colors
/device,vector,0              ! raster plots
ernorm,off
dsys,0
/show,file,,0                 ! plot to file
! /edge,,1,10                   ! edge plot

/dscale,,1                    ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20               ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/auto,1                       ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-1.02,0.71,-0.07,-0.77
/auto,1                       ! zoom - fit

/dscale,,1                    ! displacement scale

/com shell elements
esel,s,type,,1
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,5
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot
```

```
/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                        ! end load step loop

allsel

fini

exit,nosave
```

Appendix A29

ANSYS Analysis Run Summary and Input Listings for B24PRAM

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PRAM (analysis) [1] PB24PRAM (postprocessing) [1]

Date/Time: 5/10/00 3:42 PM 5/10/00 5:25 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Ram push loads [2]

Analysis Type: ☒Static _Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: _Linear ☒Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

B24PRAM.inp

```
/batch,list
/filname,b24pram
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,500              ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) *************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
IR_gr=5.0                 ! inner radius of the grapple ring
T_gr=1.00                 ! thickness of the grapple ring
```

```
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
lsel,none
k,200,0,,H_dsc/2
```

```
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,22,kp(0,IR-1.4,0),kp(0,IR-1.4,0),28,32,kp(0,IR-.93,T_obc),kp(0,IR-.93,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
cm,voutbot,volume
ksel,all
```

```
/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr        ! select lines for dividing
lesize,all,,,2                 ! 2 divisions thru support ring thickness
vdrag,all,,,,,,2               ! generate volume along line 2 ("swp_arc2")
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
asel,none
vsel,none
```

```
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,2             ! generate volume along line 2 ("swp_arc2")
esize,0.75                   ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                  ! lower shell to weld to outer bottom cover plate
                       ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                  ! upper & lower welds of inner bottom cover plate

csys,0                       ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max   ! get maximum node number
nsym,x,maxnode,all           ! reflect all nodes
esym,,maxnode,all            ! reflect all elements

*do,i,1,7,1                  ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com tie together grapple to outer bottom cover
esel,s,type,,6
allsel,below,elem
nsel,r,loc,z,0
esel,s,type,,2
ceintf

/com define contact elements
/com bottom end plates

esel,s,type,,1
```

```
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
real,202
gcgen,cont2,targ32,1           ! generate contact elem btwn plug & outer plate
gcgen,cont2a,targ32a,1         ! gen contact btwn plug & outer pl (outer ring)
real,203
gcgen,cont4,targ34,1           ! generate contact elem btwn plug & inner plate
gcgen,cont4a,targ34a,1         ! gen contact btwn plug & inner pl (outer ring)
```

```
/com Define soft springs to stabilize shield plug (connect to outer cover plate)
/com Valid for ram load
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,T_obc)
node2i=node(-IR,0,T_obc)
esel,s,type,,1
nsle
node1j=node(IR,0,T_obc)
node2j=node(-IR,0,T_obc)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

/com compress node and element numbering
allsel
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

/com end-of-shell boundary conditions
csys,1
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,uz,0
csys,0
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,ux,0                ! restrain point at far end, away from grapple ring
!nsel,s,loc,z,0.75
!nsel,r,loc,x,OR-.01,OR+.01
!d,all,ux,0                ! restrain point at near end, near grapple ring
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & ram loading **********
esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
nropt,auto
pred,on,,on
autots,on
```

```
nlgeom,on
neqit,500

/com load step 1 - 1 lb ram compr. load w/ far end restr.
/title,24P-s DSC (Bot.End) 1 lb Ram Compression Load
nsubst,1,20
pload=1/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 60 kip ram compr. load w/ far end restr.
/title,24P-s DSC (Bot.End) 60k Ram Compression Load
nsubst,1,8
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
pload=60000/2                   ! ram load for half model
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - 80 kip ram compr. load w/ far end restr.
/title,24P-s DSC (Bot.End) 80k Ram Compression Load
nsubst,1,20
pload=80000/2                   ! ram load for half model
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

fini

/exit

/eof
```

PB24PRAM.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  ram push load
resume,b24pram,db
/post1
file,b24pram,rst

/com element plots ------------------------------------------------------------
/show,pb24pram,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,3                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
nsel,u,loc,y,0,8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
nsel,u,loc,y,0,8
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo
/com
/com shell adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,1
 nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                        ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results --------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com outer cover plate adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,2
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,2
 nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                          ! theta loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,5
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,5
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                          ! theta loop

/com DSC Bottom Shield Plug Post1 Results ---------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
```

```
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results ------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results ----------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com DSC Grapple Ring Post1 Results ----------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate ------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate ------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
```

```
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots -----------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
! /edge,,1,10                  ! edge plot

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
csys,1                       ! cylindrical coordinates
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.70,0.74,0.36,-0.80
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.77,0.79,0.44,-0.69
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,1
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
esel,r,type,,1
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,2
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
```

```
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1
/view,,0.2,0.8,0.5
/replot
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1

/com outer cover plate weld elements
esel,s,type,,5
nsle
csys,0                          ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,5
csys,1                          ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave
```

Appendix A30

ANSYS Analysis Run Summary and Input Listings for B24PTHR

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTHR (analysis) [1] PB24PTHR (postprocessing) [1]

Date/Time: 6/9/00 11:40 PM 6/10/00 5:25 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ⊗PREP7 ⊗SOLUTION ⊗POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Ram push load + thermal load cases [2]

Analysis Type: ⊗Static ⊗Thermal _Other: _____

Materials: ⊗Linear _Non-Linear

Geometry: _Linear ⊗Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: Michael E. Cohen Date: 6/19/00

Checked By: Steven R. Streutker Date: 6/19/00

B24PTHR.inp

```
/batch,list
/filname,b24pthr
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
```

```
IR_gr=5.0                  ! inner radius of the grapple ring
T_gr=1.00                  ! thickness of the grapple ring
H_gr=3.75                  ! height of the grapple ring
T_grs=0.75                 ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs         ! inner radius of the grapple ring support
OR_load=8.74/2             ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                ! shell outer bottom
k,2,IR+0.21                ! shell inner bottom
k,3,IR,,T_bw               ! root of outer bottom cover plate weld
k,4,IR,,L_bplug            ! bottom of inner bottom cover plate
k,5,IR,,L_ibc              ! top of inner bottom cover plate
k,6,IR,,H_dsc/2            ! mid-height of DSC
k,7,OR,,H_dsc/2            ! mid-height of DSC
k,8,OR,,L_ibc              ! line up with KP5
k,9,OR,,L_bplug            ! line up with KP4
k,10,OR,,0.75              ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49               ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                 ! outer radius of grapple ring
k,24,IR_grs                ! inner radius of grapple ring
k,26,0,0,0                 ! center at bottom surface
k,28,0,,T_obc              ! center at top surface
k,30,IR_grs,,T_obc         ! line up with KP24
k,31,OR_gr,,T_obc          ! line up with KP23
k,32,IR-0.93,,T_obc        ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc             ! outer radius at bottom surface
k,41,0,,T_obc              ! center at bottom surface
k,42,0,,L_bplug            ! center at top surface
k,43,IR,,L_bplug           ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug           ! outer radius at bottom surface
k,51,0,,L_bplug            ! center radius at bottom surface
k,52,0,,L_ibc              ! center radius at top surface
k,53,IR,,L_ibc             ! outer radius at top surface
k,54,IR-0.25,,L_bplug      ! radius of shield plug contact
k,55,IR-0.25,,L_ibc        ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr     ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75     ! outer chamfer
k,62,OR_gr-0.25,,-H_gr     ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr     ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75     ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr     ! inner top surface
k,67,IR_grs,,-H_gr+T_gr    ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc             ! shell inner top
k,77,OR,,L_otc             ! shell outer top

klist

/com meshing ***************************************************************

/com define arcs to sweep volumes and lines
```

```
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,22,kp(0,IR-1.4,0),kp(0,IR-1.4,0),28,32,kp(0,IR-.93,T_obc),kp(0,IR-.93,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
```

```
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr        ! select lines for dividing
lesize,all,,,2                 ! 2 divisions thru support ring thickness
vdrag,all,,,,,,2               ! generate volume along line 2 ("swp_arc2")
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
```

```
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,2              ! generate volume along line 2 ("swp_arc2")
esize,0.75                    ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                   ! lower shell to weld to outer bottom cover plate
                        ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                        ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                   ! upper & lower welds of inner bottom cover plate

csys,0                        ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max    ! get maximum node number
nsym,x,maxnode,all            ! reflect all nodes
esym,,maxnode,all             ! reflect all elements

*do,i,1,7,1                   ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com tie together grapple to outer bottom cover
esel,s,type,,6
allsel,below,elem
nsel,r,loc,z,0
esel,s,type,,2
ceintf

/com define contact elements
/com bottom end plates
```

```
esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
real,202
gcgen,cont2,targ32,1           ! generate contact elem btwn plug & outer plate
gcgen,cont2a,targ32a,1         ! gen contact btwn plug & outer pl (outer ring)
real,203
gcgen,cont4,targ34,1           ! generate contact elem btwn plug & inner plate
```

```
gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com Define soft springs to stabilize shield plug (connect to outer cover plate)
/com Valid for thermal + ram
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,T_obc)
node2i=node(-IR,0,T_obc)
esel,s,type,,1
nsle
node1j=node(IR,0,T_obc)
node2j=node(-IR,0,T_obc)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

/com compress node and element numbering
allsel
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2          ! shell ends at mid-height
d,all,uz
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & ram loading **********
esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
nropt,auto
pred,on,,on
autots,on
nlgeom,on
neqit,500

/com load step 1 - 1 lb ram compression load axisymmetric far end restr.
```

```
/title,24P-s DSC (Bot.End) 1 lb Ram Compression Load
nsubst,1,20
pload=1/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 60 kip ram compression load w/ axisymmetric far end restr.
/title,24P-s DSC (Bot.End) 60k Ram Compression Load
nsubst,1,20
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
pload=60000/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

!/com load step 3 - 60 kip ram load + Temperature Case 5, -40 deg Ambient
!/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 5, -40 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-65.76*yt+370.5
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
```

```
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=9.05*zt-1.355*yt*zt-44.77*yt+230.2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp1=.195*zt*xt-.0410*yt*zt*xt
!    ntemp2=-1.36*yt*xt-4.99*xt+2.62*zt+394.7
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 3
!save
!solve
!save

!/com load step 4 - 60 kip ram load + Temperature Case 6, 100 deg Ambient
!/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 6, 100 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-55.48*yt+447.7
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
```

```
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=8.18*zt-1.42*yt*zt-33.48*yt+320.9
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp1=.171*zt*xt-.043*yt*zt*xt
!    ntemp2=-1.01*yt*xt-4.49*xt+2.54*zt+469.1
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                          ! end of load step 4
!save
!solve
!save

/com load step 5 - 60 kip ram load + Temperature Case 7, -40 deg Ambient
/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 7, -40 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-74.39*yt+379.6
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC shell below active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
```

```
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=5.38*zt-.306*yt*zt-69.65*yt+296.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.1221*zt*xt-.0093*yt*zt*xt
   ntemp2=-2.1106*yt*xt-.816*xt+1.35*zt+323.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                          ! end of load step 5
save
solve
save

/com load step 6 - 60 kip ram load + Temperature Case 8, 100 deg Ambient
/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 8, 100 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-60.05*yt+439.5
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC shell below active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
```

```
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=4.875*zt-.3992*yt*zt-53.86*yt+363.9
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.10608*zt*xt-.012098*yt*zt*xt
   ntemp2=-1.632*yt*xt-.7924*xt+1.375*zt+390.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                         ! end of load step 6
save
solve
save

fini

/exit

/eof
```

PB24PTHR.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  thermal + ram load
resume,b24pthr,db
/post1
file,b24pthr,rst

/com element plots ------------------------------------------------------------
/show,pb24pthr,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

/dscale,,300                  ! dscale for load step 2 only

*do,iset,2,6                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo
/com
/com shell adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,1
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,1
nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
/com shell at mid-height
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com
/com outer cover plate adjacent to DSC end components
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,2
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,2
nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
esel,s,type,,5
nsle
nsel,r,loc,y,theta-1,theta+1
esln
esel,r,type,,5
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Bottom Shield Plug Post1 Results ------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
```

```
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results ------------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo

/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate ------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate ------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,z,T_bw-.01,T_bw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ----------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots ---------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
! /edge,,1,10                  ! edge plot

! /dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-1.02,0.71,-0.07,-0.77
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,1
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com outer cover plate weld elements
esel,s,type,,5
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
```

```
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

/dscale,,auto                 ! auto scaling for load steps > 2

*enddo                        ! end load step loop

allsel

fini

exit,nosave
```

Appendix A31

ANSYS Analysis Run Summary and Input Listings for B24PTR2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTR2 (analysis) [1] PB24PTR2 (postprocessing) [1]

Date/Time: 6/10/00 4:46 AM 6/10/00 6:18 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Ram push load + thermal load cases [2]

Analysis Type: ☒Static ☒Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: _Linear ☒Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: MECohen Date: 6/19/00
Michael E. Cohen

Checked By: Date: 6/19/00
Steven R. Streutker

B24PTR2.inp

```
/batch,list
/filname,b24ptr2
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
```

```
IR_gr=5.0                   ! inner radius of the grapple ring
T_gr=1.00                   ! thickness of the grapple ring
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ******************************************************************

/com define arcs to sweep volumes and lines
```

```
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,22,kp(0,IR-1.4,0),kp(0,IR-1.4,0),28,32,kp(0,IR-.93,T_obc),kp(0,IR-.93,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
```

```
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr        ! select lines for dividing
lesize,all,,,2                 ! 2 divisions thru support ring thickness
vdrag,all,,,,,,2               ! generate volume along line 2 ("swp_arc2")
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
```

```
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,2             ! generate volume along line 2 ("swp_arc2")
esize,0.75                   ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                  ! lower shell to weld to outer bottom cover plate
                       ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                  ! upper & lower welds of inner bottom cover plate

csys,0                       ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max   ! get maximum node number
nsym,x,maxnode,all           ! reflect all nodes
esym,,maxnode,all            ! reflect all elements

*do,i,1,7,1                  ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com tie together grapple to outer bottom cover
esel,s,type,,6
allsel,below,elem
nsel,r,loc,z,0
esel,s,type,,2
ceintf

/com define contact elements
/com bottom end plates
```

```
esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
real,202
gcgen,cont2,targ32,1           ! generate contact elem btwn plug & outer plate
gcgen,cont2a,targ32a,1         ! gen contact btwn plug & outer pl (outer ring)
real,203
gcgen,cont4,targ34,1           ! generate contact elem btwn plug & inner plate
```

```
gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com Define soft springs to stabilize shield plug (connect to outer cover plate)
/com Valid for thermal + ram
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,T_obc)
node2i=node(-IR,0,T_obc)
esel,s,type,,1
nsle
node1j=node(IR,0,T_obc)
node2j=node(-IR,0,T_obc)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

/com compress node and element numbering
allsel
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

/com end-of-shell boundary conditions
csys,1
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,uz,0
csys,0
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,ux,0                ! restrain point at far end, away from grapple ring
!nsel,s,loc,z,0.75
!nsel,r,loc,x,OR-.01,OR+.01
!d,all,ux,0                ! restrain point at near end, near grapple ring
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & ram loading **********
esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
nropt,auto
```

```
pred,on,,on
autots,on
nlgeom,on
neqit,200

/com load step 1 - 1 lb ram compression load w/ far end restr.
/title,24P-s DSC (Bot.End) 1 lb Ram Compression Load
nsubst,1,8
pload=1/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 60 kip ram compression load w/ far end restr.
/title,24P-s DSC (Bot.End) 60k Ram Compression Load
nsubst,1,8
r,202,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
pload=60000/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

!/com load step 3 - 60 kip ram load + Temperature Case 5, -40 deg Ambient
!/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 5, -40 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-65.76*yt+370.5
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
!nsle
```

```
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=9.05*zt-1.355*yt*zt-44.77*yt+230.2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp1=.195*zt*xt-.0410*yt*zt*xt
!    ntemp2=-1.36*yt*xt-4.99*xt+2.62*zt+394.7
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 3
!save
!solve
!save

!/com load step 4 - 60 kip ram load + Temperature Case 6, 100 deg Ambient
!/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 6, 100 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-55.48*yt+447.7
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
```

```
!nsle
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=8.18*zt-1.42*yt*zt-33.48*yt+320.9
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp1=.171*zt*xt-.043*yt*zt*xt
!    ntemp2=-1.01*yt*xt-4.49*xt+2.54*zt+469.1
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 4
!save
!solve
!save

/com load step 5 - 60 kip ram load + Temperature Case 7, -40 deg Ambient
/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 7, -40 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
    !/gopr
    tnode=node(0,0,0)
    *get,xt,node,tnode,loc,x
    *get,ytdeg,node,tnode,loc,y
    *get,zt,node,tnode,loc,z
    yt=(180-ytdeg)*3.14156/180
    ntemp=-74.39*yt+379.6
    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo

/com Define temps for DSC shell below active fuel region
```

```
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=5.38*zt-.306*yt*zt-69.65*yt+296.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.1221*zt*xt-.0093*yt*zt*xt
   ntemp2=-2.1106*yt*xt-.816*xt+1.35*zt+323.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                          ! end of load step 5
save
solve
save

/com load step 6 - 60 kip ram load + Temperature Case 8, 100 deg Ambient
/title,24P-s DSC (Bot.End) 60k Ram Load + Temp Case 8, 100 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-60.05*yt+439.5
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
```

```
/com Define temps for DSC shell below active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=4.875*zt-.3992*yt*zt-53.86*yt+363.9
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.10608*zt*xt-.012098*yt*zt*xt
   ntemp2=-1.632*yt*xt-.7924*xt+1.375*zt+390.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                        ! end of load step 6
save
solve
save

fini

/exit

/eof
```

PB24PTR2.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  thermal + ram push load (non-axisymmetric boundary conditions)
resume,b24ptr2,db
/post1
file,b24ptr2,rst

/com element plots ------------------------------------------------------------
/show,pb24ptr2,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,3,6                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
nsel,u,loc,y,0,8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
nsel,u,loc,y,0,8
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo
/com
/com shell adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,1
 nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                        ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results ------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com outer cover plate adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,2
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,2
 nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                          ! theta loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,5
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,5
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                          ! theta loop

/com DSC Bottom Shield Plug Post1 Results ------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln       ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
```

```
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results -------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results ------------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate ------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate ------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
```

```
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots ---------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
! /edge,,1,10                  ! edge plot

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
csys,1                       ! cylindrical coordinates
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.70,0.74,0.36,-0.80
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.77,0.79,0.44,-0.69
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,1
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
esel,r,type,,1
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,2
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
```

```
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1
/view,,0.2,0.8,0.5
/replot
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1

/com outer cover plate weld elements
esel,s,type,,5
nsle
csys,0                          ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,5
csys,1                          ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave
```

Appendix A32

ANSYS Analysis Run Summary and Input Listings for B24PTR3

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTR3 (analysis) [1] PB24PTR3 (postprocessing) [1]

Date/Time: 6/1/00 9:55 AM 6/10/00 9:55 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-III 450 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Ram push load + thermal load cases [2]

Analysis Type: ☒Static ☒Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: _Linear ☒Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Combin14: 3-D spring damper

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.

Run By: MBCohen Date: 6/14/00
Michael E. Cohen

Checked By: Date: 6/19/00
Steven R. Streutker

B24PTR3.inp

```
/batch,list
/filname,b24ptr3
/title,24P-short DSC Shell Assembly (Bottom End, 180 Degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

et,20,contac49        ! 3-D point to surface contact elements
! r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+06,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ********************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) ***************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
```

```
IR_gr=5.0                   ! inner radius of the grapple ring
T_gr=1.00                   ! thickness of the grapple ring
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-height of DSC
k,7,OR,,H_dsc/2             ! mid-height of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ***************************************************************

/com define arcs to sweep volumes and lines
```

```
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,22,kp(0,IR-1.4,0),kp(0,IR-1.4,0),28,32,kp(0,IR-.93,T_obc),kp(0,IR-.93,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
```

```
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr        ! select lines for dividing
lesize,all,,,2                 ! 2 divisions thru support ring thickness
vdrag,all,,,,,,2               ! generate volume along line 2 ("swp_arc2")
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
```

```
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,2             ! generate volume along line 2 ("swp_arc2")
esize,0.75                   ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                  ! lower shell to weld to outer bottom cover plate
                       ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                  ! upper & lower welds of inner bottom cover plate

csys,0                       ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max   ! get maximum node number
nsym,x,maxnode,all           ! reflect all nodes
esym,,maxnode,all            ! reflect all elements

*do,i,1,7,1                  ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

/com tie together grapple to outer bottom cover
esel,s,type,,6
allsel,below,elem
nsel,r,loc,z,0
esel,s,type,,2
ceintf

/com define contact elements
/com bottom end plates
```

```
esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-.94,IR-.92
csys,0                         ! cartesian coordinates
cm,cont2a,node                 ! nodes of outer bottom cover plate at IR-.93

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1                         ! cylindrical coordinates
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0                         ! cartesian coordinates
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ32,node                 ! bottom shield plug bottom surface nodes (w/o outer row)

allsel,below,elem
nsel,r,loc,z,T_obc
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ32a,node                 ! bottom shield plug bottom surface nodes (outer row)

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (outer row)

csys,0                         ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
real,202
gcgen,cont2,targ32,1           ! generate contact elem btwn plug & outer plate
gcgen,cont2a,targ32a,1         ! gen contact btwn plug & outer pl (outer ring)
real,203
gcgen,cont4,targ34,1           ! generate contact elem btwn plug & inner plate
```

```
gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

/com Define soft springs to stabilize shield plug (connect to outer cover plate)
/com Valid for thermal + ram
allsel
esel,s,type,,3
nsle
node1i=node(IR,0,T_obc)
node2i=node(-IR,0,T_obc)
esel,s,type,,1
nsle
node1j=node(IR,0,T_obc)
node2j=node(-IR,0,T_obc)
type,22
real,22
nsel,all
e,node1i,node1j
e,node2i,node2j

/com compress node and element numbering
allsel
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

/com end-of-shell boundary conditions
csys,1
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,uz,0
csys,0
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
d,all,ux,0                ! restrain point at far end, away from grapple ring
!nsel,s,loc,z,0.75
!nsel,r,loc,x,OR-.01,OR+.01
!d,all,ux,0                ! restrain point at near end, near grapple ring
allsel

/com ux couple shield plug to DSC shell for stability (one location)
/com ********* valid for temp & ram loading **********
esel,s,type,,1,3,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all

allsel

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
nropt,auto
```

```
pred,on,,on
autots,on
nlgeom,on
neqit,200

/com load step 1 - 1 lb ram compression load w/ far end restr.
/title,24P-s DSC (Bot.End) 1 lb Ram Compression Load
nsubst,1,8
pload=1/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 80 kip ram compression load w/ far end restr.
/title,24P-s DSC (Bot.End) 80k Ram Compression Load
nsubst,1,8
r,202,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+05,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
pload=80000/2
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,-.01,.01
nsel,r,loc,x,3.3,5.3
nsel,u,loc,y,57,180-57          ! select nodes for 6 elements
sf,all,pres,pload/1.38/6        ! force/area for 6 elements
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

!/com load step 3 - 80 kip ram load + Temperature Case 5, -40 deg Ambient
!/title,24P-s DSC (Bot.End) 80k Ram Load + Temp Case 5, -40 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-65.76*yt+370.5
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo
!
!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
!nsle
```

```
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=9.05*zt-1.355*yt*zt-44.77*yt+230.2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp1=.195*zt*xt-.0410*yt*zt*xt
!    ntemp2=-1.36*yt*xt-4.99*xt+2.62*zt+394.7
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 3
!save
!solve
!save

!/com load step 4 - 80 kip ram load + Temperature Case 6, 100 deg Ambient
!/title,24P-s DSC (Bot.End) 80k Ram Load + Temp Case 6, 100 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in active fuel region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,15.5,159.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!    !/gopr
!    tnode=node(0,0,0)
!    *get,xt,node,tnode,loc,x
!    *get,ytdeg,node,tnode,loc,y
!    *get,zt,node,tnode,loc,z
!    yt=(180-ytdeg)*3.14156/180
!    ntemp=-55.48*yt+447.7
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below active fuel region
!esel,s,type,,1
```

```
!nsle
!nsel,r,loc,z,0,15.5
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!   !/gopr
!   tnode=node(0,0,0)
!   *get,xt,node,tnode,loc,x
!   *get,ytdeg,node,tnode,loc,y
!   *get,zt,node,tnode,loc,z
!   yt=(180-ytdeg)*3.14156/180
!   ntemp=8.18*zt-1.42*yt*zt-33.48*yt+320.9
!   bf,tnode,temp,ntemp
!   nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
!esel,s,type,,2,7,1
!nsle
!*get,totnode,node,,count
!*DO,i,1,totnode,1
!   !/gopr
!   tnode=node(0,0,0)
!   *get,xt,node,tnode,loc,x
!   *get,ytdeg,node,tnode,loc,y
!   *get,zt,node,tnode,loc,z
!   yt=(180-ytdeg)*3.14156/180
!   ntemp1=.171*zt*xt-.043*yt*zt*xt
!   ntemp2=-1.01*yt*xt-4.49*xt+2.54*zt+469.1
!   ntemp=ntemp1+ntemp2
!   bf,tnode,temp,ntemp
!   nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 4
!save
!solve
!save

/com load step 5 - 80 kip ram load + Temperature Case 7, -40 deg Ambient
/title,24P-s DSC (Bot.End) 80k Ram Load + Temp Case 7, -40 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-74.39*yt+379.6
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC shell below active fuel region
```

```
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=5.38*zt-.306*yt*zt-69.65*yt+296.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.1221*zt*xt-.0093*yt*zt*xt
   ntemp2=-2.1106*yt*xt-.816*xt+1.35*zt+323.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                        ! end of load step 5
save
solve
save

/com load step 6 - 80 kip ram load + Temperature Case 8, 100 deg Ambient
/title,24P-s DSC (Bot.End) 80k Ram Load + Temp Case 8, 100 deg Ambient
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,15.5,159.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=-60.05*yt+439.5
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
```

```
/com Define temps for DSC shell below active fuel region
esel,s,type,,1
nsle
nsel,r,loc,z,0,15.5
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp=4.875*zt-.3992*yt*zt-53.86*yt+363.9
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Bottom Shield Plug, Cover Plates, Weld & Grapple Ring
esel,s,type,,2,7,1
nsle
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,ytdeg,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   yt=(180-ytdeg)*3.14156/180
   ntemp1=.10608*zt*xt-.012098*yt*zt*xt
   ntemp2=-1.632*yt*xt-.7924*xt+1.375*zt+390.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                          ! end of load step 6
save
solve
save

fini

/exit

/eof
```

PB24PTR3.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  thermal + ram push load (non-axisymmetric boundary conditions)
resume,b24ptr3,db
/post1
file,b24ptr3,rst

/com element plots ------------------------------------------------------------
/show,pb24ptr3,pic,1          ! plot to file
/triad,lbot                   ! triad in lower left corner
/device,vector,1              ! vector plots
/num,2                        ! numbers, no colors
/vup,1,-x                     ! x-axis down
/view,,-0.2,-0.8,-0.5
/type,1,4                     ! precise hidden
esel,u,type,,20               ! unselect contact elements
eplot                         ! plot elements
/zoom,1,rect,-0.94,0.60,0.0,-0.80
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

csys,1                        ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,3,6                  ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,0.8,L_ibc+5
nsel,u,loc,y,0,8
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw+.1,L_ibc+5
nsel,u,loc,y,0,8
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(OR,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,1
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
```

```
*enddo
/com
/com shell adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,1
 nsle
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,theta,T_bw)
   onode=node(OR,theta,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                        ! theta loop

/com DSC Outer Bottom Cover Plate Post1 Results ------------------------------
esel,s,type,,2
nsle
nsel,r,loc,z,0
nsel,r,loc,x,0,IR-1.3
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
nsel,r,loc,x,0,IR-0.9
csys,0                        ! cartesian coordinates
nsel,u,loc,x,IR-0.5,IR+.01
csys,1                        ! cylindrical coordinates
cm,reminner,node              ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,T_obc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer              ! select outer surface nodes
   onode=node(xt,yt,0)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,2
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner           ! select remaining inner surface nodes
   nsel,u,node,,inode         ! unselect lpath nodes
   cm,reminner,node
*enddo
/com
```

```
/com outer cover plate adjacent to DSC end components
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,2
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,2
 nsle
   inode=node(IR-.46,theta,1.19)
   onode=node(IR-.95,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,T_bw)
   onode=node(IR-.49,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                          ! theta loop

/com DSC Outer Bottom Cover Plate Weld Postl Results ---------------------------
*do,theta,2*90/26,180,90/26  ! sections at 3.46 degree intervals
 esel,s,type,,5
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,5
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,T_bw)
   onode=node(ix,theta,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                          ! theta loop

/com DSC Bottom Shield Plug Postl Results ---------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,z,T_obc-.01,T_obc+.01
cm,outer,node                   ! outer surface nodes
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,reminner,node                ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_bplug)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer                ! select outer surface nodes
   onode=node(xt,yt,T_obc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   nsle
   esln        ! select elem attached to nodes twice to capture 3 thru thickness
   esel,r,type,,3
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
```

```
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Inner Bottom Cover Plate Post1 Results ------------------------------
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ibc)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(xt,yt,L_bplug)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,4
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo

/com DSC Grapple Ring Support Post1 Results ----------------------------------
esel,s,type,,6
nsle
nsel,r,loc,x,OR_gr-.01,OR_gr+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,x,IR_grs-.01,IR_grs+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer             ! select outer surface nodes
   onode=node(OR_gr,yt,zt)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,6
   nsle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner          ! select remaining inner surface nodes
   nsel,u,node,,inode        ! unselect lpath nodes
   cm,reminner,node
*enddo
```

```
/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,z,-H_gr-.01,-H_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,x,IR_gr-.01,IR_grs+.01
cm,grnodes,node                ! nodes out to grapple ring support IR
esln,,1                        ! only elements within grapple ring support IR
nsel,r,loc,z,-H_gr+T_gr-.01,-H_gr+T_gr+.01
nsel,r,loc,x,IR_gr-.1,IR_grs+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,0)
   *get,xt,node,inode,loc,x
   *get,yt,node,inode,loc,y
   *get,zt,node,inode,loc,z
   cmsel,s,outer               ! select all nodes out to grapple ring support IR
   onode=node(xt,yt,-H_gr)
   cmsel,s,grnodes             ! select outer surface nodes
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   cmsel,s,reminner            ! select remaining inner surface nodes
   nsel,u,node,,inode          ! unselect lpath nodes
   cm,reminner,node
*enddo

/com Nodal Forces for Weld of Inner Bottom Cover Plate -------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0              ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate -------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
```

```
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots -----------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
! /edge,,1,10                  ! edge plot

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
csys,1                       ! cylindrical coordinates
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.70,0.74,0.36,-0.80
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.77,0.79,0.44,-0.69
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,1
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
nsel,u,loc,z,H_dsc/4,H_dsc/2+.01
esln,,1
esel,r,type,,1
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/view,,0.2,0.8,-0.5
/replot

/com outer cover plate elements
esel,s,type,,2
nsle
csys,0                       ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,2
csys,1                       ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
```

```
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1
/view,,0.2,0.8,0.5
/replot
/zoom,1,rect,-0.40,0.80,0.46,-0.84
/auto,1

/com outer cover plate weld elements
esel,s,type,,5
nsle
csys,0                          ! cartesian coordinates
nsel,u,loc,x,IR-0.5,OR+.01
esln,,1
esel,r,type,,5
csys,1                          ! cylindrical coordinates
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave
```

Appendix A33

ANSYS Analysis Run Summary and Input Listings for B24THER2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24THER2 (analysis) [1] PB24THRM (analysis) [1]

Date/Time: 6/14/00 1:30 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-II 266 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Steady State Thermal Solutions for Thermal cases 15, 16, and 26 [2] for "refined mesh" temperature distribution

Analysis Type: _Static ☒Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: _Linear ☒Non-Linear

Element Types Used:

Solid70: 3-D thermal solid

Other Information:

1. Input filenames use *.inp* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Results from this calculation are read into the appropriate load step for runs requiring any of the above temperature loads.

Run By: MBCohen Date: 6/19/00
Michael B. Cohen

Checked By: SRStreutker Date: 6/19/00
Steven R. Streutker

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24THER2 (analysis) [1] PB24THR2 (analysis) [1]

Date/Time: 6/14/00 1:30 PM 6/19/00 1:22 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-II 266 MHz

Analysis Modules Used: ☒PREP7 ☒SOLUTION ☒POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and bottom end components

Loads Considered: Steady State Thermal Solutions for Thermal cases 15, 16, and 26 [2] for "refined mesh" temperature distribution

Analysis Type: _Static ☒Thermal _Other: _____

Materials: ☒Linear _Non-Linear

Geometry: _Linear ☒Non-Linear

Element Types Used:

Solid70: 3-D thermal solid

Other Information:

1. Input filenames use *.inp* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Results from this calculation are read into the appropriate load step for runs requiring any of the above temperature loads.

Run By: _____ Date: _____
Michael E. Cohen

Checked By: _____ Date: _____
Steven R. Streutker

B24THER2.inp

```
/batch,list
/filname,b24ther2
/title,24P-FO DSC Shell Assembly (Bottom End, 180 Degree Model)
/com refined model in region of grapple ring assembly
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45          ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45          ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45          ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45          ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell

!et,20,contac49        ! 3-D point to surface contact elements
!r,201,1.0E+07         ! normal stiffness of gap elem btwn plug & shell
!r,202,1.0E+06         ! norm stiffness of gap elem btwn plug & outer plate
!r,203,1.0E+06         ! norm stiffness of gap elem btwn plug & inner plate
!keyopt,20,7,1         ! keyopt (7)=1

et,22,combin14        ! 3-D spring-damper for shield plug stability
keyopt,22,2,3         ! uz direction only
r,22,50               ! 50 lb/in

tref,70               ! reference temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ******************
mptemp,1,70,200,300,400,500,600
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,alpx,1,1,0,8.76E-06,8.97E-06,9.21E-06,9.42E-06,9.60E-06
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) **************************
mptemp,1,70,200,300,400,500,600
dens,2,490/1728
mpdata,ex,2,1,29.5E+06,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,alpx,2,1,0,5.89E-06,6.26E-06,6.61E-06,6.91E-06,7.17E-06
nuxy,2,0.29

csys,0                    ! cartesian coordinates

/com geometry
T_shell=.53               ! shell thickness
OR=67.19/2                ! shell outside radius
IR=OR-T_shell             ! shell inside radius
H_dsc=186.17              ! height (length) of DSC

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)

T_ibc=0.75                ! inner bottom cover plate thickness
T_bplug=6.25              ! bottom shield plug thickness
T_obc=1.75                ! outer bottom cover plate thickness
T_bw=0.625                ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc     ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0                 ! outer radius of the grapple ring & support
```

```
IR_gr=5.0                   ! inner radius of the grapple ring
T_gr=1.00                   ! thickness of the grapple ring
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load

/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-height of DSC
k,7,OR,,H_dsc/2             ! mid-height of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ***************************************************************

/com define arcs to sweep volumes and lines
```

```
lsel,none
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
a,22,23,31,32
a,23,24,30,31
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
lsel,r,loc,x,IR_grs,OR_gr     ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru pl thickness & at grapple suppt
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.875                   ! 0.875" element width for unmeshed lines
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,24,kp(0,IR_grs,0),kp(0,IR_grs,0),28,30,kp(0,IR_grs,T_obc),kp(0,IR_grs,T_obc)
```

```
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
cm,voutbot,volume
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2             ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3               ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                 ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21      ! 2 divisions, generate node at IR
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr       ! select lines for dividing
lesize,all,,,2                ! 2 divisions thru support ring thickness
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,T_grs                   ! element height for unmeshed lines
```

```
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
asel,none
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
esize,0.75                     ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume

allsel

/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                    ! lower shell to weld to outer bottom cover plate
                         ! & outer bottom cover to grapple ring components

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                         ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                    ! upper & lower welds of inner bottom cover plate

csys,0                         ! cartesian coordinates
allsel

/com reflect quarter geometry to generate half model

*get,maxnode,node,,num,max     ! get maximum node number
nsym,x,maxnode,all             ! reflect all nodes
esym,,maxnode,all              ! reflect all elements

*do,i,1,7,1                    ! merge nodes at line of symmetry (bottom shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

allsel

/com change structural elements to thermal elements
```

```
etchg
keyopt,1,4,1
keyopt,2,4,1
keyopt,3,4,1
keyopt,4,4,1
keyopt,5,4,1
keyopt,6,4,1
keyopt,7,4,1

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ********************
mptemp,1,70,100,150,200,250,300
mptemp,7,400,500,600,700
dens,1,493/1728
!mpdata,kxx,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kxx,1,6,9.5/12,10.0/12,10.5/12,11.0/12                  ! SA-240 Type 316
!mpdata,kyy,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kyy,1,6,9.5/12,10.0/12,10.5/12,11.0/12                  ! SA-240 Type 316
!mpdata,kzz,1,1,7.7/12,7.9/12,8.2/12,8.4/12,8.7/12,9.0/12 ! SA-240 Type 316
!mpdata,kzz,1,6,9.5/12,10.0/12,10.5/12,11.0/12                  ! SA-240 Type 316

mpdata,kxx,1,1,7.7/12,7.7/12,7.7/12,7.7/12,7.7/12,7.7/12  ! SA-240 Type 316
mpdata,kxx,1,6,7.7/12,7.7/12,7.7/12,7.7/12                ! SA-240 Type 316

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) ***************************
mptemp,1,70,100,150,200,250,300
mptemp,7,400,500,600,700
dens,2,490/1728
!mpdata,kxx,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kxx,2,6,30.9/12,29.5/12,28.0/12,26.6/12                      ! SA-36
!mpdata,kyy,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kyy,2,6,30.9/12,29.5/12,28.0/12,26.6/12                      ! SA-36
!mpdata,kzz,2,1,35.1/12,34.7/12,34.1/12,33.6/12,32.9/12,32.3/12 ! SA-36
!mpdata,kzz,2,6,30.9/12,29.5/12,28.0/12,26.6/12                      ! SA-36

mpdata,kxx,2,1,35.1/12,35.1/12,35.1/12,35.1/12,35.1/12,35.1/12  ! SA-36
mpdata,kxx,2,6,35.1/12,35.1/12,35.1/12,35.1/12                      ! SA-36

save

fini

/solution

/com analysis parameters
antype,static
eqslv,pcg,1e-7
!nropt,auto
!pred,on,,on
!autots,on
!nlgeom,on
!neqit,50

/com BC's at planes of symmetry
nsel,s,loc,z,H_dsc/2
sf,all,hflux,0
f,all,heat,0
allsel

/com Define x y z location arrays (in cylindrical coordinates)
*dim,t_xloc,array,31
*dim,t_yloc,array,5
*dim,t_zloc,array,31
*dim,t_val,array,31,5
```

```
t_xloc(1) = 33.31
t_xloc(2) = 33.33
t_xloc(3) = 33.33
t_xloc(4) = 33.33
t_xloc(5) = 33.33
t_xloc(6) = 33.33
t_xloc(7) = 33.33
t_xloc(8) = 33.33
t_xloc(9) = 33.33
t_xloc(10) = 33.33
t_xloc(11) = 33.33

t_yloc(1) = 0
t_yloc(2) = 45
t_yloc(3) = 90
t_yloc(4) = 135
t_yloc(5) = 180

t_zloc(1) = 0
t_zloc(2) = 1.6625
t_zloc(3) = 5.075
t_zloc(4) = 8.375
t_zloc(5) = 16.33
t_zloc(6) = 21.562
t_zloc(7) = 28.48
t_zloc(8) = 37.624
t_zloc(9) = 46.367
t_zloc(10) = 65.682
t_zloc(11) = 93.085

/com
/com get angular locations for SHELL, OTCP, ITCP interpolation points
/com
csys,1
esel,s,type,,1
nsle
nsel,r,loc,x,OR
nsel,r,loc,z,H_dsc/2
cm,temp,node

*get,ubound,node,,count
*DIM,y_ang,array,ubound

*DO,i,1,ubound,1
    cmsel,s,temp
    *get,y_ang(i),node,,mnloc,y
    nsel,r,loc,y,y_ang(i)
    *get,nnum,node,,num,min
!   *get,y_ang(i),node,nnum,ang,xy
    cmsel,s,temp
    nsel,u,node,,nnum
    cm,temp,node
*ENDDO
alls

/com
/com get angular locations for SHIELD PLUG interpolation points
/com
esel,s,type,,3
nsle
nsel,r,loc,x,IR
nsel,r,loc,z,L_bplug
cm,temp,node
```

```
*get,ubound,node,,count
*DIM,sp_ang,array,ubound

*DO,i,1,ubound,1
    cmsel,s,temp
    *get,sp_ang(i),node,,mnloc,y
    nsel,r,loc,y,sp_ang(i)
    *get,nnum,node,,num,min
!   *get,sp_ang(i),node,nnum,ang,xy
    cmsel,s,temp
    nsel,u,node,,nnum
    cm,temp,node
*ENDDO
alls

/com Temperature Case 15, -40 deg Ambient
/title, 24P-FO DSC (Bottom End) Temperature Case 15, -40 deg Ambient
/com define nodal temps
csys,1

t_val(1,1) = 148
t_val(2,1) = 151
t_val(3,1) = 156
t_val(4,1) = 161
t_val(5,1) = 194
t_val(6,1) = 216
t_val(7,1) = 230
t_val(8,1) = 249
t_val(9,1) = 257
t_val(10,1) = 267
t_val(11,1) = 271

t_val(1,2) = 144
t_val(2,2) = 146
t_val(3,2) = 151
t_val(4,2) = 156
t_val(5,2) = 187
t_val(6,2) = 208
t_val(7,2) = 222
t_val(8,2) = 241
t_val(9,2) = 249
t_val(10,2) = 259
t_val(11,2) = 262

t_val(1,3) = 140
t_val(2,3) = 142
t_val(3,3) = 147
t_val(4,3) = 151
t_val(5,3) = 180
t_val(6,3) = 200
t_val(7,3) = 214
t_val(8,3) = 233
t_val(9,3) = 241
t_val(10,3) = 251
t_val(11,3) = 253

t_val(1,4) = 135
t_val(2,4) = 137
t_val(3,4) = 141
t_val(4,4) = 146
t_val(5,4) = 173
t_val(6,4) = 192
t_val(7,4) = 207
t_val(8,4) = 225
```

```
t_val(9,4) = 233
t_val(10,4) = 242
t_val(11,4) = 240

t_val(1,5) = 130
t_val(2,5) = 132
t_val(3,5) = 136
t_val(4,5) = 140
t_val(5,5) = 166
t_val(6,5) = 185
t_val(7,5) = 199
t_val(8,5) = 218
t_val(9,5) = 226
t_val(10,5) = 233
t_val(11,5) = 227

/inp,interp,inp

! -40 F TEMPERATURE GRADIENTS EXCEPT FOR SHELLS, Bottom
/com Define temps for DSC shell above active fuel region

! Define temperatures for DSC Bottom Shield Plug
alls
esel,s,type,,3
nsle
! -40 F temperatures at top, bottom, at 90° intervals

csys,0

t1=174.0
t2=132.0
t3=142.0
t4=189.0
t5=140.0
t6=151.0
t7=151.0
t8=160.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 1.75
Z1 = 6.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
```

```
    zm=zt-Z0
    F1=1/Z1
    *if,tm,lt,0.0,then
      F2=-2*rm/pi/R1*(t6-t8)*tm
    *else
      F2=2*rm/pi/R1*(t6-t5)*tm
    *endif
    *if,tm,lt,0.0,then
      F3=(t8-t4)/R1*rm
    *else
      F3=(t5-t4)/R1*rm
    *endif
    F4=t4
    *if,tm,lt,0.0,then
      F5=2*rm/pi/R1*(t3-t7)*tm
    *else
      F5=-2*rm/pi/R1*(t3-t2)*tm
    *endif
    *if,tm,lt,0.0,then
      F6=-(t7-t1)/R1*rm
    *else
      F6=-(t2-t1)/R1*rm
    *endif
    F7=-t1
    F8=zm

    *if,tm,lt,0.0,then
      F9=-2*rm/pi/R1*(t3-t7)*tm
    *else
      F9=2*rm/pi/R1*(t3-t2)*tm
    *endif

    *if,tm,lt,0.0,then
      F10=+(t7-t1)/R1*rm
    *else
      F10=+(t2-t1)/R1*rm
    *endif
    F11=t1
    ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
    d,tnode,temp,ntemp
!    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo
alls



! Define temperatures for DSC Outer Bottom Cover
alls
esel,s,type,,2
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=170.0
t2=130.0
t3=140.0
t4=174.0
t5=132.0
t6=142.0
t7=148.0
t8=151.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
```

```
! Z1 = Thickness of Top Cover
Z0 = 0.0
Z1 = 1.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
```

```
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Inner bottom Cover
alls
esel,s,type,,4
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=189.0
t2=140.0
t3=151.0
t4=191.0
t5=140.0
t6=152.0
t7=160.0
t8=161.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 8.00
Z1 = 0.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
```

```
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for GRAPPLE RING assembly
ntemp=127
nsel,s,loc,z,-H_gr
d,all,temp,ntemp
esel,s,type,,6
nsle
nsel,r,loc,z,0
d,all,temp,160
allsel

csys,0

lswrite                          ! end of load step 1
save

solve
save

stop=0
*if,stop,eq,0,then

/com Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 16, 104 deg Ambient
/com define nodal temps
csys,1

t_val(1,1) = 277
t_val(2,1) = 280
t_val(3,1) = 285
t_val(4,1) = 290
t_val(5,1) = 325
t_val(6,1) = 347
t_val(7,1) = 360
t_val(8,1) = 379
t_val(9,1) = 387
t_val(10,1) = 396
t_val(11,1) = 399
```

```
t_val(1,2) = 272
t_val(2,2) = 274
t_val(3,2) = 279
t_val(4,2) = 284
t_val(5,2) = 316
t_val(6,2) = 336
t_val(7,2) = 350
t_val(8,2) = 368
t_val(9,2) = 376
t_val(10,2) = 385
t_val(11,2) = 387

t_val(1,3) = 266
t_val(2,3) = 268
t_val(3,3) = 273
t_val(4,3) = 277
t_val(5,3) = 306
t_val(6,3) = 326
t_val(7,3) = 340
t_val(8,3) = 357
t_val(9,3) = 365
t_val(10,3) = 374
t_val(11,3) = 376

t_val(1,4) = 260
t_val(2,4) = 262
t_val(3,4) = 266
t_val(4,4) = 270
t_val(5,4) = 297
t_val(6,4) = 316
t_val(7,4) = 329
t_val(8,4) = 347
t_val(9,4) = 355
t_val(10,4) = 362
t_val(11,4) = 358

t_val(1,5) = 254
t_val(2,5) = 256
t_val(3,5) = 259
t_val(4,5) = 263
t_val(5,5) = 288
t_val(6,5) = 306
t_val(7,5) = 319
t_val(8,5) = 337
t_val(9,5) = 344
t_val(10,5) = 351
t_val(11,5) = 341

/inp,interp,inp

! 104 F TEMPERATURE GRADIENTS EXCEPT FOR SHELLS, Bottom
/com Define temps for DSC shell above active fuel region

! Define temperatures for DSC Bottom Shield Plug
alls
esel,s,type,,3
nsle
! 104 F temperatures at top, bottom, at 90° intervals

csys,0

t1=299.0
t2=256.0
```

```
t3=269.0
t4=313.0
t5=263.0
t6=277.0
t7=280.0
t8=289.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 1.75
Z1 = 6.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif
```

```
   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls


! Define temperatures for DSC Outer Bottom Cover
alls
esel,s,type,,2
nsle
! 104 F temperatures at top, bottom, at 90° intervals

t1=295.0
t2=254.0
t3=266.0
t4=299.0
t5=256.0
t6=269.0
t7=277.0
t8=280.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
! Z1 = Thickness of Top Cover
Z0 = 0.0
Z1 = 1.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
```

```
    *if,tm,lt,0.0,then
      F3=(t8-t4)/R1*rm
    *else
      F3=(t5-t4)/R1*rm
    *endif
    F4=t4
    *if,tm,lt,0.0,then
      F5=2*rm/pi/R1*(t3-t7)*tm
    *else
      F5=-2*rm/pi/R1*(t3-t2)*tm
    *endif
    *if,tm,lt,0.0,then
      F6=-(t7-t1)/R1*rm
    *else
      F6=-(t2-t1)/R1*rm
    *endif
    F7=-t1
    F8=zm

    *if,tm,lt,0.0,then
      F9=-2*rm/pi/R1*(t3-t7)*tm
    *else
      F9=2*rm/pi/R1*(t3-t2)*tm
    *endif

    *if,tm,lt,0.0,then
      F10=+(t7-t1)/R1*rm
    *else
      F10=+(t2-t1)/R1*rm
    *endif
    F11=t1
    ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
    d,tnode,temp,ntemp
!    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Inner bottom Cover
alls
esel,s,type,,4
nsle
! 104 F temperatures at top, bottom, at 90° intervals

t1=313.0
t2=263.0
t3=277.0
t4=315.0
t5=263.0
t6=278.0
t7=289.0
t8=291.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 8.00
Z1 = 0.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
    !/gopr
    tnode=node(0,0,0)
    *get,xt,node,tnode,loc,x
```

```
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for GRAPPLE RING assembly
ntemp=257
nsel,s,loc,z,-H_gr
d,all,temp,ntemp
```

```
esel,s,type,,6
nsle
nsel,r,loc,z,0
d,all,temp,285

allsel
csys,0

lswrite                         ! end of load step 2
save

solve
save

/com Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 26, 117 deg Ambient
/com define nodal temps
csys,1

t_val(1,1) = 287
t_val(2,1) = 290
t_val(3,1) = 295
t_val(4,1) = 300
t_val(5,1) = 335
t_val(6,1) = 357
t_val(7,1) = 370
t_val(8,1) = 388
t_val(9,1) = 396
t_val(10,1) = 406
t_val(11,1) = 408

t_val(1,2) = 282
t_val(2,2) = 284
t_val(3,2) = 289
t_val(4,2) = 294
t_val(5,2) = 325
t_val(6,2) = 346
t_val(7,2) = 360
t_val(8,2) = 377
t_val(9,2) = 385
t_val(10,2) = 394
t_val(11,2) = 397

t_val(1,3) = 276
t_val(2,3) = 278
t_val(3,3) = 283
t_val(4,3) = 287
t_val(5,3) = 316
t_val(6,3) = 336
t_val(7,3) = 349
t_val(8,3) = 366
t_val(9,3) = 374
t_val(10,3) = 383
t_val(11,3) = 385

t_val(1,4) = 270
t_val(2,4) = 272
t_val(3,4) = 276
t_val(4,4) = 280
t_val(5,4) = 306
t_val(6,4) = 325
t_val(7,4) = 339
t_val(8,4) = 356
```

```
t_val(9,4) = 364
t_val(10,4) = 371
t_val(11,4) = 367

t_val(1,5) = 263
t_val(2,5) = 265
t_val(3,5) = 269
t_val(4,5) = 272
t_val(5,5) = 297
t_val(6,5) = 315
t_val(7,5) = 328
t_val(8,5) = 346
t_val(9,5) = 353
t_val(10,5) = 360
t_val(11,5) = 350

/inp,interp,inp

! 117 F TEMPERATURE GRADIENTS EXCEPT FOR SHELLS, Bottom
/com Define temps for DSC shell above active fuel region

! Define temperatures for DSC Bottom Shield Plug
alls
esel,s,type,,3
nsle
! 117 F temperatures at top, bottom, at 90° intervals

csys,0

t1=309.0
t2=265.0
t3=278.0
t4=323.0
t5=272.0
t6=287.0
t7=290.0
t8=299.0
! R1 = OD of shield plug
R1 = 33.065
! Z0 = z minimum of Shield Plug
! Z1 = Thickness of Shield plug
Z0 = 1.75
Z1 = 6.25
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
```

```
    zm=zt-Z0
    F1=1/Z1
    *if,tm,lt,0.0,then
      F2=-2*rm/pi/R1*(t6-t8)*tm
    *else
      F2=2*rm/pi/R1*(t6-t5)*tm
    *endif
    *if,tm,lt,0.0,then
      F3=(t8-t4)/R1*rm
    *else
      F3=(t5-t4)/R1*rm
    *endif
    F4=t4
    *if,tm,lt,0.0,then
      F5=2*rm/pi/R1*(t3-t7)*tm
    *else
      F5=-2*rm/pi/R1*(t3-t2)*tm
    *endif
    *if,tm,lt,0.0,then
      F6=-(t7-t1)/R1*rm
    *else
      F6=-(t2-t1)/R1*rm
    *endif
    F7=-t1
    F8=zm

    *if,tm,lt,0.0,then
      F9=-2*rm/pi/R1*(t3-t7)*tm
    *else
      F9=2*rm/pi/R1*(t3-t2)*tm
    *endif

    *if,tm,lt,0.0,then
      F10=+(t7-t1)/R1*rm
    *else
      F10=+(t2-t1)/R1*rm
    *endif
    F11=t1
    ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
    d,tnode,temp,ntemp
!    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo
alls

! Define temperatures for DSC Outer Bottom Cover
alls
esel,s,type,,2
nsle
! 117 F temperatures at top, bottom, at 90° intervals

t1=305.0
t2=263.0
t3=276.0
t4=309.0
t5=265.0
t6=278.0
t7=287.0
t8=290.0
! R1 = OD of Top Cover
R1 = 33.065
! Z0 = z minimum of Top Cover
! Z1 = Thickness of Top Cover
Z0 = 0.0
```

```
Z1 = 1.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
```

```
*enddo
alls

! Define temperatures for DSC Inner bottom Cover
alls
esel,s,type,,4
nsle
! -40 F temperatures at top, bottom, at 90° intervals

t1=323.0
t2=272.0
t3=287.0
t4=324.0
t5=273.0
t6=288.0
t7=299.0
t8=301.0
! R1 = OD of Inner Top Cover
R1 = 33.065
! Z0 = z minimum of Inner Top Cover
! Z1 = Thickness of Inner Top Cover
Z0 = 8.00
Z1 = 0.75
pi = 3.1416
*get,totnode,node,,count
*DO,i,1,totnode,1
   !/gopr
   tnode=node(0,0,0)
   *get,xt,node,tnode,loc,x
   *get,yt,node,tnode,loc,y
   *get,zt,node,tnode,loc,z
   rm=(xt**2+yt**2)**0.5
   *if,xt,eq,0.0,then
     tm=1.5707963267949
   *else
      tm=atan(yt/xt)
   *endif
   *if,tm,eq,0.0,then
      *if,xt,lt,0.0,then
         tm=-1.0e-6
      *else
      *endif
   *else
   *endif
   zm=zt-Z0
   F1=1/Z1
   *if,tm,lt,0.0,then
     F2=-2*rm/pi/R1*(t6-t8)*tm
   *else
     F2=2*rm/pi/R1*(t6-t5)*tm
   *endif
   *if,tm,lt,0.0,then
     F3=(t8-t4)/R1*rm
   *else
     F3=(t5-t4)/R1*rm
   *endif
   F4=t4
   *if,tm,lt,0.0,then
     F5=2*rm/pi/R1*(t3-t7)*tm
   *else
     F5=-2*rm/pi/R1*(t3-t2)*tm
   *endif
   *if,tm,lt,0.0,then
     F6=-(t7-t1)/R1*rm
```

```
   *else
     F6=-(t2-t1)/R1*rm
   *endif
   F7=-t1
   F8=zm

   *if,tm,lt,0.0,then
     F9=-2*rm/pi/R1*(t3-t7)*tm
   *else
     F9=2*rm/pi/R1*(t3-t2)*tm
   *endif

   *if,tm,lt,0.0,then
     F10=+(t7-t1)/R1*rm
   *else
     F10=+(t2-t1)/R1*rm
   *endif
   F11=t1
   ntemp=F1*(F2+F3+F4+F5+F6+F7)*F8 +F9 +F10 +F11
   d,tnode,temp,ntemp
!   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo
alls

! Define temperatures for GRAPPLE RING assembly
ntemp=267
nsel,s,loc,z,-H_gr
d,all,temp,ntemp

esel,s,type,,6
nsle
nsel,r,loc,z,0
d,all,temp,295

allsel
csys,0

lswrite                          ! end of load step 3
save

solve
save

fini

/exit

/eof


*endif
```

PB24THRM.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal loads
resume,b24therm,db
/post1
file,b24therm,rth

*do,iset,1,3                    ! define steps to postprocess
/go
set,iset

/com Stress Plots ------------------------------------------------------------
/num,0                          ! numbers and colors
/device,vector,0                ! raster plots
ernorm,off
dsys,0
/show,file,,0                   ! plot to file

/dscale,,auto                   ! displacement scale

/com all elements (excluding contact elements)
/vup,1,-x                       ! x-axis down
/auto,1
/view,,-0.2,-0.8,-0.5
plnsol,temp                          ! plot temperature distribution
/auto,1                         ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave

/eof
```

Appendix A34

ANSYS Analysis Run Summary and Input Listings for QB24PED

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QT24PED (analysis) [1] PT24PED (postprocessing) [1]

Date/Time: 9/6/00 6:20 PM 9/6/00 7:13 PM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 3.51 (Build 1057)

CPU: PentiumPro 200

Analysis Modules Used: •PREP7 •SOLUTION •POST1

Component Analyzed: 24P-FO DSC Shell Assembly: Shell and top end components

Loads Considered: 60g bottom end drop, internal pressure [2, 3]

Analysis Type: •Static _Thermal _Other: _____

Materials: •Linear _Non-Linear

Geometry: _Linear •Non-Linear

Element Types Used:

Solid45: 3-D elastic/plastic solid

Contac49: 3-D point to surface contact

Other Information:

1. Input filenames use *.inp* extensions while output filenames use *.out* extensions. Plot filenames use *.plc* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Step 6 reverses an earlier "ekill" command used to pin the weld of the outer cover plate. Consideration of nonlinear geometry may yield inaccurate results for this load step. However, results from Step 6 are not used.

Run By: Michael E. Cohen Date: 9/8/00

Checked By: Craig M. Standafer Date: 9/8/00

QB24PED.inp

```
/batch,list
/filname,qb24ped
/title,24PT1-DSC Shell Assembly (Bottom End, 90 Degree Model)
/prep7

/com shell assembly components
et,1,solid45            ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,2,solid45            ! 3-D Elastic/Plastic Solid - DSC Outer Bottom Cover Pl
et,3,solid45            ! 3-D Elastic/Plastic Solid - DSC Bottom Shield Plug
et,4,solid45            ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl
et,5,solid45            ! 3-D Elastic/Plastic Solid - Bottom Plate Weld
et,6,solid45            ! 3-D Elastic/Plastic Solid - DSC Grapple Ring Support
et,7,solid45            ! 3-D Elastic/Plastic Solid - DSC Grapple Ring

et,11,solid45           ! 3-D Elastic/Plastic Solid - DSC Upper Shell

et,20,contac49          ! 3-D point to surface contact elements
r,201,1.0E+06           ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+06,1E7/100   ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+06,1E7/100   ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1           ! keyopt (7)=1


tref,650                ! maximum temperature

/com material 1 - DSC Shell: SA-240 Type 316  (18Cr-8Ni) ********************
mptemp,1,70,200,300,400,500,600
mptemp,7,700
dens,1,493/1728
mpdata,ex,1,1,28.3E+06,27.6E+06,27.0E+06,26.5E+06,25.8E+06,25.3E+06 ! SA-240 Type 316
mpdata,ex,1,7,24.8E+06 ! SA-240 Type 316
nuxy,1,0.29

/com material 2 - Shield Plugs:  SA-36  (C-Mn-Si) ***************************
mptemp,1,70,200,300,400,500,600
mptemp,7,700
dens,2,490/1728
mpdata,ex,2,1,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06
mpdata,ex,2,7,25.5E+06
nuxy,2,0.29

csys,0                  ! cartesian coordinates

/com geometry
T_shell=.53             ! shell thickness
OR=67.19/2              ! shell outside radius
IR=OR-T_shell           ! shell inside radius
H_dsc=186.17            ! height (length) of DSC

L_otc=H_dsc-0.12        ! outer top cover plate location (top surface)

T_ibc=0.75              ! inner bottom cover plate thickness
T_bplug=6.25            ! bottom shield plug thickness
T_obc=1.75              ! outer bottom cover plate thickness
T_bw=0.625              ! thickness of outer bottom cover plate weld

L_bplug=T_bplug+T_obc   ! bottom shield plug location (top surface)
L_ibc=T_ibc+T_bplug+T_obc ! inner bottom cover plate location (top surface)

OR_gr=8.0               ! outer radius of the grapple ring & support
IR_gr=5.0               ! inner radius of the grapple ring
T_gr=1.00               ! thickness of the grapple ring
```

```
H_gr=3.75                   ! height of the grapple ring
T_grs=0.75                  ! thickness of the grapple ring support
IR_grs=OR_gr-T_grs          ! inner radius of the grapple ring support
OR_load=8.74/2              ! radius of the ram load


/com lower shell keypoints
k,1,OR-0.25                 ! shell outer bottom
k,2,IR+0.21                 ! shell inner bottom
k,3,IR,,T_bw                ! root of outer bottom cover plate weld
k,4,IR,,L_bplug             ! bottom of inner bottom cover plate
k,5,IR,,L_ibc               ! top of inner bottom cover plate
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC
k,8,OR,,L_ibc               ! line up with KP5
k,9,OR,,L_bplug             ! line up with KP4
k,10,OR,,0.75               ! lower chamfer

/com outer bottom cover plate keypoints
k,21,IR-0.49                ! weld interface at bottom surface
k,22,IR-1.4
k,23,OR_gr                  ! outer radius of grapple ring
k,24,IR_grs                 ! inner radius of grapple ring
k,26,0,0,0                  ! center at bottom surface
k,28,0,,T_obc               ! center at top surface
k,30,IR_grs,,T_obc          ! line up with KP24
k,31,OR_gr,,T_obc           ! line up with KP23
k,32,IR-0.93,,T_obc         ! outer radius (chamfer) at top surface

/com bottom shield plug keypoints
k,40,IR,,T_obc              ! outer radius at bottom surface
k,41,0,,T_obc               ! center at bottom surface
k,42,0,,L_bplug             ! center at top surface
k,43,IR,,L_bplug            ! outer radius at top surface

/com inner bottom cover plate keypoints
k,50,IR,,L_bplug            ! outer radius at bottom surface
k,51,0,,L_bplug             ! center radius at bottom surface
k,52,0,,L_ibc               ! center radius at top surface
k,53,IR,,L_ibc              ! outer radius at top surface
k,54,IR-0.25,,L_bplug       ! radius of shield plug contact
k,55,IR-0.25,,L_ibc         ! line up with KP54

/com grapple ring keypoints
k,60,OR_gr,,-H_gr+T_gr      ! interface of grapple ring with support
k,61,OR_gr,,-H_gr+0.75      ! outer chamfer
k,62,OR_gr-0.25,,-H_gr      ! outer bottom surface
k,63,IR_grs-0.25,,-H_gr
k,64,IR_gr+0.25,,-H_gr      ! inner bottom surface
k,65,IR_gr,,-H_gr+0.75      ! inner chamfer
k,66,IR_gr,,-H_gr+T_gr      ! inner top surface
k,67,IR_grs,,-H_gr+T_gr     ! interface of grapple ring with support
k,68,IR_grs,,-H_gr+0.75

/com upper shell keypoints
k,76,IR,,L_otc              ! shell inner top
k,77,OR,,L_otc              ! shell outer top

klist

/com meshing ***********************************************************************

/com define arcs to sweep volumes and lines
lsel,none
```

```
k,200,0,,H_dsc/2
k,201,IR-5,,H_dsc/2
k,202,0,IR-5,H_dsc/2
larc,201,202,200,IR-5
cm,swp_arc1,line
lesize,swp_arc1,,,26,1        ! 26 divisions on "swp_arc1"

lsel,none
k,203,IR-7,,H_dsc/2
k,204,0,IR-7,H_dsc/2
larc,203,204,200,IR-7
cm,swp_arc2,line
lesize,swp_arc2,,,12,1        ! 12 divisions on "swp_arc2"
allsel

/com lower shell elements
lsel,none
asel,none
vsel,none
mat,1
type,1
a,1,2,3,10
a,3,4,9,10
a,4,5,8,9
a,5,6,7,8
lsel,r,loc,x,IR+0.01,OR-0.01 ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions thru shell thickness
ksel,s,,,5,6,1                ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,10           ! 0.5" to 4" element size
ksel,s,,,7,8,1                ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.5,,,0.1          ! 4" to 0.5" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.5                     ! 0.5" element height for unmeshed lines
vmesh,all
cm,alshell,area
cm,vlshell,volume
ksel,all

/com outer bottom cover plate elements
lsel,none
asel,none
vsel,none
type,2
mat,1
a,21,22,32,3
lsel,r,loc,x,IR-1.4,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
vmesh,all
vsel,none
lsla,s                        ! lines contained in above areas
v,26,22,kp(0,IR-1.4,0),kp(0,IR-1.4,0),28,32,kp(0,IR-.93,T_obc),kp(0,IR-.93,T_obc)
ksel,s,,,26,28,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
vsel,s,type,,2
cm,aoutbot,area
cm,voutbot,volume
```

```
ksel,all

/com bottom shield plug elements
lsel,none
asel,none
vsel,none
type,3
mat,2
ksel,s,kp,,40,43
ldrag,40,43,,,,,2              ! generate lines along line 2 ("swp_arc2")
v,41,40,kp(0,IR,T_obc),kp(0,IR,T_obc),42,43,kp(0,IR-.25,L_bplug),kp(0,IR-.25,L_bplug)
esize,T_bplug/3                ! 3 elements thru plate
vmesh,all
cm,abotplug,area
cm,vbotplug,volume
ksel,all

/com inner bottom cover plate elements
lsel,none
asel,none
vsel,none
type,4
mat,1
a,50,54,55,53
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
v,54,kp(0,IR-0.25,L_bplug),51,51,55,kp(0,IR-0.25,L_ibc),52,52
esize,T_ibc/2                  ! 2 elements thru plate
vmesh,all
cm,ainbot,area
cm,vinbot,volume
ksel,all

/com weld of outer bottom cover plate
lsel,none
asel,none
vsel,none
type,5
mat,1
a,2,21,3,3
lsel,r,loc,z,0
lesize,all,,,2,0.49/0.21       ! 2 divisions, generate node at IR
vdrag,all,,,,,,1               ! generate volume along line 1 ("swp_arc1")
vmesh,all
cm,abotweld,area
cm,vbotweld,volume

/com grapple support elements
lsel,none
asel,none
vsel,none
type,6
mat,1
a,23,60,67,24
lsel,r,loc,z,-H_gr+T_gr        ! select lines for dividing
lesize,all,,,2                 ! 2 divisions thru support ring thickness
vdrag,all,,,,,,2               ! generate volume along line 2 ("swp_arc2")
esize,T_grs                    ! element height for unmeshed lines
vmesh,all
cm,agrapsup,area
cm,vgrapsup,volume

/com grapple ring elements
lsel,none
asel,none
```

```
vsel,none
type,7
mat,1
a,60,61,68,67
a,67,68,65,66
a,61,62,63,68
a,68,63,64,65
lsel,s,loc,z,-H_gr+.1,-H_gr+.7 ! select lines for dividing
lesize,all,,,1                 ! 1 line division
vdrag,all,,,,,,2             ! generate volume along line 2 ("swp_arc2")
esize,0.75                   ! 0.75 element size for unmeshed lines
vmesh,all
cm,agraprng,area
cm,vgraprng,volume


allsel


/com merge nodes for material continuity

esel,s,type,,1,2,1
esel,a,type,,5,7,1
allsel,below,elem
nummrg,node                  ! lower shell to weld to outer bottom cover plate
                       ! & outer bottom cover to grapple ring components
/com tie together grapple to outer bottom cover
esel,s,type,,6
allsel,below,elem
nsel,r,loc,z,0
esel,s,type,,2
ceintf                       ! tie together grapple to outer bottom cover

allsel

/com merge nodes to represent pin-welded connections
/com (acceptable only for solid45, which has translational DOF only)

csys,1                       ! cylindrical coordinates

esel,s,type,,1,4,3
allsel,below,elem
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_ibc+.01
nummrg,node                  ! upper & lower welds of inner bottom cover plate

csys,0                       ! cartesian coordinates
allsel


! /com reflect quarter geometry to generate half model

! *get,maxnode,node,,num,max   ! get maximum node number
! nsym,x,maxnode,all           ! reflect all nodes
! esym,,maxnode,all            ! reflect all elements

! *do,i,1,7,1                  ! merge nodes at line of symmetry (bottom shell components)
!    /gopr
!     esel,s,type,,i
!     nsle
!     nummrg,node
! *enddo

! esel,s,type,,11
```

```
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (upper shell)

! esel,s,type,,20
! nsle
! nummrg,node                    ! merge coincident contact nodes (if any)
! nummrg,elem                    ! merge coincident contact elements (if any)


/com define contact elements
/com bottom end plates

esel,s,type,,1
allsel,below,elem
cm,cont1,node                  ! nodes of lower shell

esel,s,type,,2
allsel,below,elem
cm,cont2,node                  ! nodes of outer bottom cover plate

esel,s,type,,4
allsel,below,elem
cm,cont4,node                  ! nodes of inner bottom cover plate

/com inner bottom cover plate nodes at IR-.25
esel,s,type,,4
allsel,below,elem
csys,1
nsel,r,loc,x,IR-0.26,IR-0.24
csys,0
cm,cont4a,node                 ! inner bottom cover plate nodes at IR-.25

csys,1                         ! cylindrical coordinates

esel,s,type,,3
allsel,below,elem
nsel,r,loc,x,IR
cm,targ31,node                 ! bottom shield plug circumferential nodes

allsel,below,elem
nsel,r,loc,z,T_obc
cm,targ32,node                 ! bottom shield plug bottom surface nodes

allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,u,loc,x,11/12*IR+.1,IR+.01  ! unselect outer row of contact elements
cm,targ34,node                 ! bottom shield plug top surface nodes (w/o outer row)

/com outer row of contact elements
allsel,below,elem
nsel,r,loc,z,L_bplug
nsel,r,loc,x,11/12*IR-.5,IR+.01  ! one outer row of contact elements
cm,targ34a,node                ! bottom shield plug top surface nodes (w/o outer row)

csys,0                         ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont1,targ31,1          ! generate contact elem btwn plug & shell
real,202
gcgen,cont2,targ32,1           ! generate contact elem btwn plug & outer plate
real,203
gcgen,cont4,targ34,1           ! generate contact elem btwn plug & inner plate
```

```
gcgen,cont4a,targ34a,1        ! gen contact btwn plug & inner pl (outer ring)

!/com couple UZ all inner bottom cover plate nodes at radius IR-0.25, at ...
!/com surface in contact with bottom shield plug
!csys,1                       ! cylindrical coordinates
!esel,s,type,,4
!nsle
!nsel,r,loc,x,IR-.26,IR-.24
!nsel,r,loc,z,L_bplug
!cp,next,uz,all
!csys,0                       ! cartesian coordinates
!allsel

!/com couple UZ all outer bottom cover plate nodes at radius IR-0.93, at ...
!/com surface in contact with bottom shield plug
!csys,1                       ! cylindrical coordinates

!esel,s,type,,2
!nsle
!nsel,r,loc,z,T_obc
!nsel,r,loc,x,IR-0.94,IR-0.92
!cp,next,uz,all
!csys,0                       ! cartesian coordinates
!allsel


/com compress node and element numbering
numcmp,node
numcmp,elem

/com specify symmetric boundary conditions
nsel,s,loc,y,-.01,.01
d,all,uy,0                    ! symmetry about x-z plane
allsel

nsel,s,loc,x,-.01,.01
d,all,ux,0                    ! symmetry about y-z plane (90 degree model only!)
allsel

/com end of shell boundary conditions
nsel,s,loc,z,H_dsc/2          ! shell now ends at mid-height
d,all,uz
allsel

/com restrain center nodes for stability
nsel,r,loc,x,0,0.1
nsel,r,loc,y,0,0.1
d,all,ux,0
allsel

save

fini

/solution

/com analysis parameters
antype,static
nropt,auto
neqit,500
pred,on,,on
autots,on
nlgeom,on
eqslv,pcg,1e-7
```

```
/com load step 1 - 0.001g top end drop
/title,24PT1-DSC (Bottom End) 0.001g Bottom End Drop
nsubst,1,8
acel,,,-0.001                  ! 0.001g acceleration
lswrite
save
solve
save

/com load step 2 - 1g bottom end drop
/title,24PT1- DSC (Bottom End) 1g Top End Drop
nsubst,1,8
r,202,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1.0E+07,1E7/100 ! norm/tan stiffness of gap elem btwn support ring & plug
acel,,,-1.                     ! 1g acceleration
lswrite
save
solve
save

/com load step 3 - 60g top end drop
/title,24PT1- DSC (Bottom End) 60g Top End Drop
nsubst,1,8
acel,,,-60.                    ! 75g acceleration
lswrite
save
solve
save

/com load step 4 - pin outer cover plate weld
/title,24PT1- DSC (Bottom End) 60g top End Drop (Outer Cover Pinned)
nsubst,1,8
esel,s,type,,15
nsle
ekill,all                      ! kill weld elements
esel,all
nsle
lswrite
save
solve
save

/com load step 5 - add 20 psi internal pressure to 75g top end drop
/title,24PT1- DSC (Bottom End) 60g Top End Drop + 20 psi (Outer Cover Pinned)
nsubst,1,8
pred,off
pred,on
csys,1                         ! cylindrical coordinates
esel,s,type,,11,13,2
nsle
nsel,r,loc,z,H_dsc/2,L_tplug+.01
nsel,r,loc,x,0,IR+.01
sf,all,pres,20
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
csys,0                         ! cartesian coordinates
allsel
lswrite
save
solve
save
```

```
/com load step 6 - unpin outer cover plate weld
/title,24PT1- DSC (Bottom End) 60g Top End Drop + 20 psi
nsubst,1,8
pred,off
pred,on,,on
ealive,all                    ! unkill weld elements
lswrite
save
solve
save

fini

/exit
```

PB24PED.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  top end drop with & without pressure
resume,qb24ped,db
/post1
file,qb24ped,rst

/com element plots ------------------------------------------------------------
/show,pb24ped,pic,1            ! plot to file
/triad,rtop                    ! triad in upper right left corner
/device,vector,1               ! vector plots
/num,2                         ! numbers, no colors
/vup,1,-z                      ! z-axis down
/view,,-0.2,-0.9,-0.3
/type,1,4                      ! precise hidden
esel,u,type,,20                ! unselect contact elements
eplot                          ! plot elements
/zoom,1,rect,-0.399,0.917,0.392,0.221
/show,off                      ! discontinue plots to file
/auto,1                        ! zoom - fit

csys,1                         ! cylindrical coordinate system
dsys,1
rsys,1

*do,iset,2,6                   ! define steps to postprocess
/go
set,iset

/com DSC Lower Shell Post1 Results ---------------------------------------------
esel,s,type,,1
nsle
nsel,r,loc,y,0
esln
esel,r,type,,1
nsle
/com
/com shell adjacent to DSC end components
 *do,ix,IR+.21,OR-.25,OR-.25-(IR+.21)
   inode=node(IR,0,T_bw)
   onode=node(ix,0,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,.75/2,.75,.75/2
   inode=node(IR,0,T_bw)
   onode=node(OR,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_bplug-7,L_ibc+5,.5
   inode=node(IR,0,iz)
   onode=node(OR,0,iz)
   *if,onode,eq,node(OR,0,iz-.5),cycle
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
/com
```

```
/com shell at mid-height
   inode=node(IR,0,H_dsc/2)
   onode=node(OR,0,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Bottom Cover Plate Post1 Results ---------------------------------
esel,s,type,,2
nsle
nsel,r,loc,y,0
esln
esel,r,type,,2
nsle
 *do,ix,0,IR-1.4,(IR-1.4)/26
   inode=node(ix,0,T_obc)
   onode=node(ix,0,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR-.46,0,1.19)
   onode=node(IR-.95,0,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,0,T_bw)
   onode=node(IR-.49,0,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
esel,s,type,,5
nsle
nsel,r,loc,y,0
esln
esel,r,type,,5
nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,0,T_bw)
   onode=node(ix,0,0)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Bottom Shield Plug Post1 Results ---------------------------------------
esel,s,type,,3
nsle
nsel,r,loc,y,0
esln
esel,r,type,,3
nsle
 *do,ix,0,IR,IR/12
   inode=node(ix,0,L_bplug)
   onode=node(ix,0,T_obc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Inner Bottom Cover Plate Post1 Results ---------------------------------
esel,s,type,,4
```

```
nsle
nsel,r,loc,y,0
esln
esel,r,type,,4
nsle
 *do,ix,0,IR-.25,(IR-.25)/26
   inode=node(ix,0,L_ibc)
   onode=node(ix,0,L_bplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR,0,L_ibc)
   onode=node(IR,0,L_bplug)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com DSC Grapple Ring Support Post1 Results ------------------------------------
esel,s,type,,6
nsle
nsel,r,loc,y,0
esln
esel,r,type,,6
nsle
 *do,iz,0,-H_gr+T_gr,(-H_gr+T_gr)/4
   inode=node(IR_grs,0,iz)
   onode=node(OR_gr,0,iz)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo

/com DSC Grapple Ring Post1 Results ------------------------------------------
esel,s,type,,7
nsle
nsel,r,loc,y,0
esln
esel,r,type,,7
nsle
 *do,ix,IR_grs-.125,5.79,(5.79-(IR_grs-.125))/2
   inode=node(ix,0,-H_gr+T_gr)
   onode=node(ix,0,-H_gr)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
   inode=node(IR_gr,0,-H_gr+T_gr)
   onode=node(IR_gr+.25,0,-H_gr)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect

/com Nodal Forces for Weld of Inner Bottom Cover Plate -------------------------
/com
/com bottom row of nodes
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
```

```
/com mid row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_bplug+.1,L_ibc-.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com top row of nodes
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ibc-.1,L_ibc+.1
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Outer Bottom Cover Plate -------------------------
esel,s,type,,2,5,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,T_bw-.01,T_bw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Reaction Forces at Shell Mid-Height ---------------------------------------
nsel,s,loc,z,H_dsc/2-.1,H_dsc/2+.1
nlist
prrsol,fz

allsel

/com Stress Plots --------------------------------------------------------------
/num,0                       ! numbers and colors
/device,vector,0             ! raster plots
ernorm,off
dsys,0
/show,file,,0                ! plot to file
! /edge,,1,10                  ! edge plot

/dscale,,auto                ! displacement scale

/com all elements (excluding contact elements)
esel,u,type,,20              ! unselect contact elements
/view,,-0.2,-0.9,-0.3
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.399,0.917,0.392,0.221
/auto,1                      ! zoom - fit
/view,,-0.2,-0.9,0.3
/replot
/zoom,1,rect,-0.399,0.917,0.392,0.221
/auto,1                      ! zoom - fit

/dscale,,1                   ! displacement scale

/com shell elements
esel,s,type,,1
nsle
/view,,-0.4,-0.9,-0.4
plnsol,s,int,0               ! plot stress intensity
/view,,0.9,0.6,-0.4
/replot

/com outer cover plate elements
```

```
esel,s,type,,2
nsle
/view,,-0.2,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,0.4
/replot

/com outer cover plate weld elements
esel,s,type,,5
nsle
/view,,-0.2,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,0.4
/replot

/com shield plug elements
esel,s,type,,3
nsle
/view,,-0.2,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,0.4
/replot

/com inner cover plate elements
esel,s,type,,4
nsle
/view,,-0.2,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,0.4
/replot

/com grapple ring support elements
esel,s,type,,6
nsle
/view,,-0.4,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.9,0.6,0.4
/replot

/com grapple ring elements
esel,s,type,,7
nsle
/view,,-0.2,-0.9,-0.4
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.9,0.4
/replot

dsys,1

*enddo                          ! end load step loop

allsel

fini

exit,nosave
```

Appendix B1

ANSYS Stress Intensity Contour Plots for Run PT24PIP

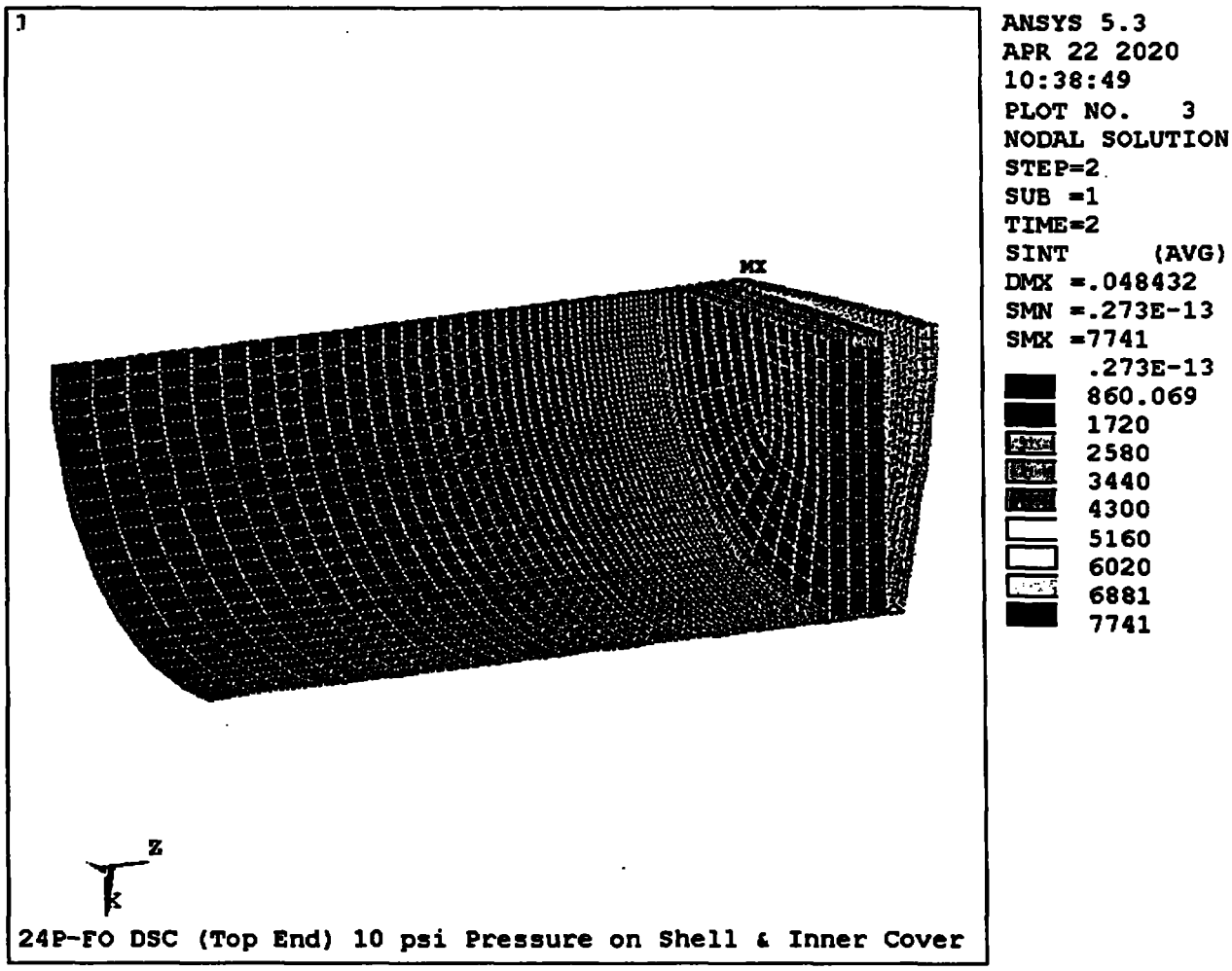

Figure B1-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

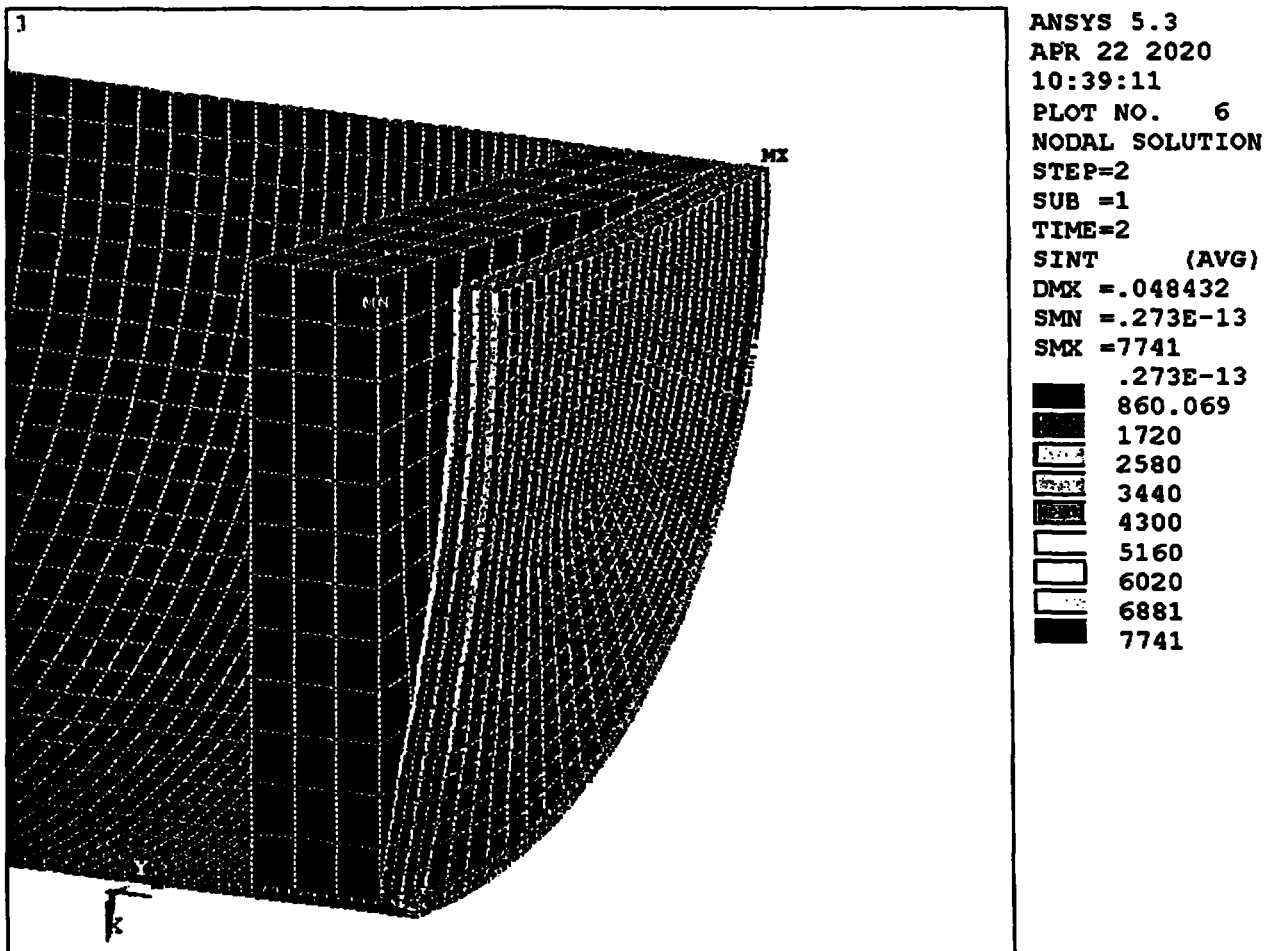

Figure B1-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

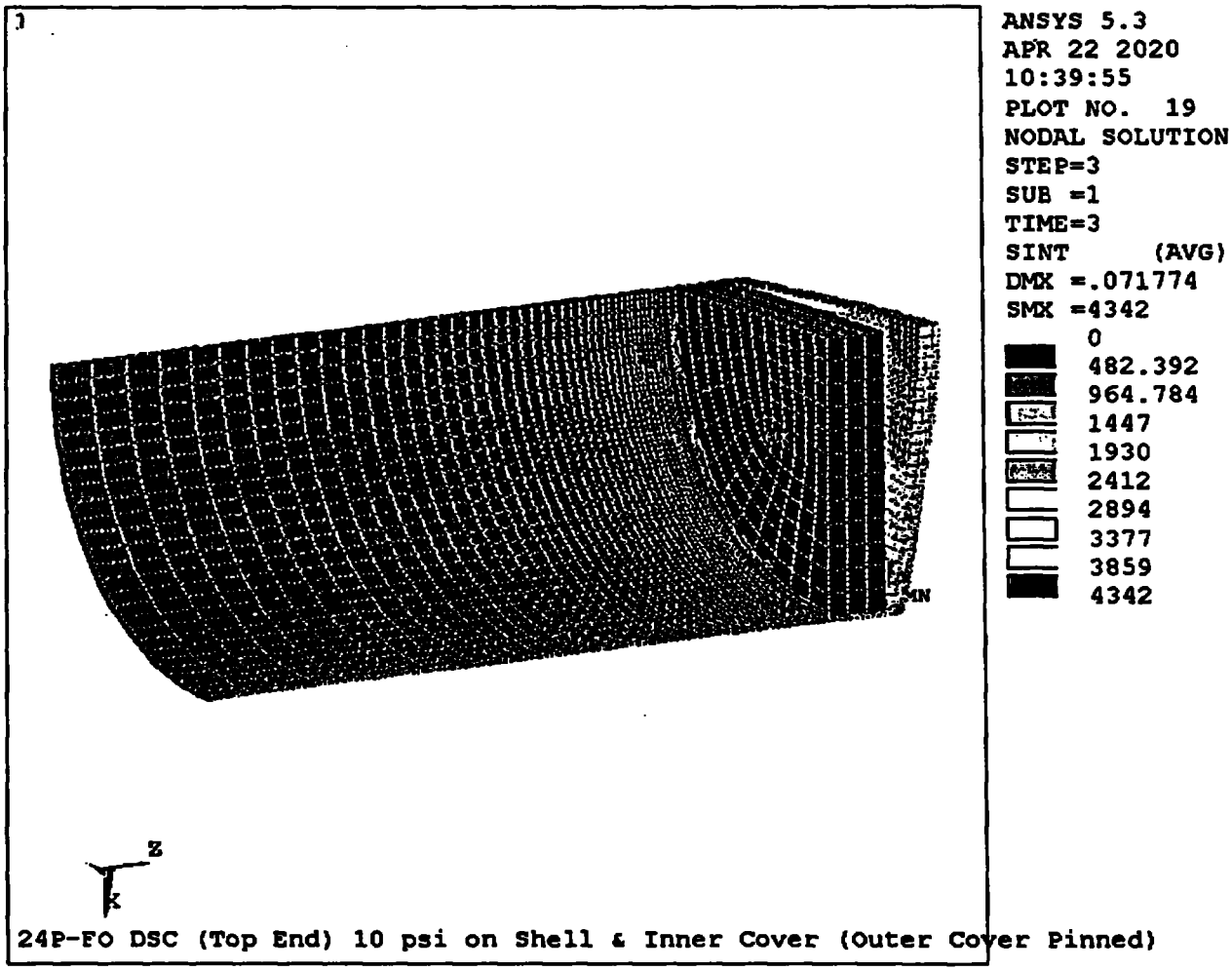

Figure B1-3

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

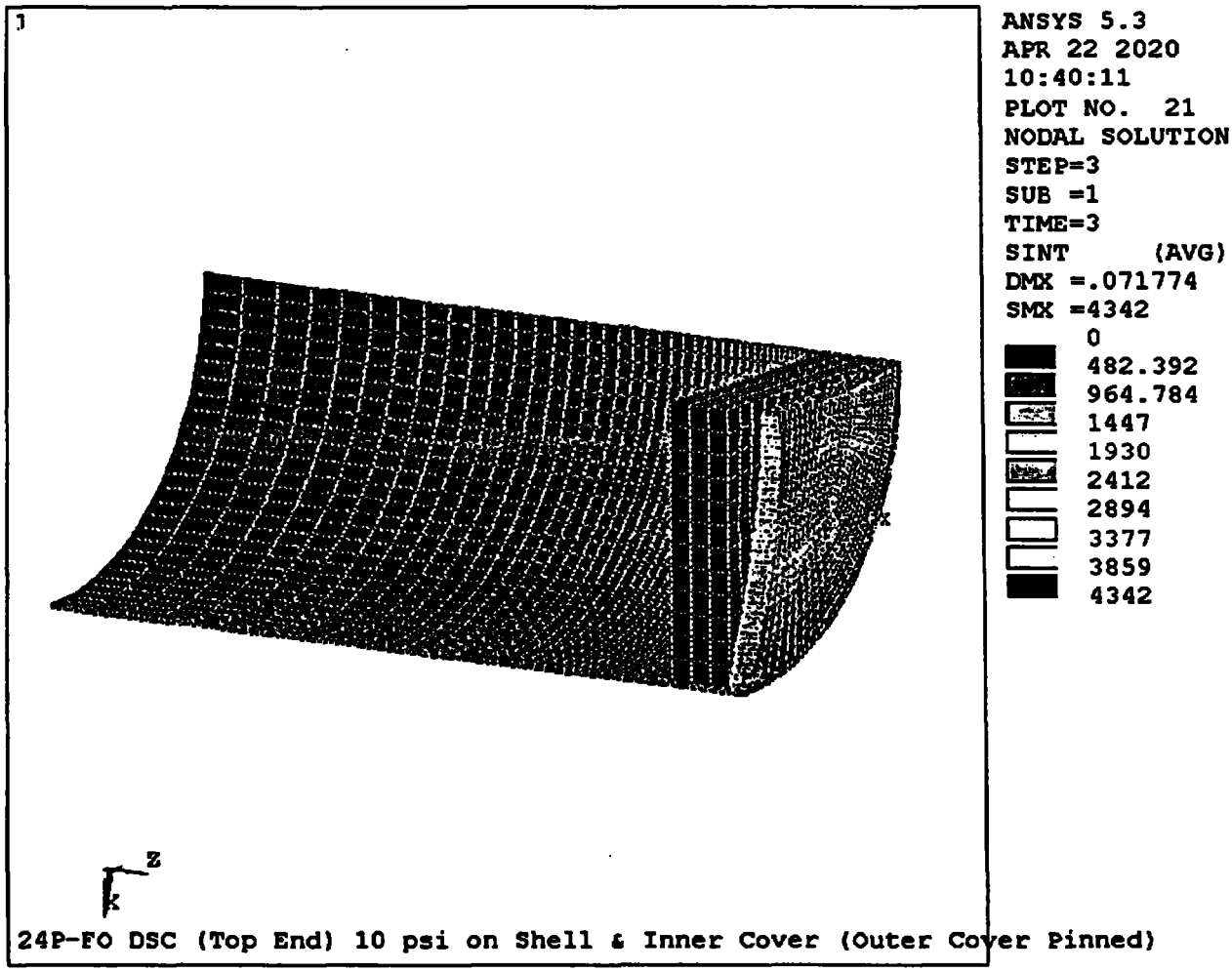

Figure B1-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

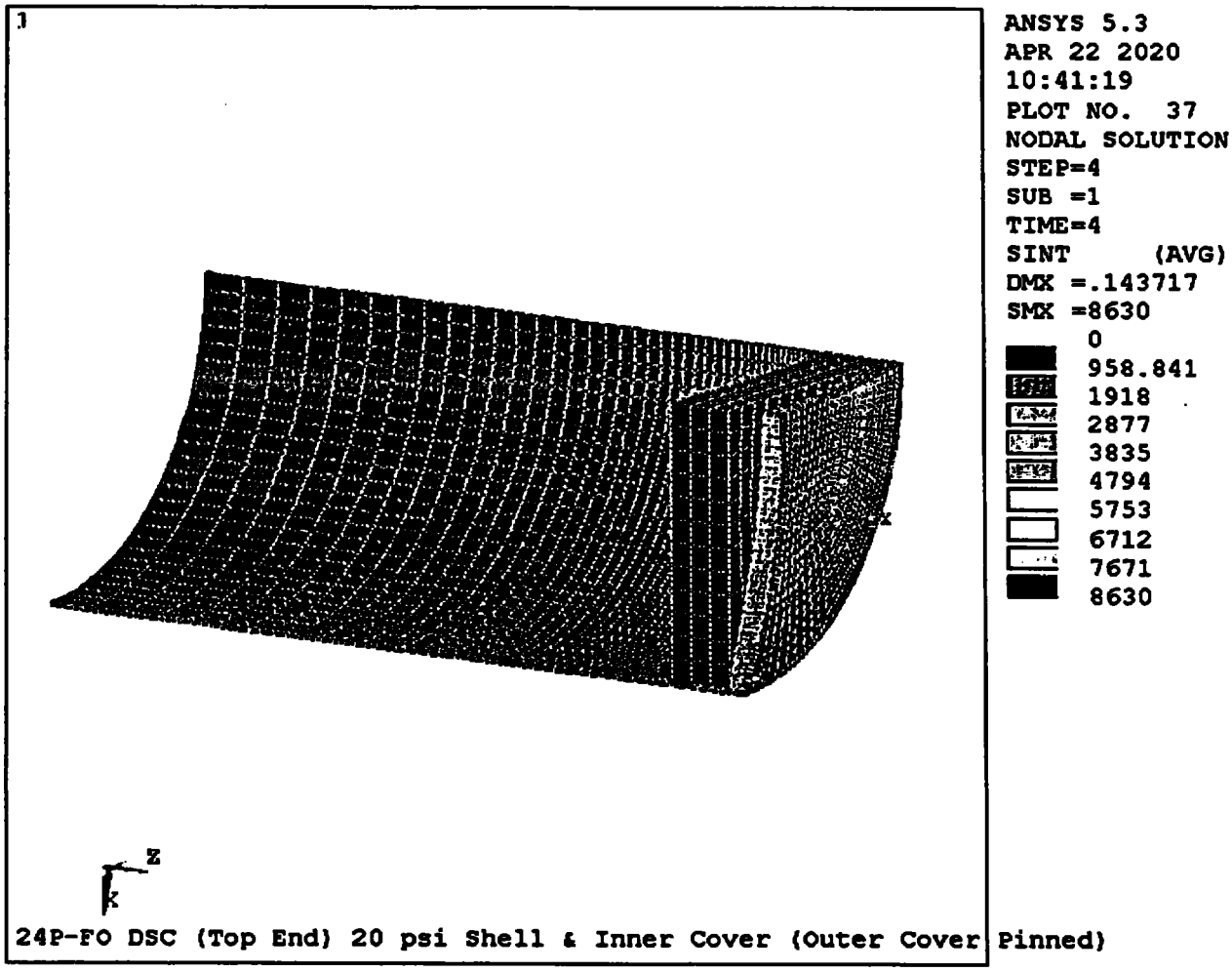

Figure B1-5

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

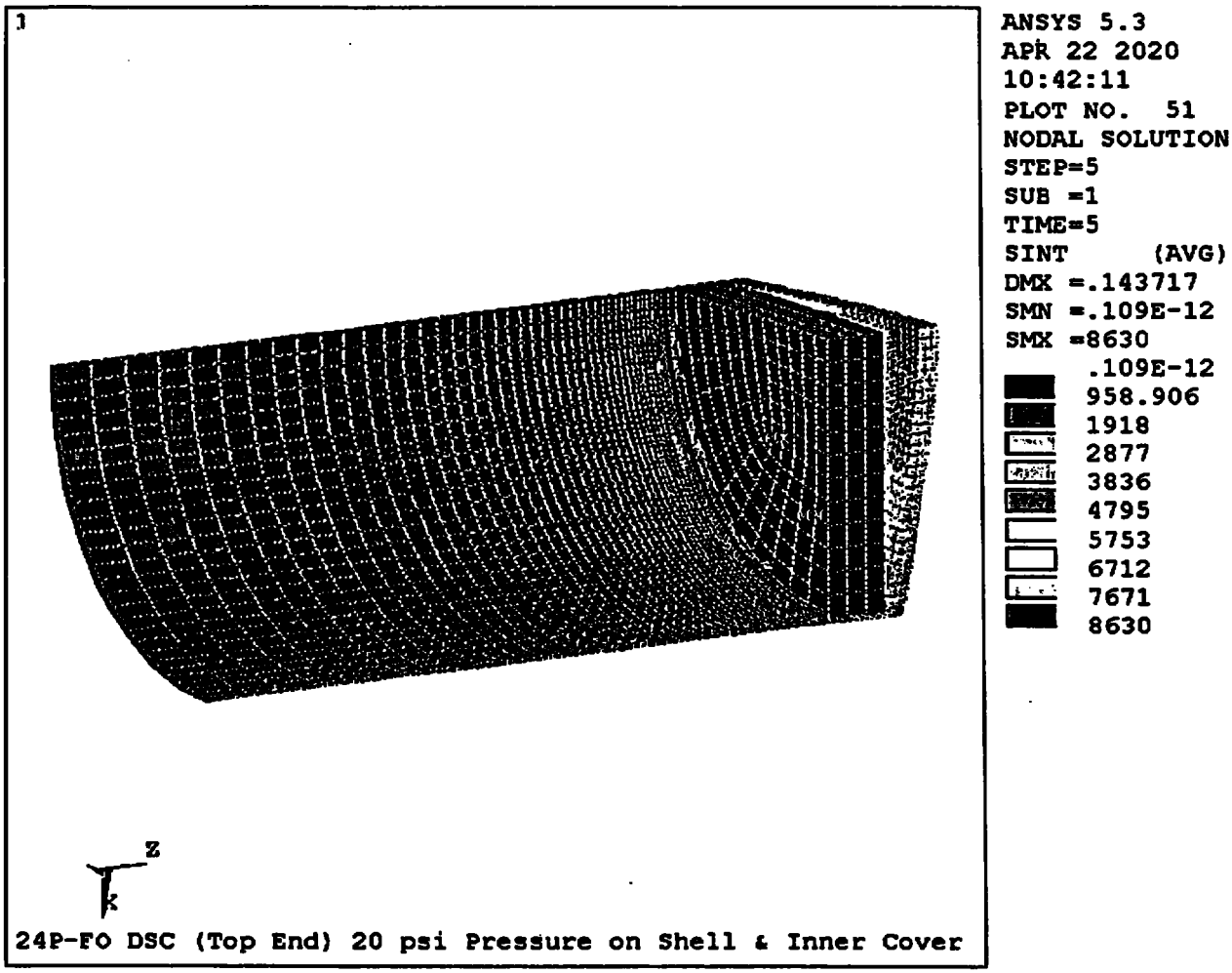

Figure B1-6

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

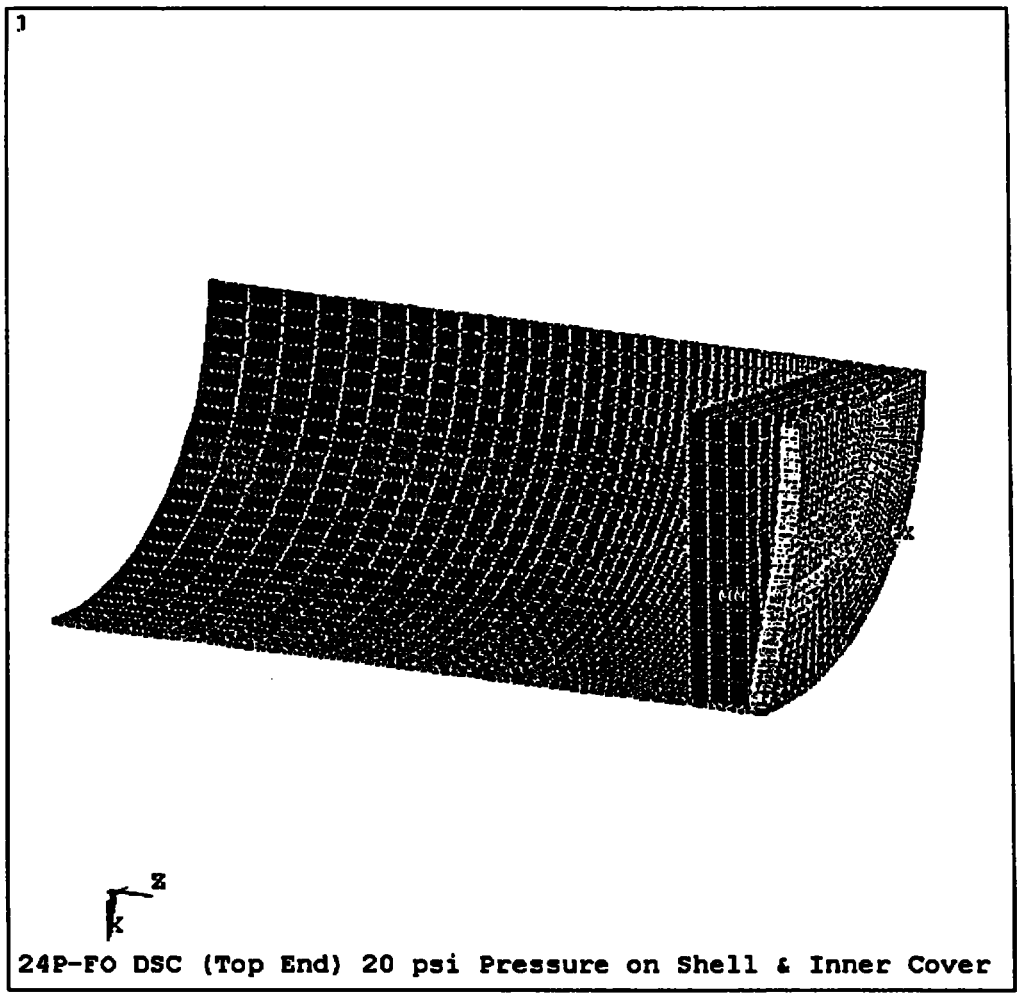

Figure B1-7

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

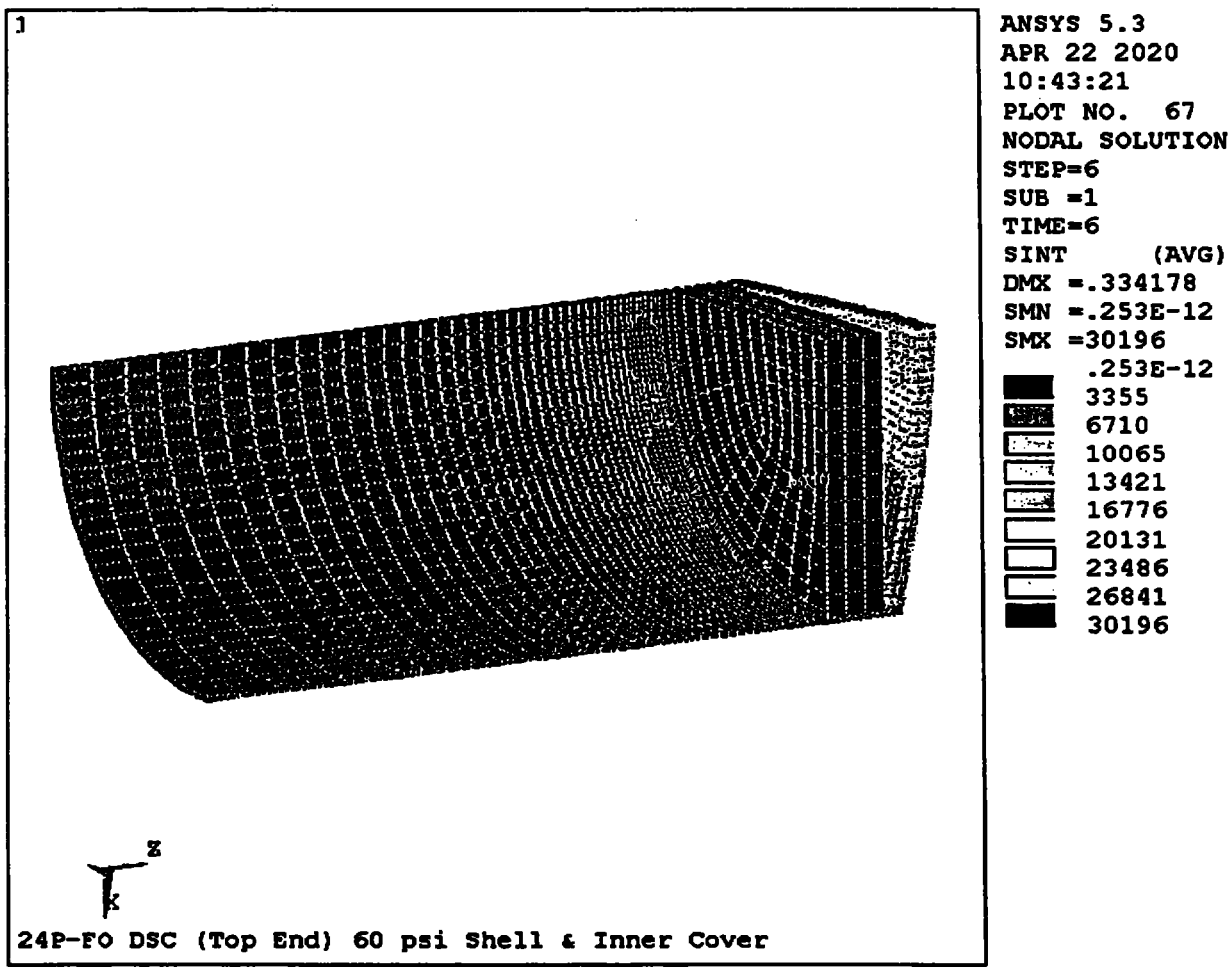

Figure B1-8

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

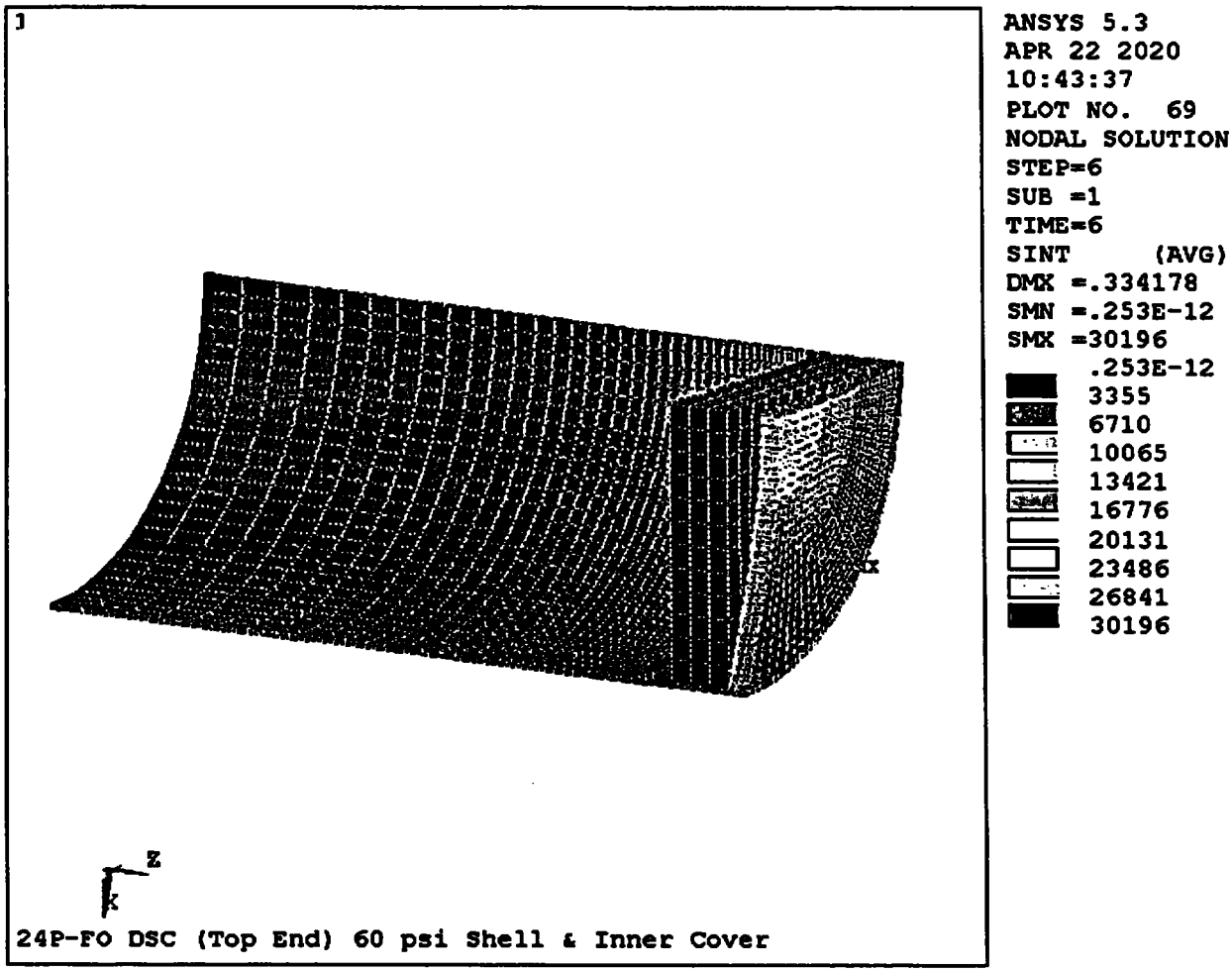

Figure B1-9

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

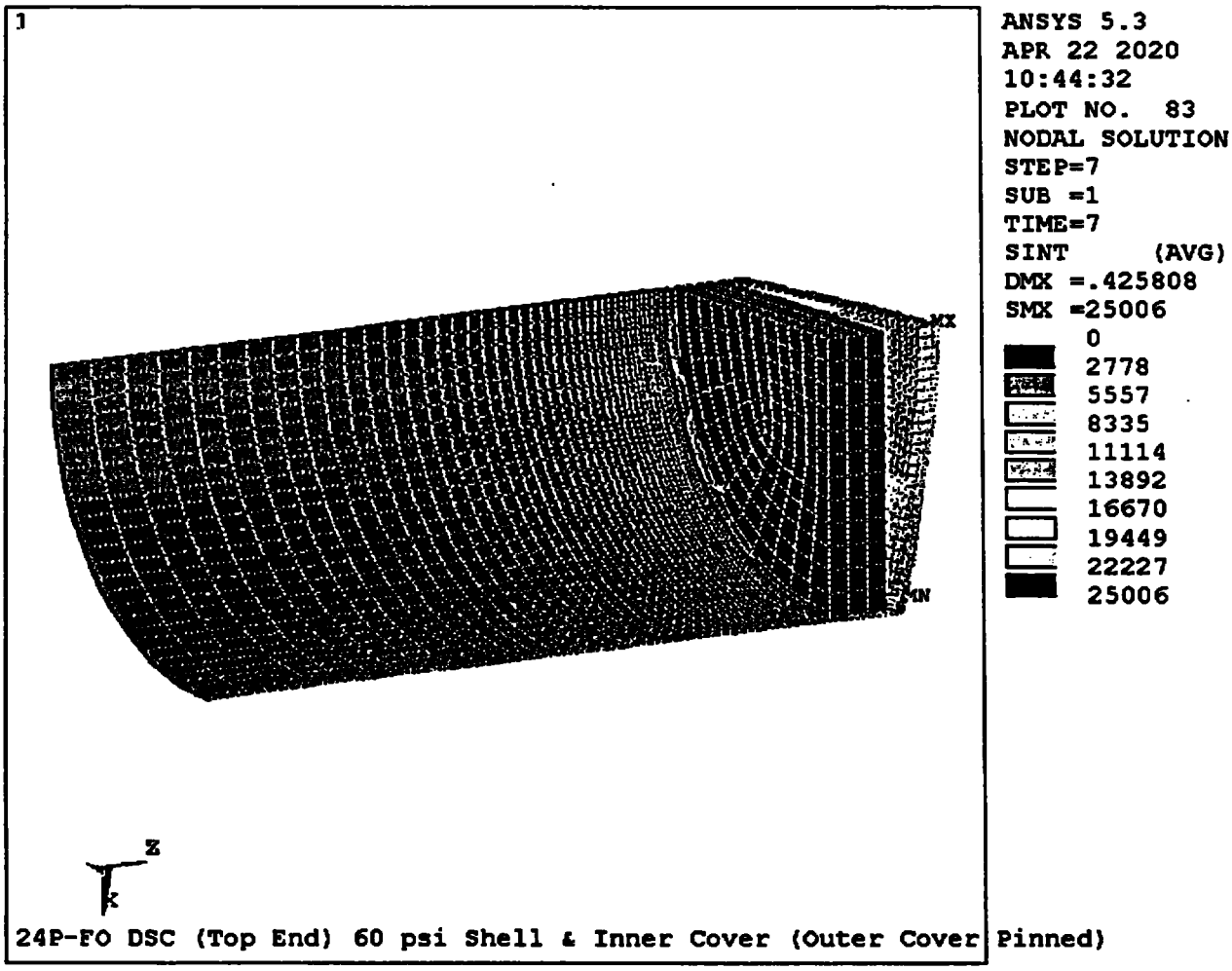

Figure B1-10

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

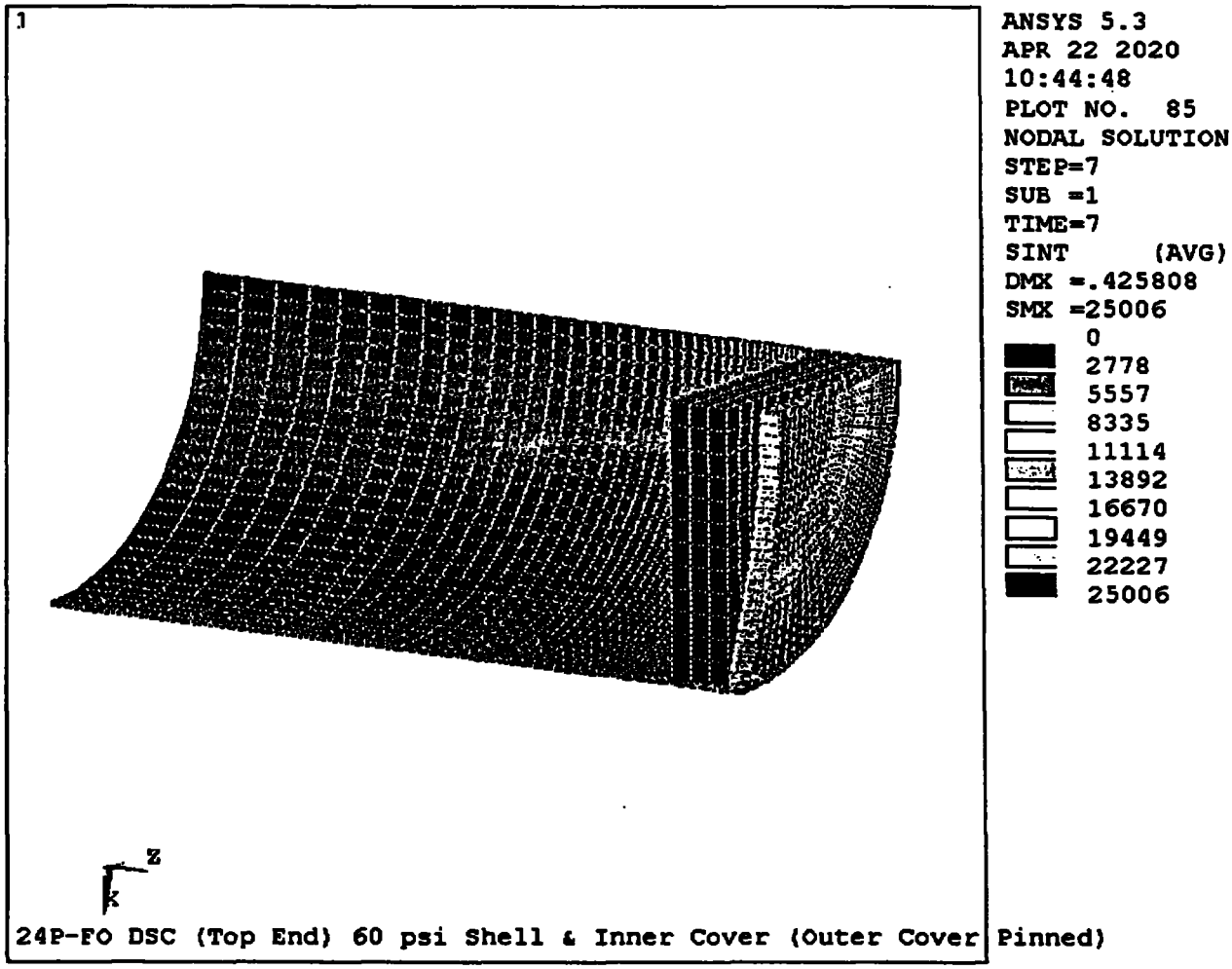

Figure B1-11

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

Appendix B2

ANSYS Stress Intensity Contour Plots for Run PT24PFL

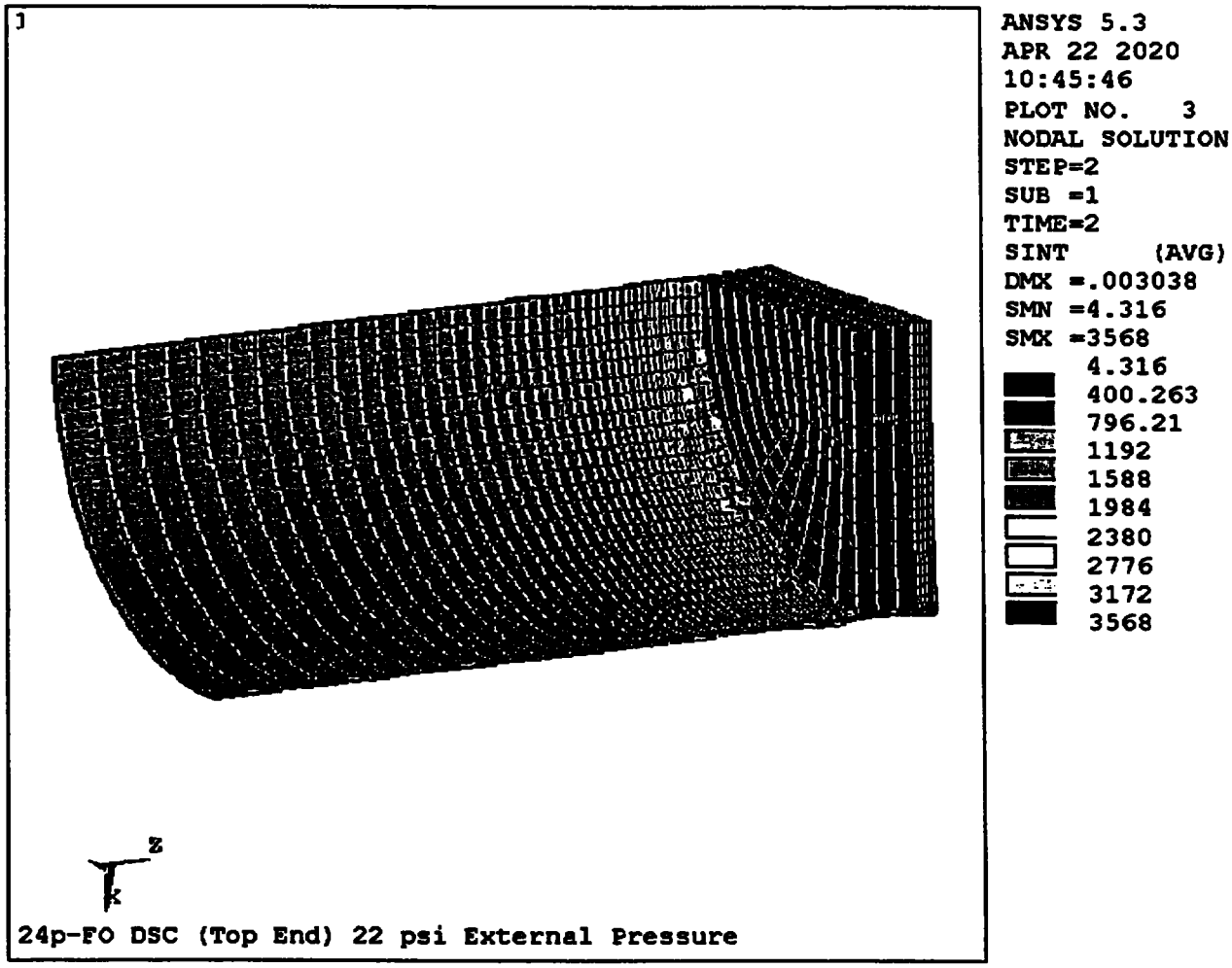

Figure B2-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

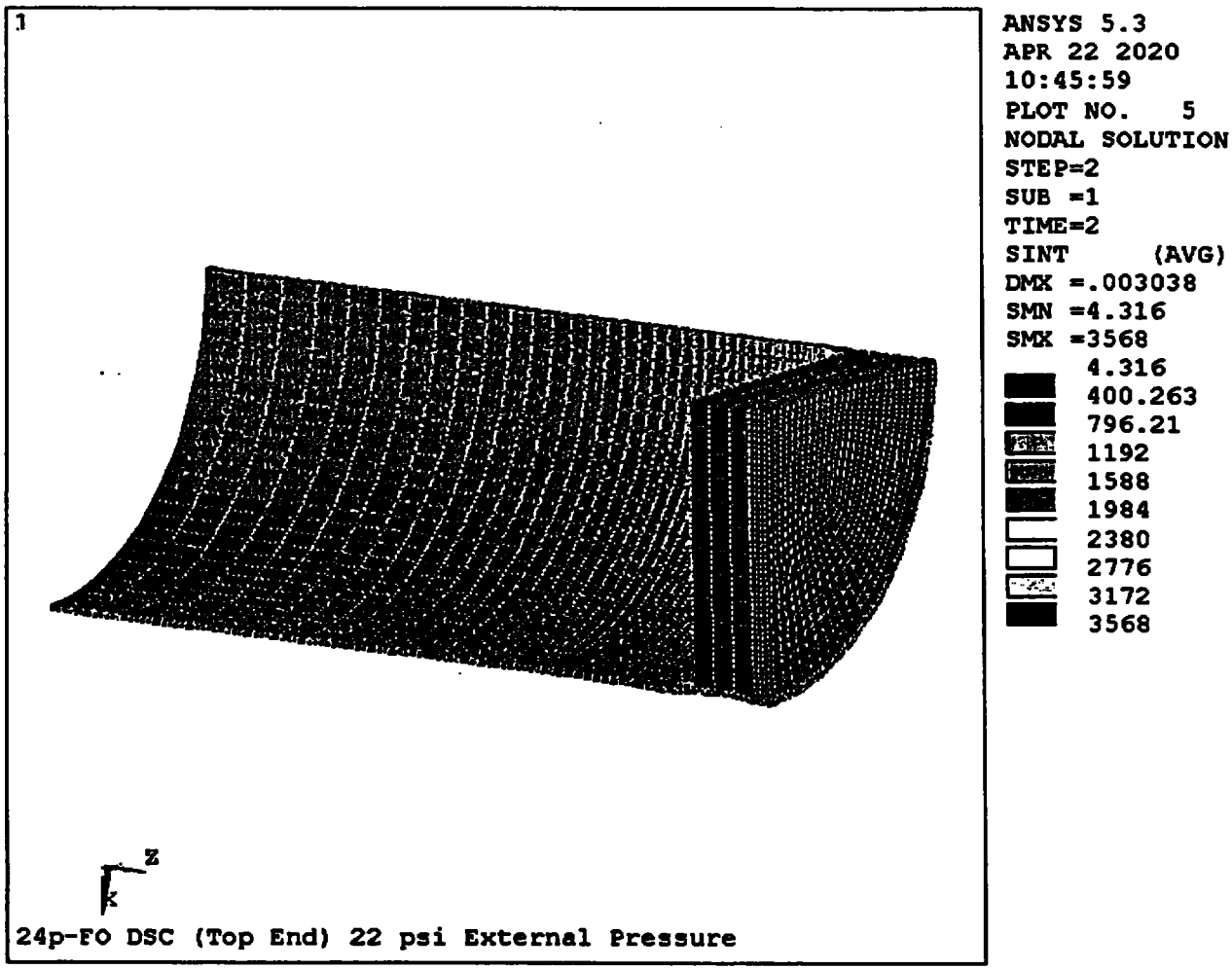

Figure B2-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

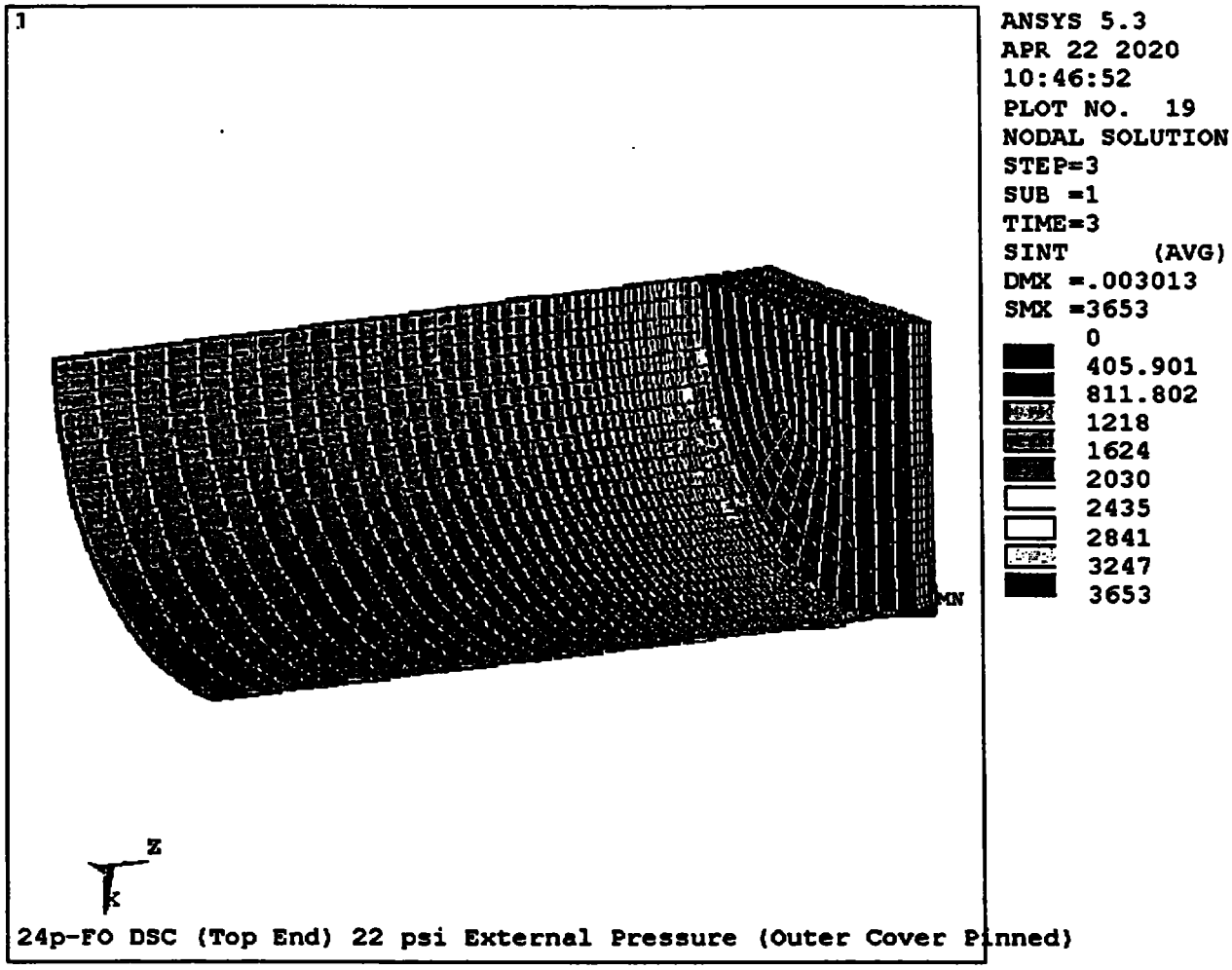

Figure B2-3

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

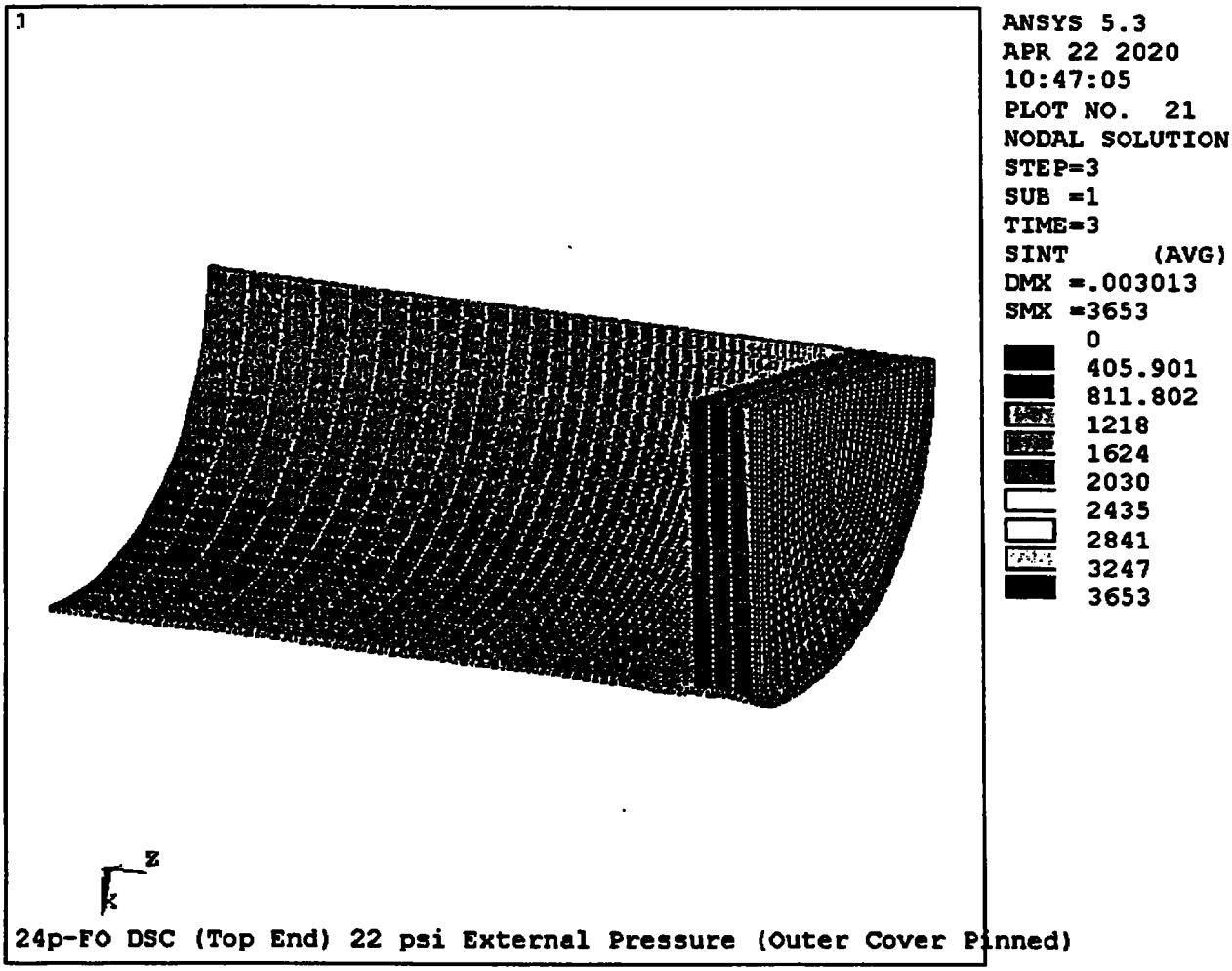

Figure B2-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

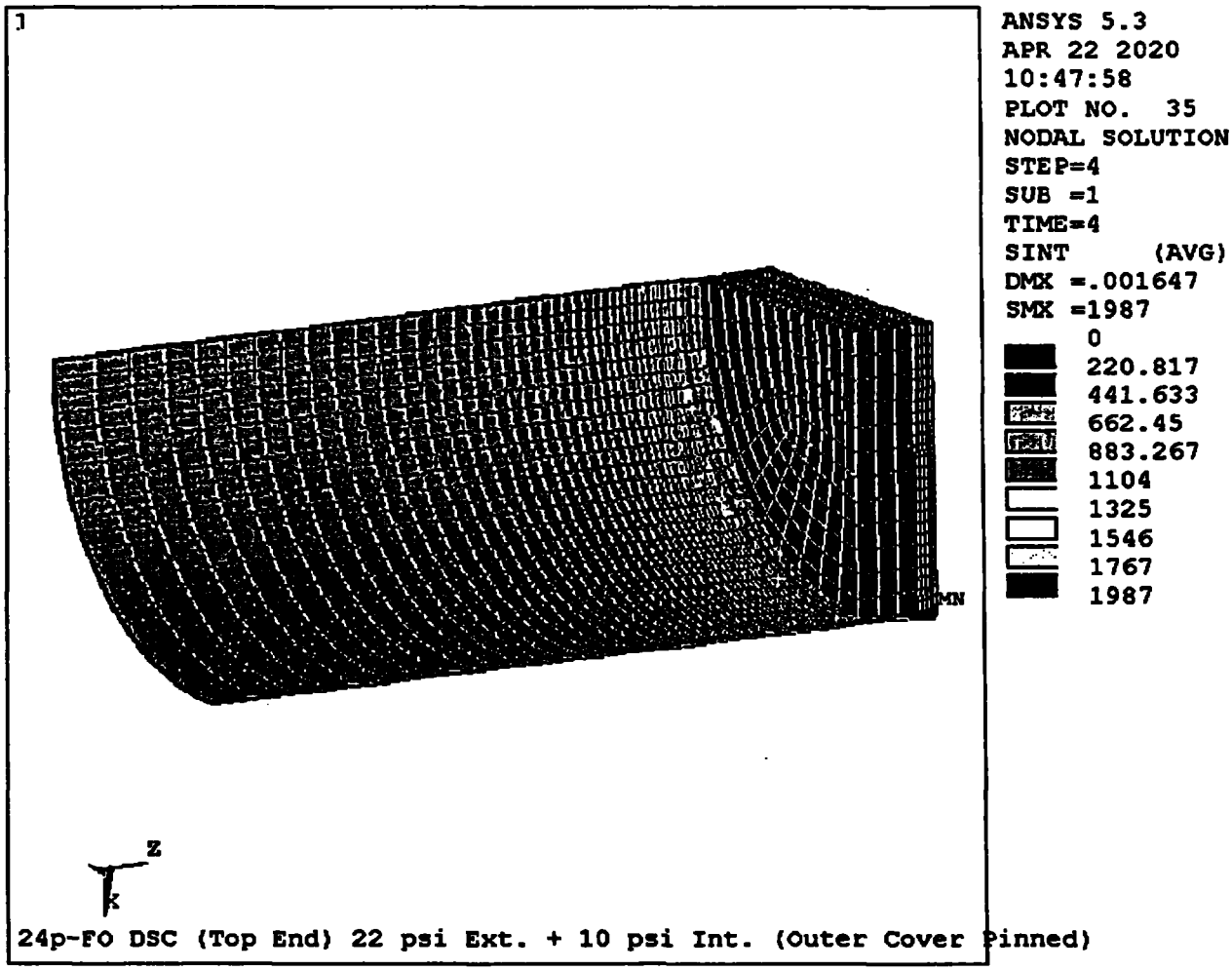

Figure B2-5

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

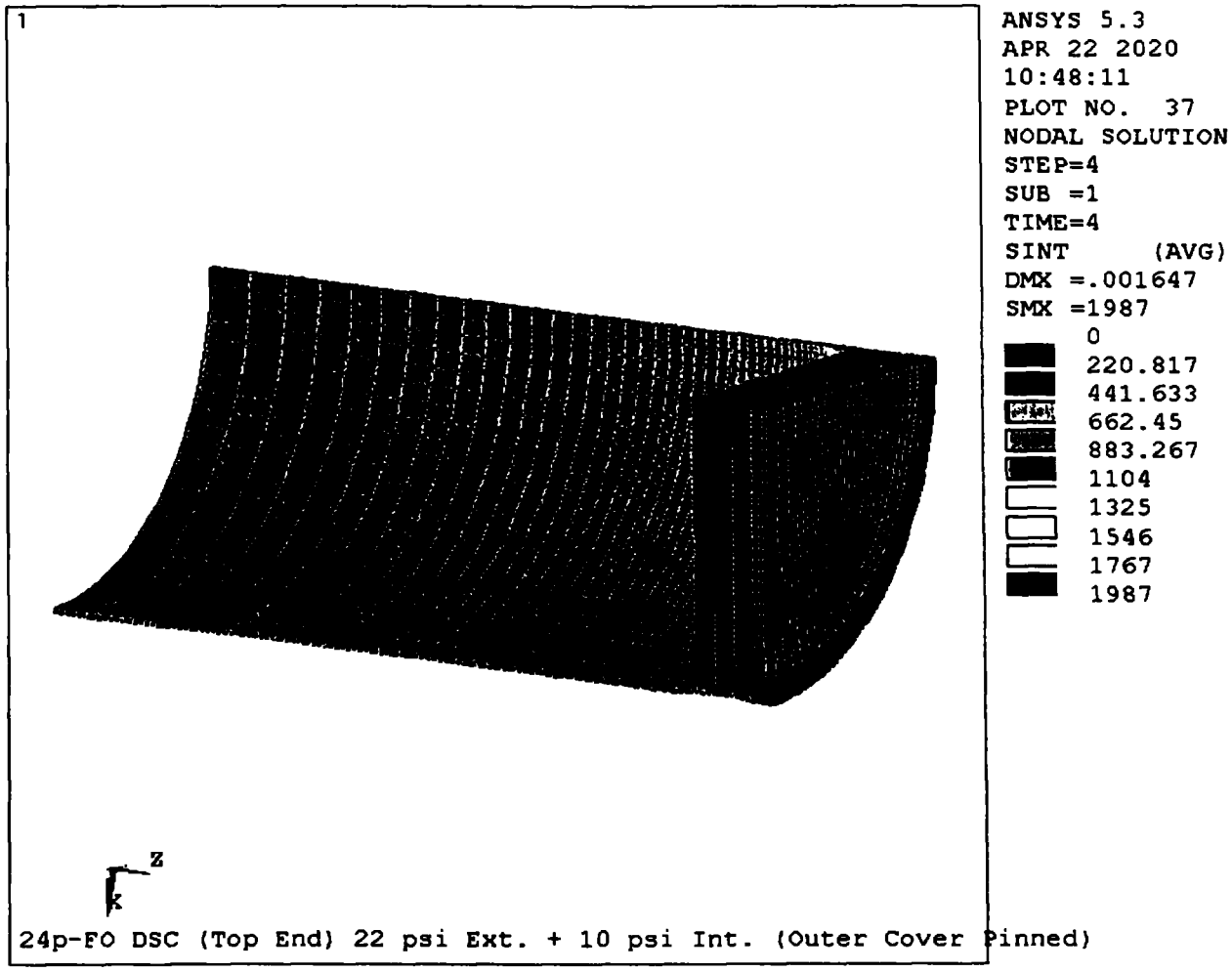

Figure B2-6

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

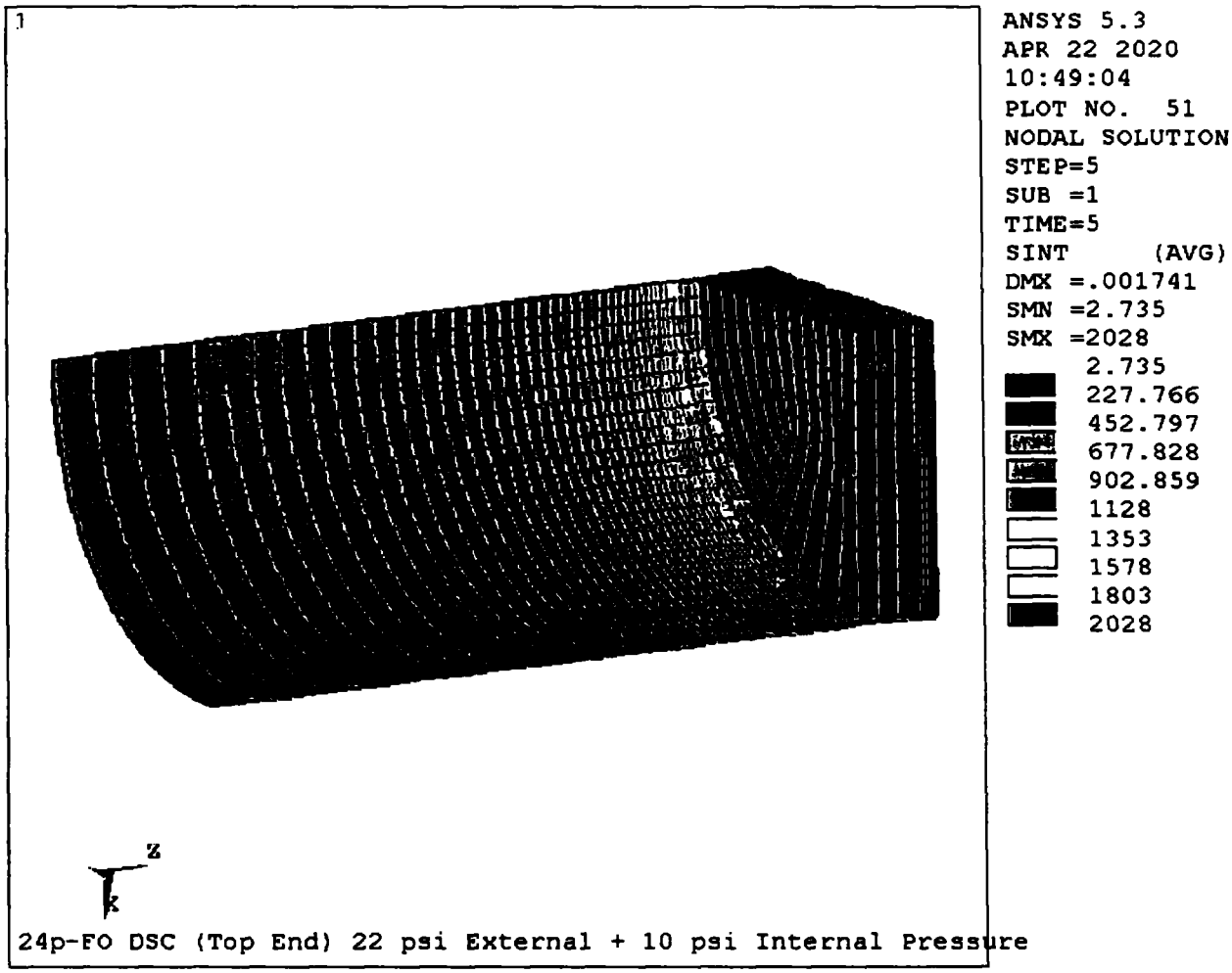

Figure B2-7

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

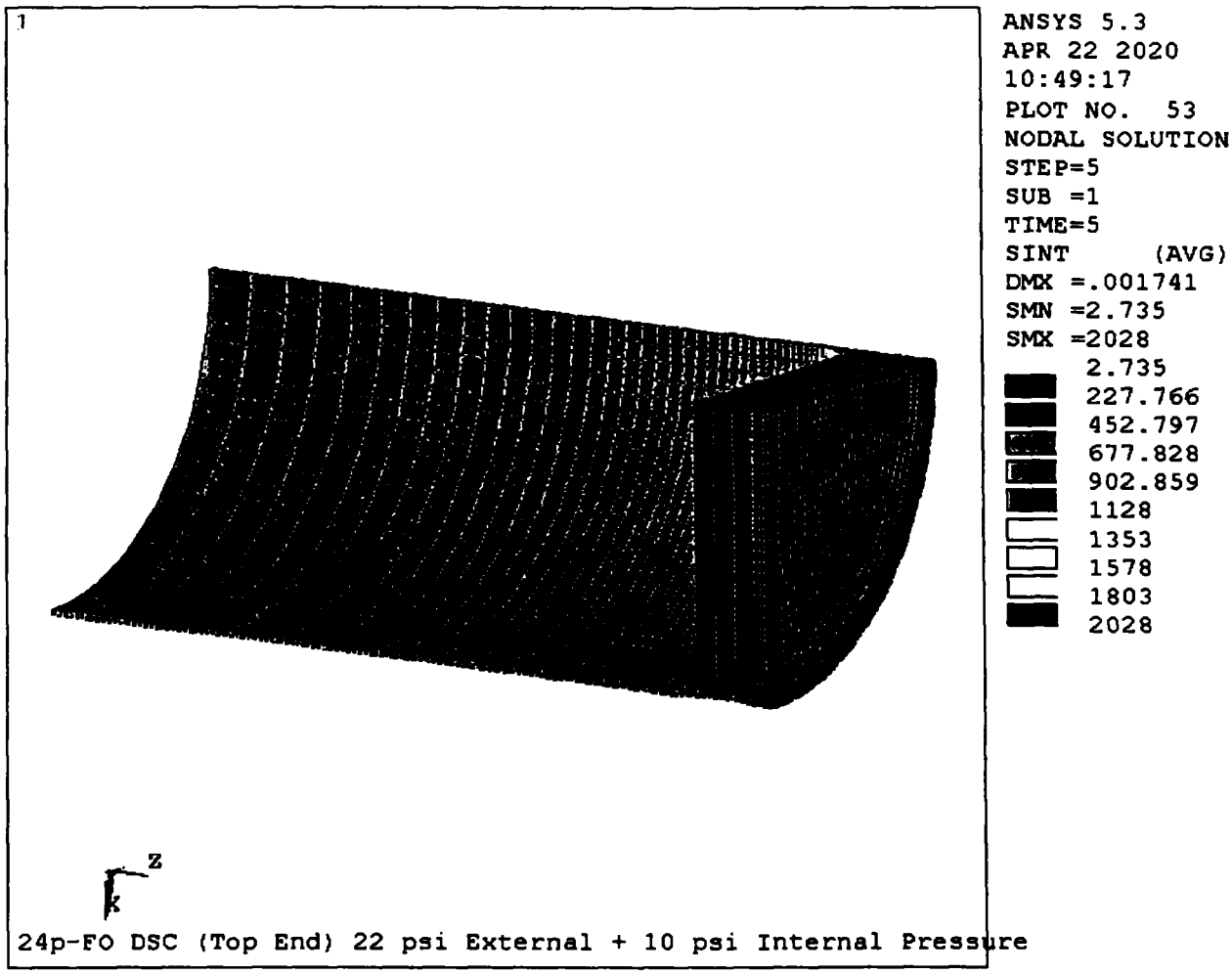

Figure B2-8

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

Appendix B3

ANSYS Stress Intensity Contour Plots for Run PT24PED

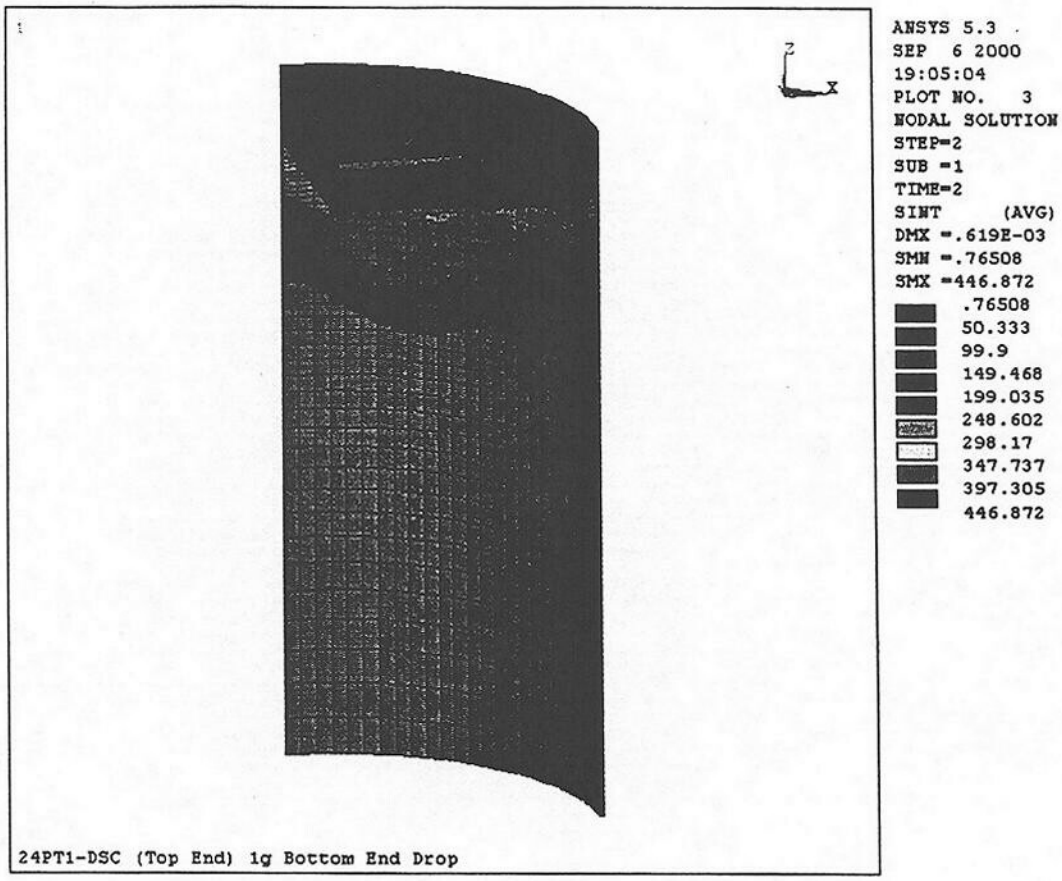

Figure B3-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

C01

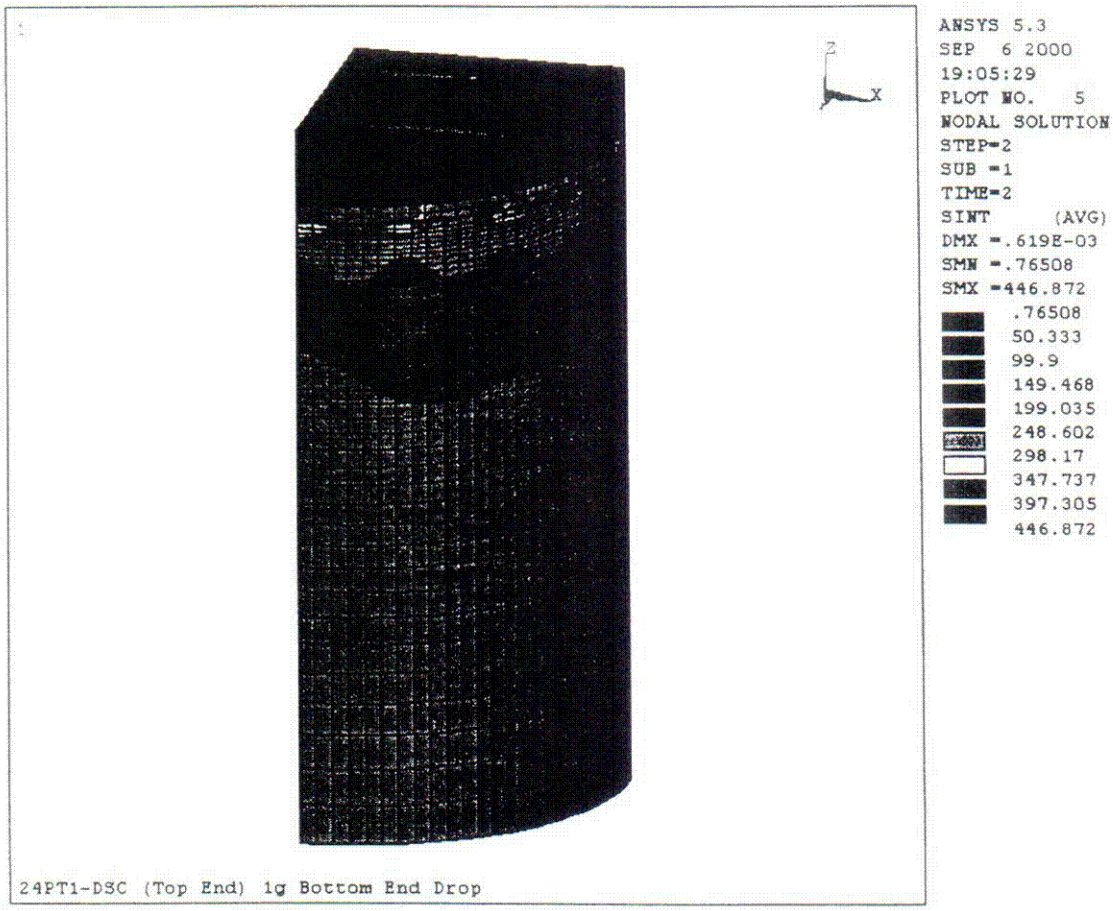

Figure B3-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

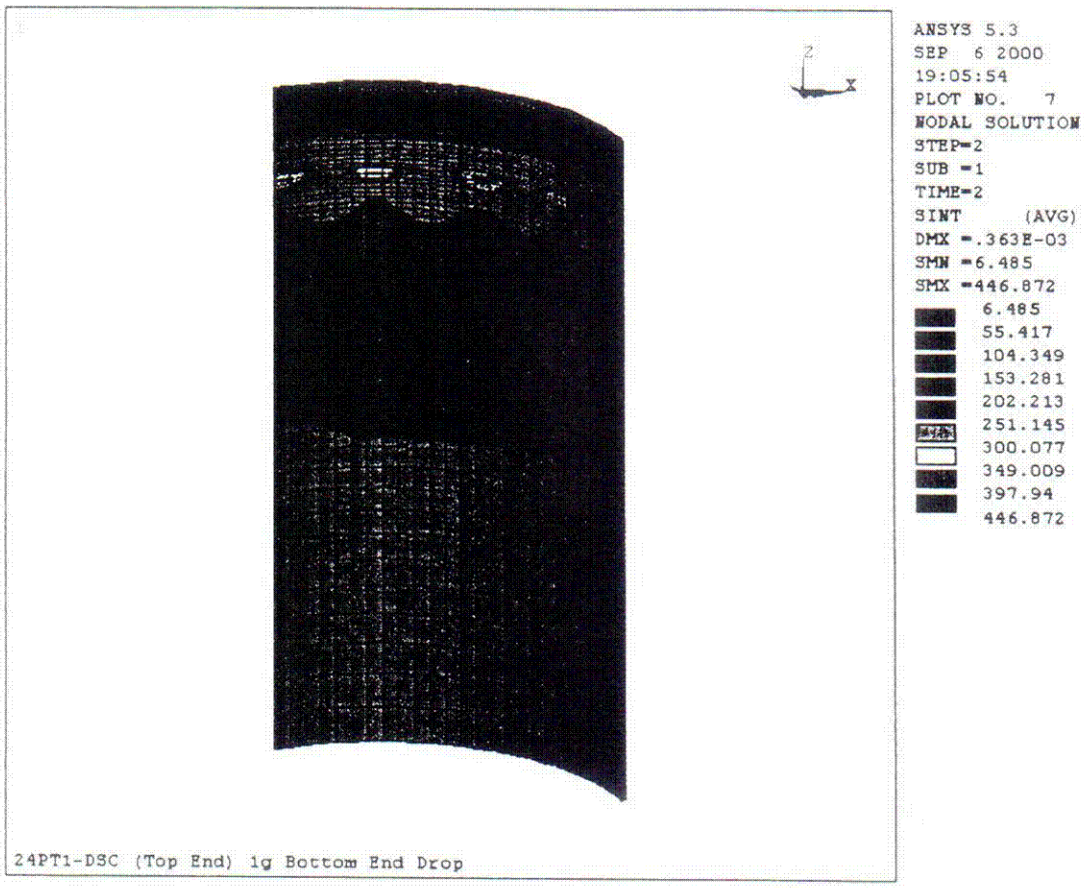

Figure B3-3

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

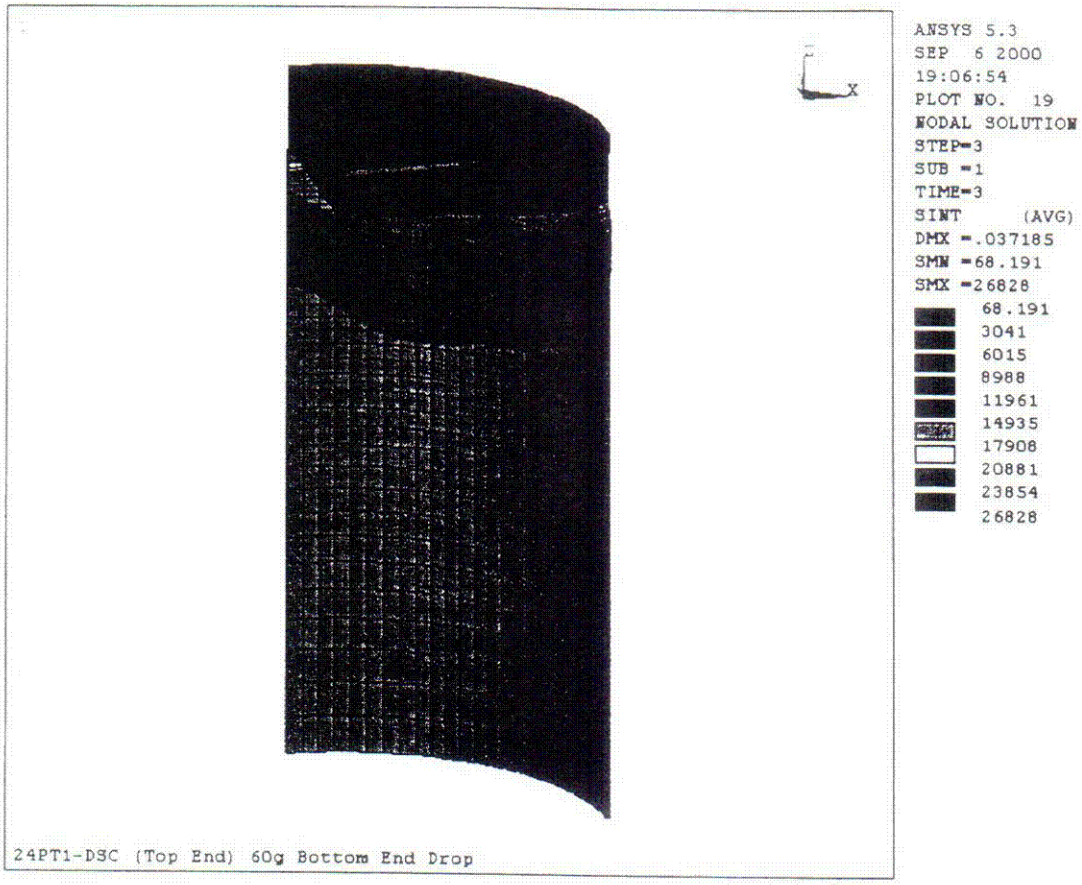

Figure B3-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

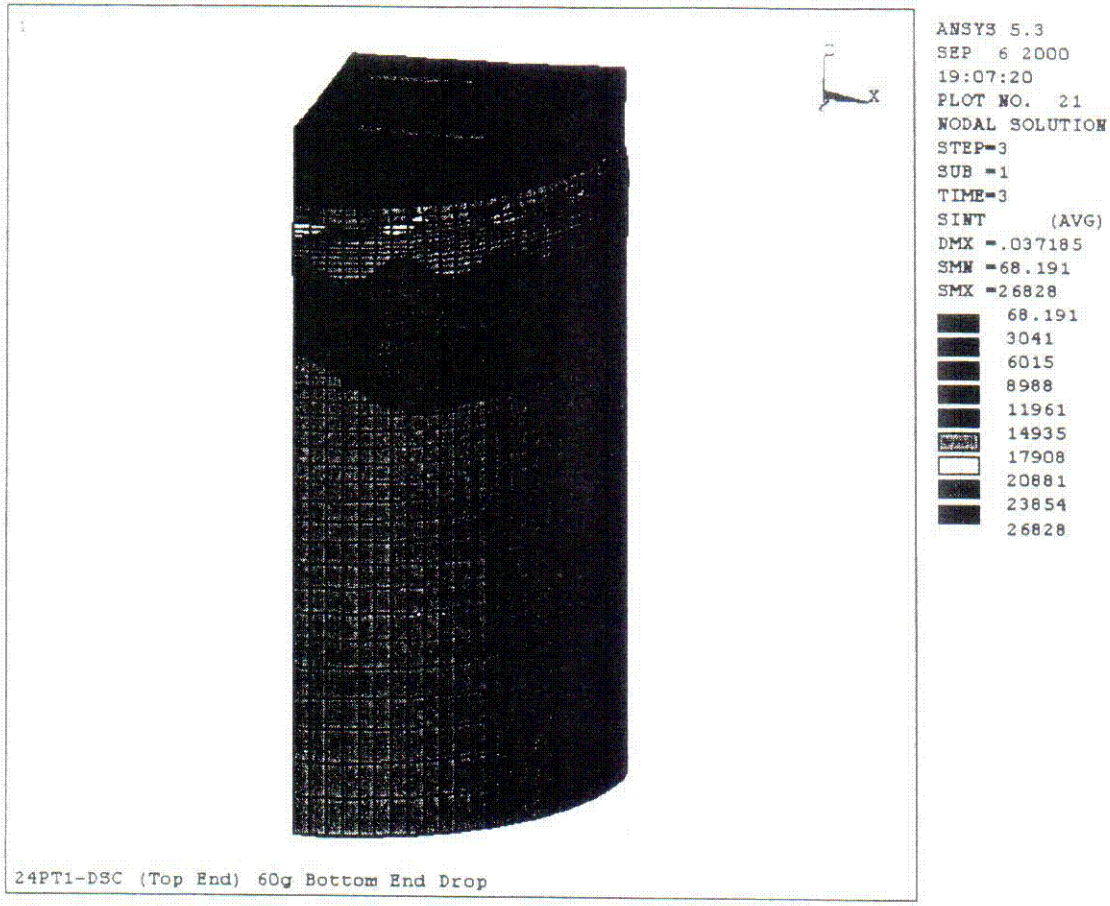

Figure B3-5

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

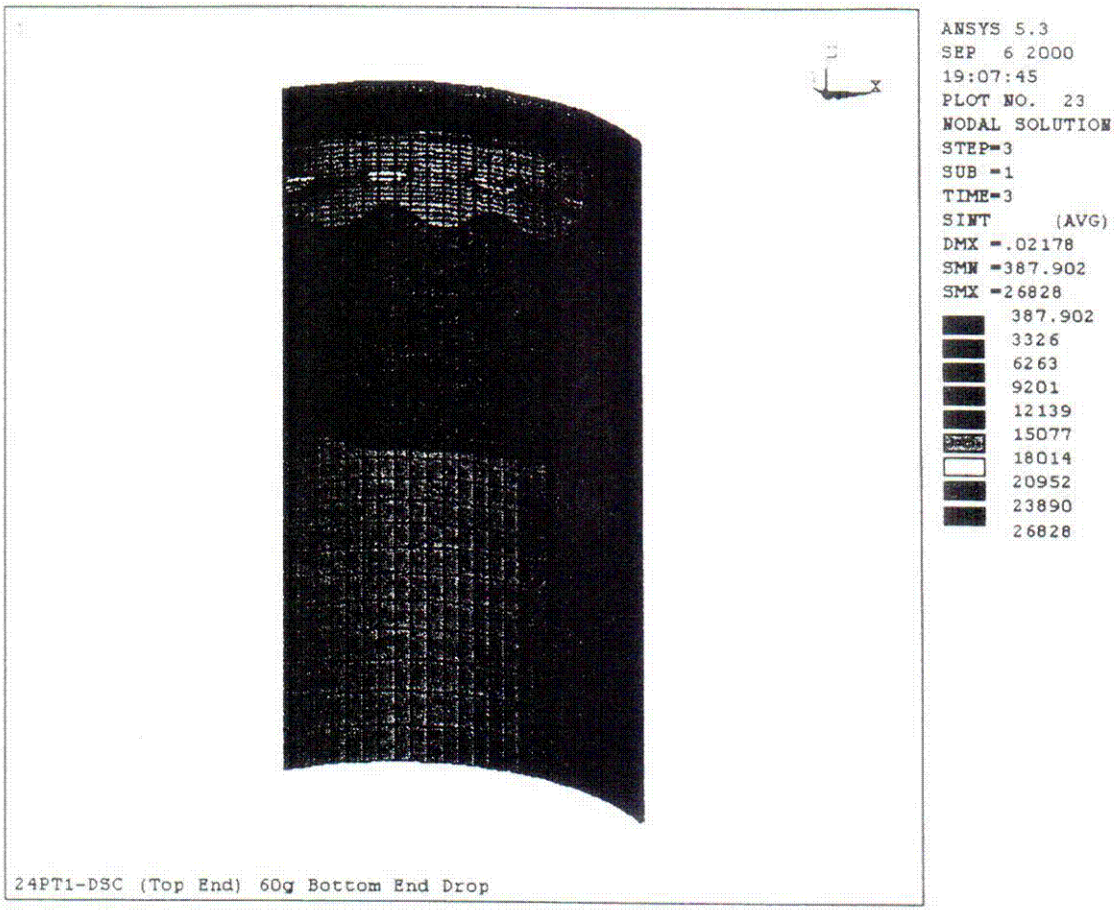

Figure B3-6

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

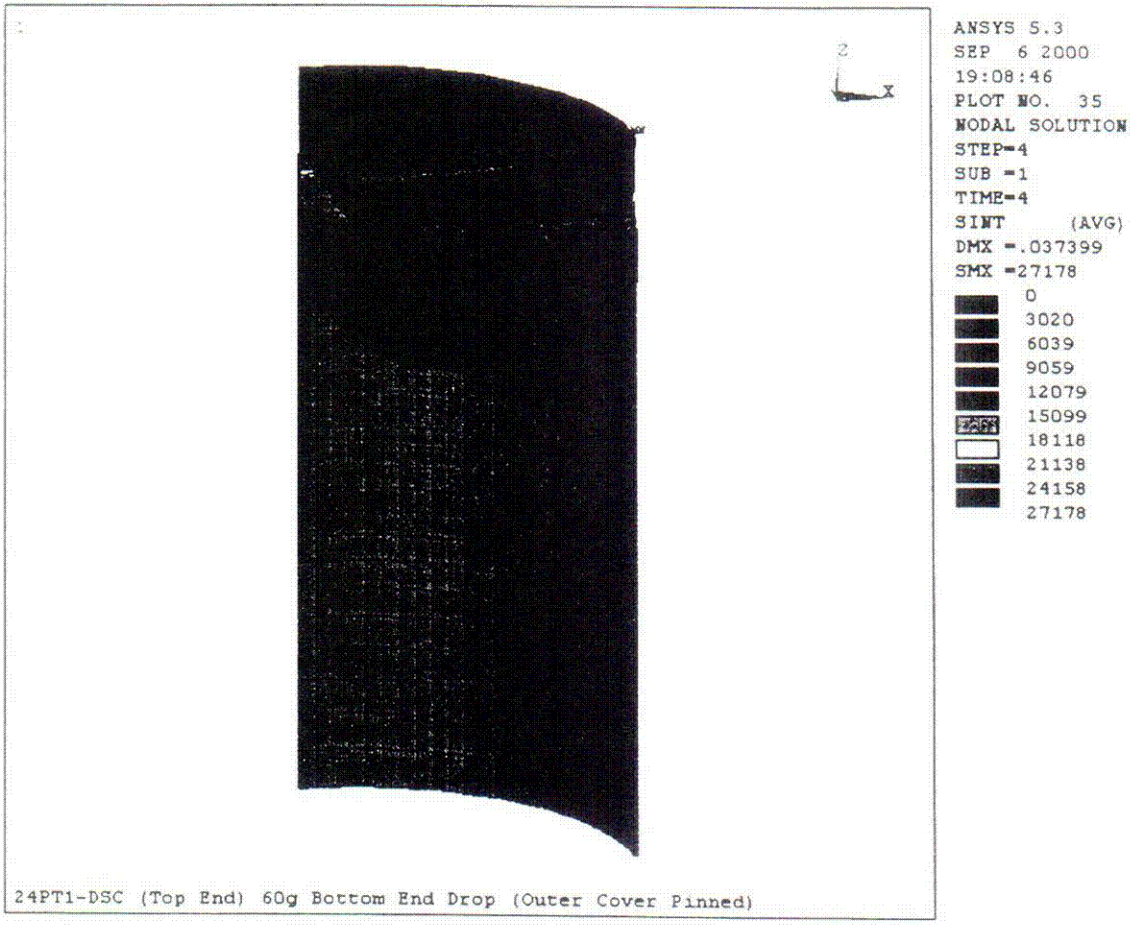

Figure B3-7

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

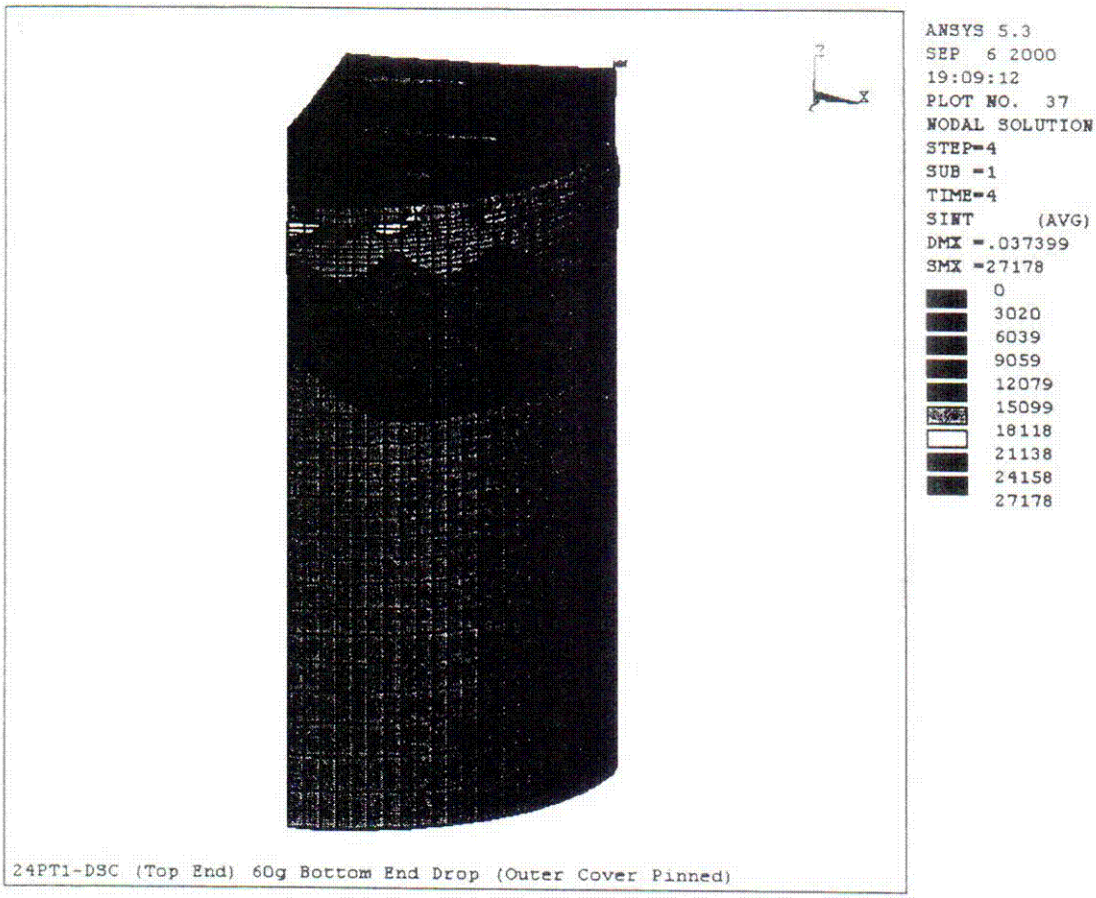

Figure B3-8

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

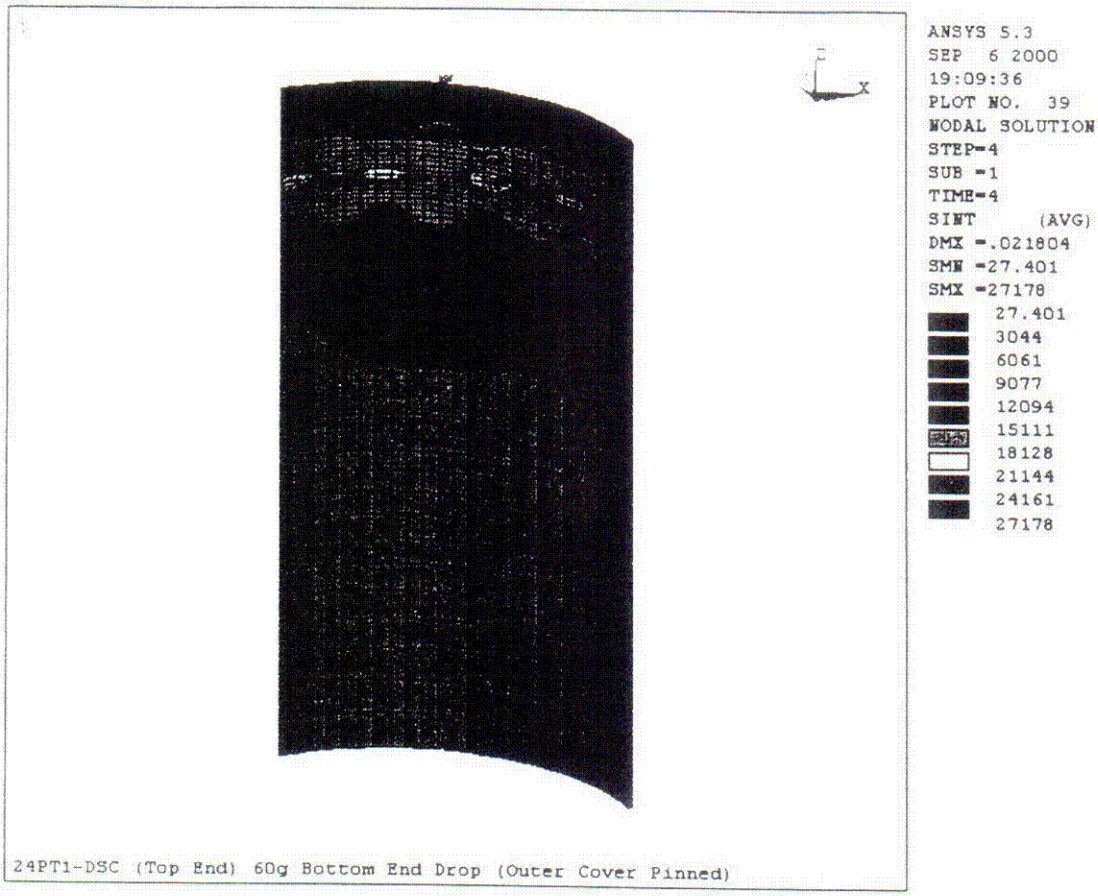

Figure B3-9

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

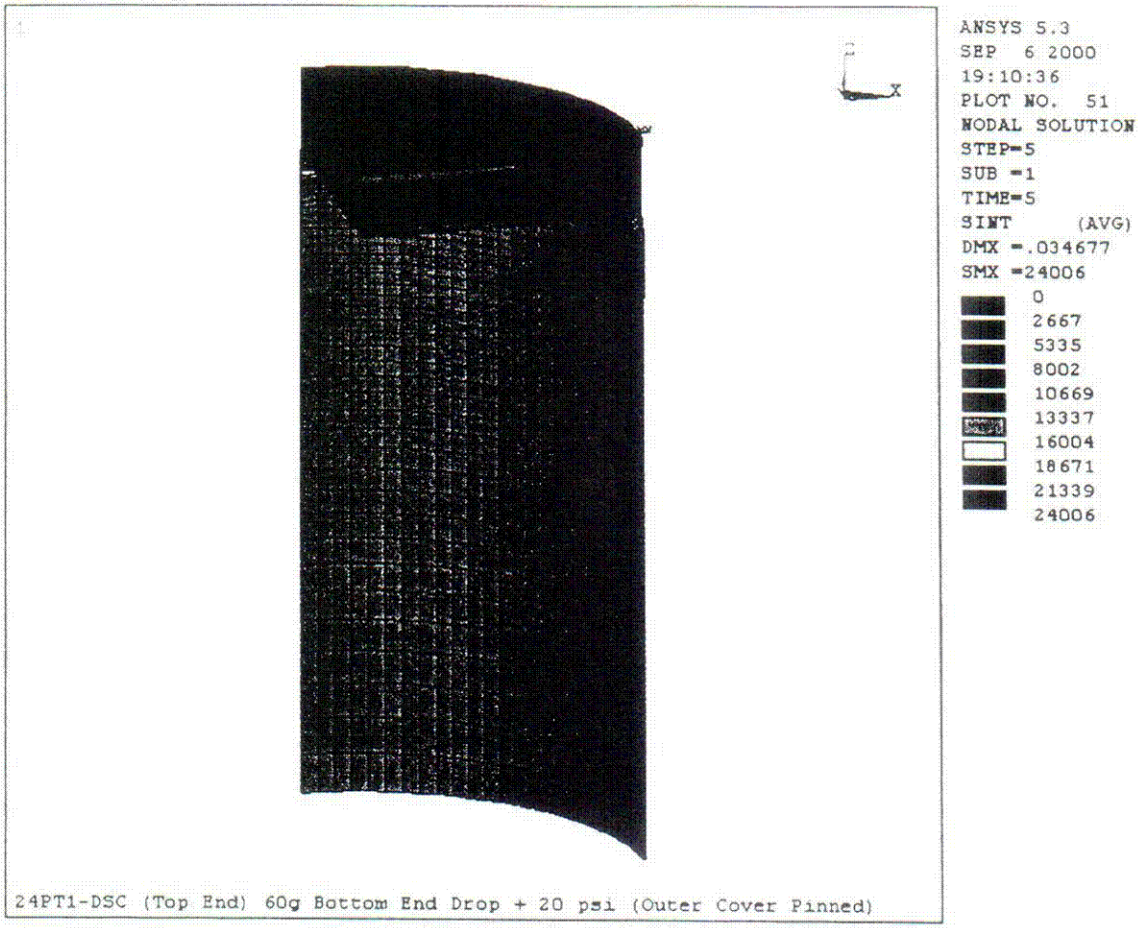

Figure B3-10

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

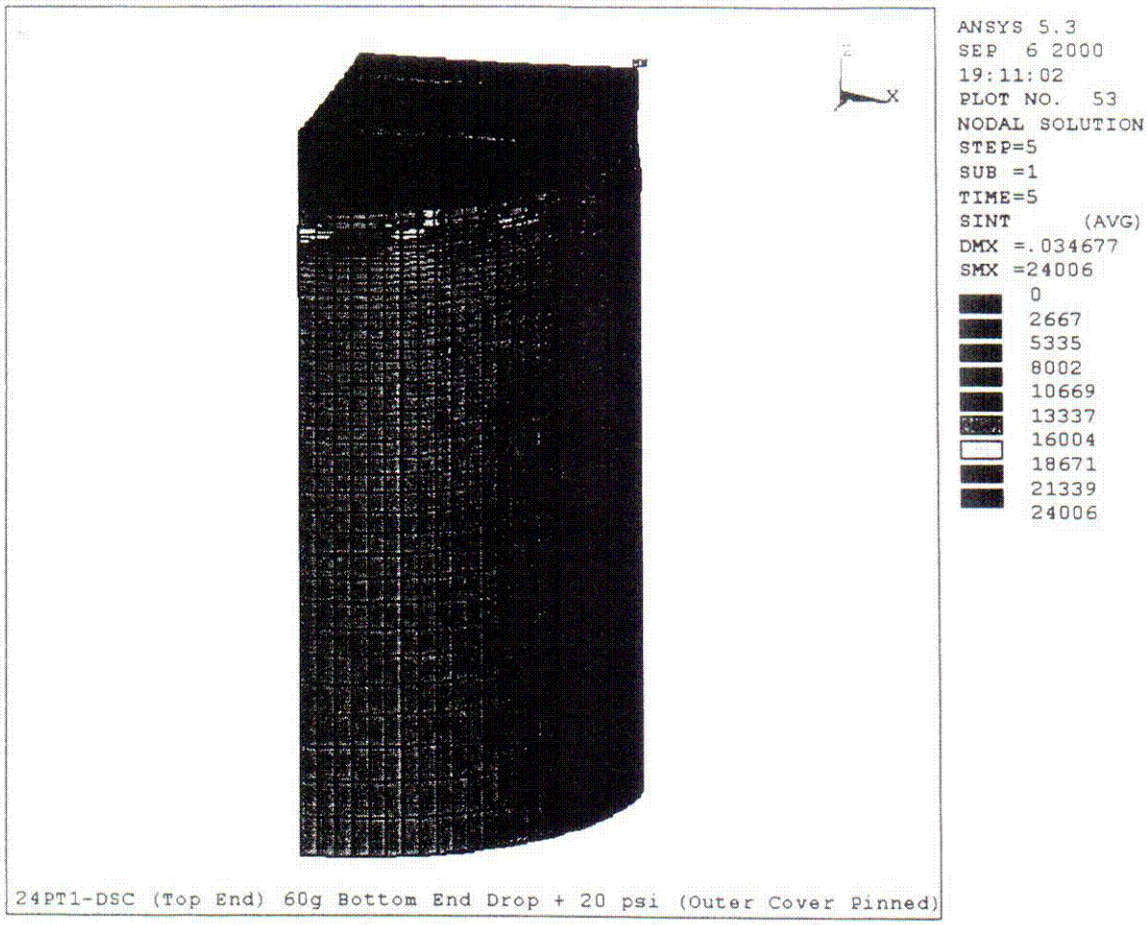

Figure B3-11

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

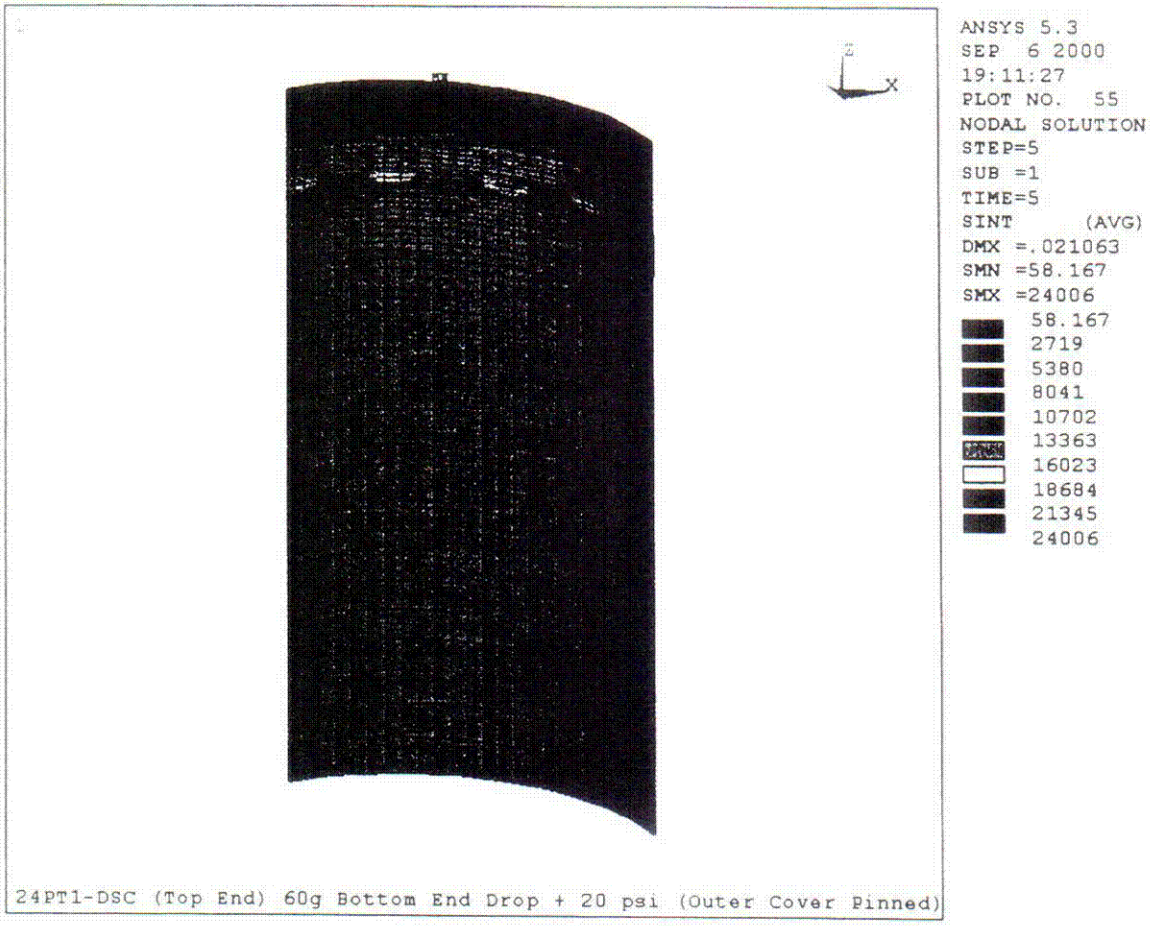

Figure B3-12

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

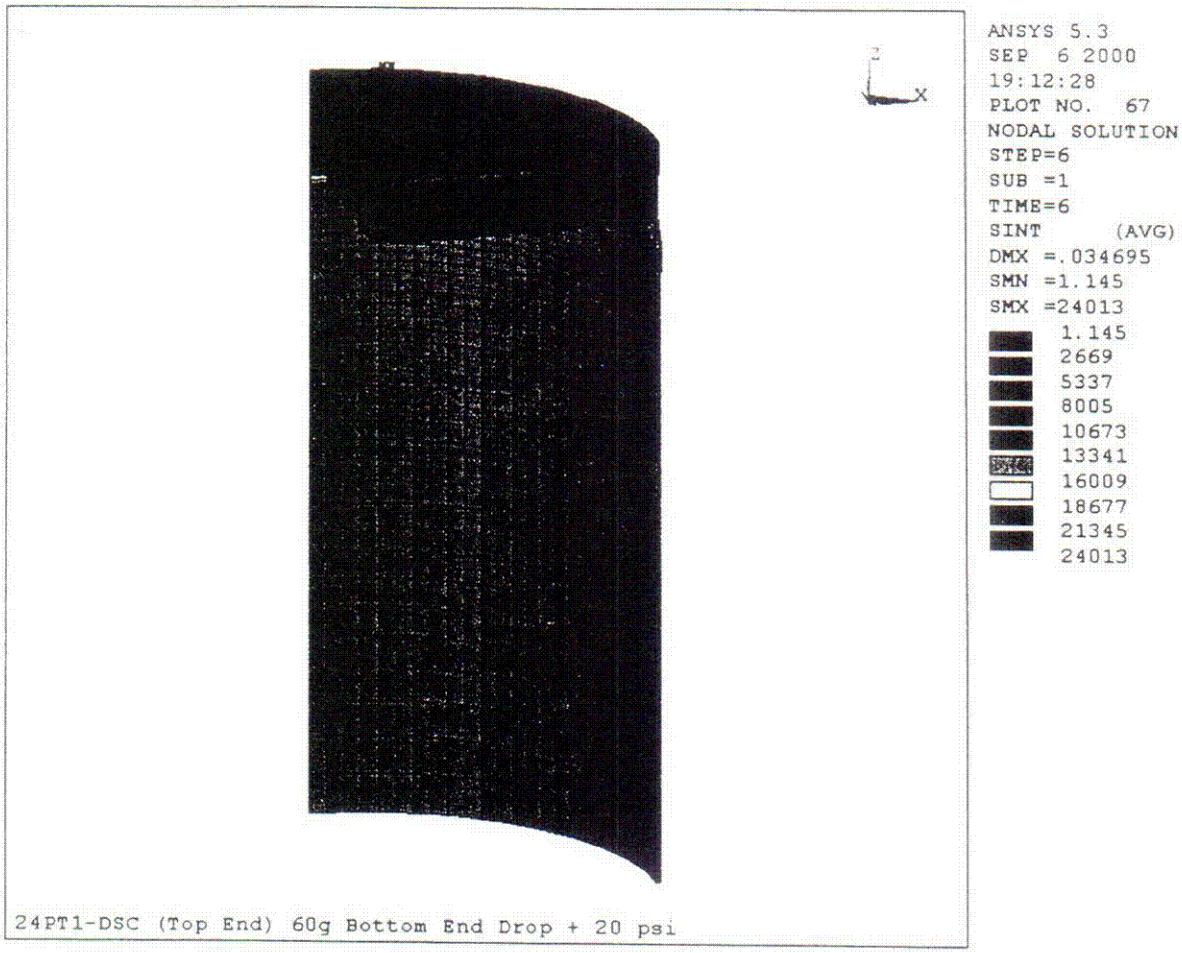

Figure B3-13

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

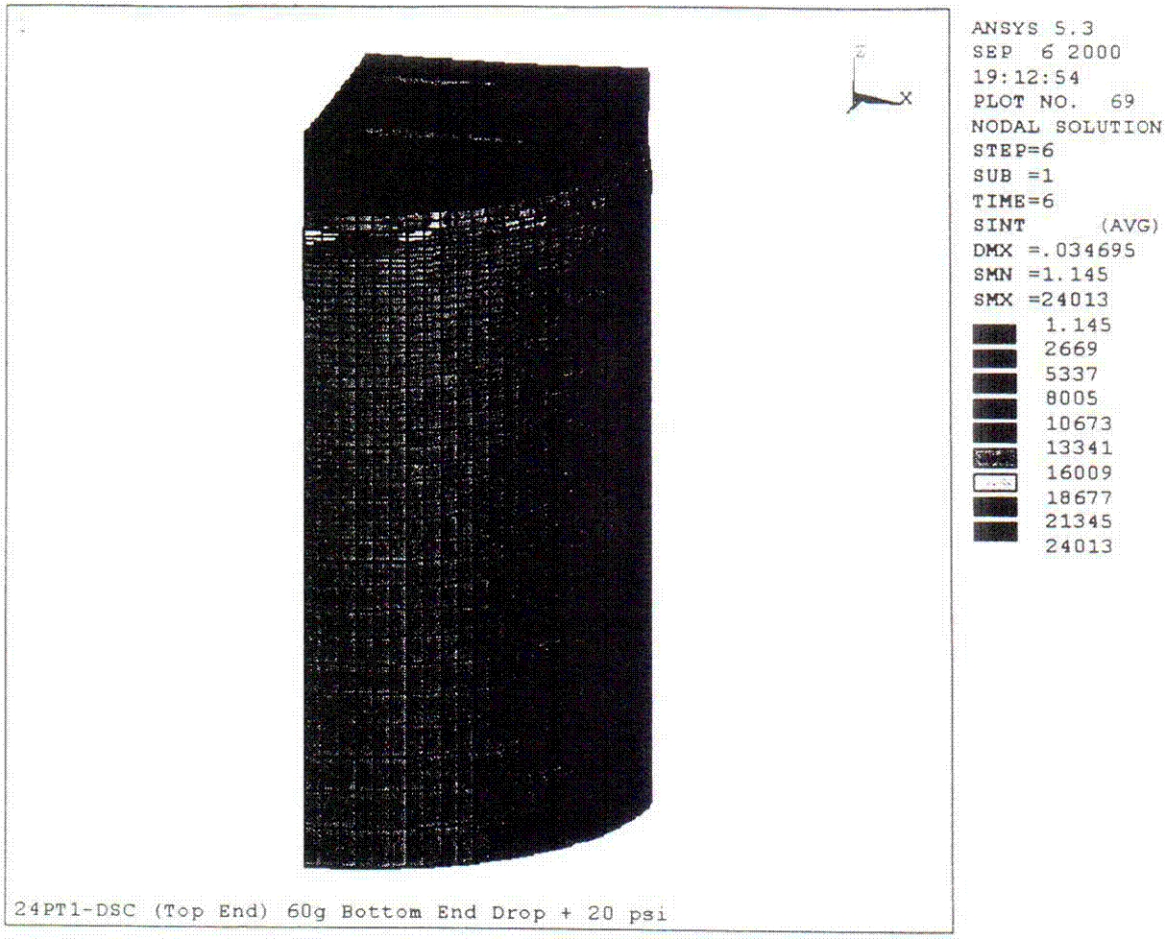

Figure B3-14

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

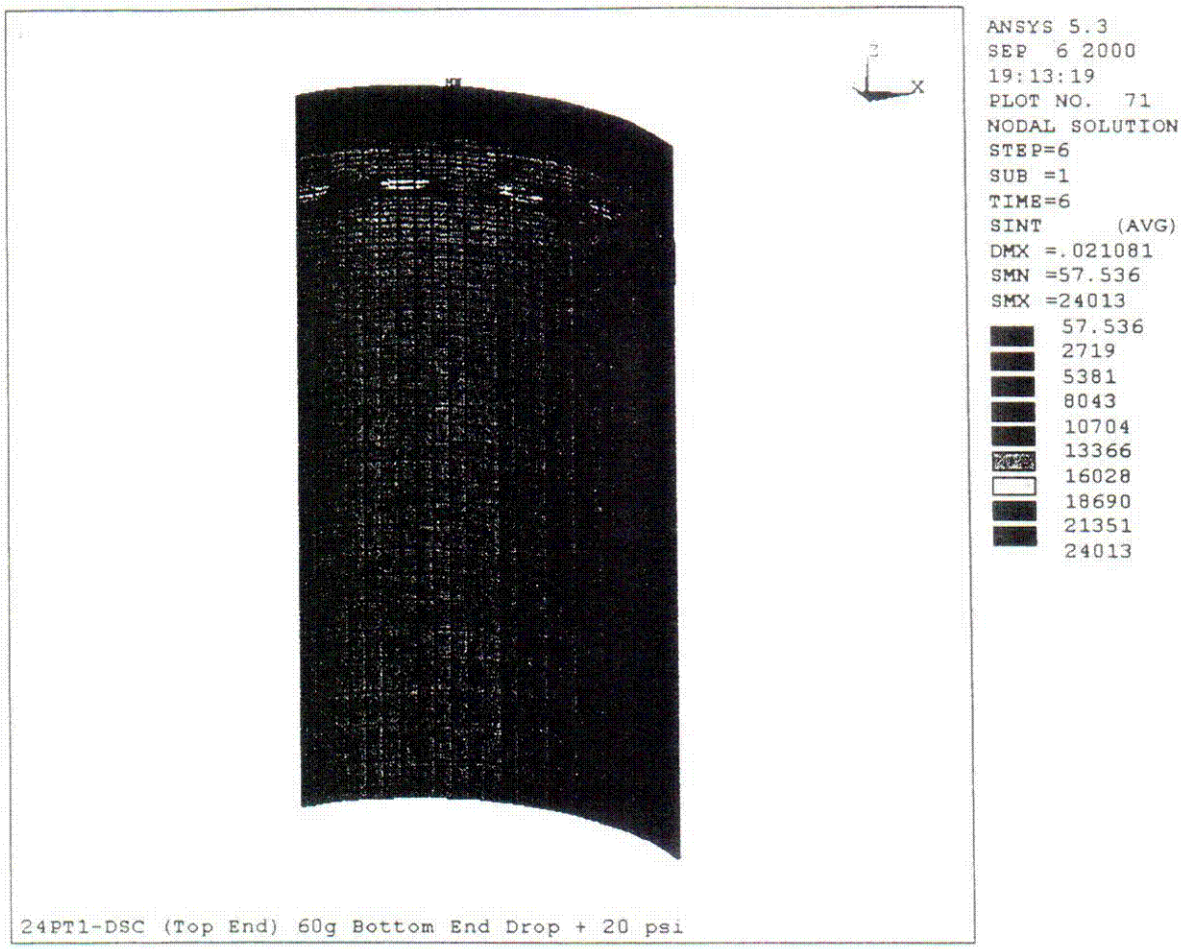

Figure B3-15

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

Appendix B4

ANSYS Stress Intensity Contour Plots for Run PT24P1G

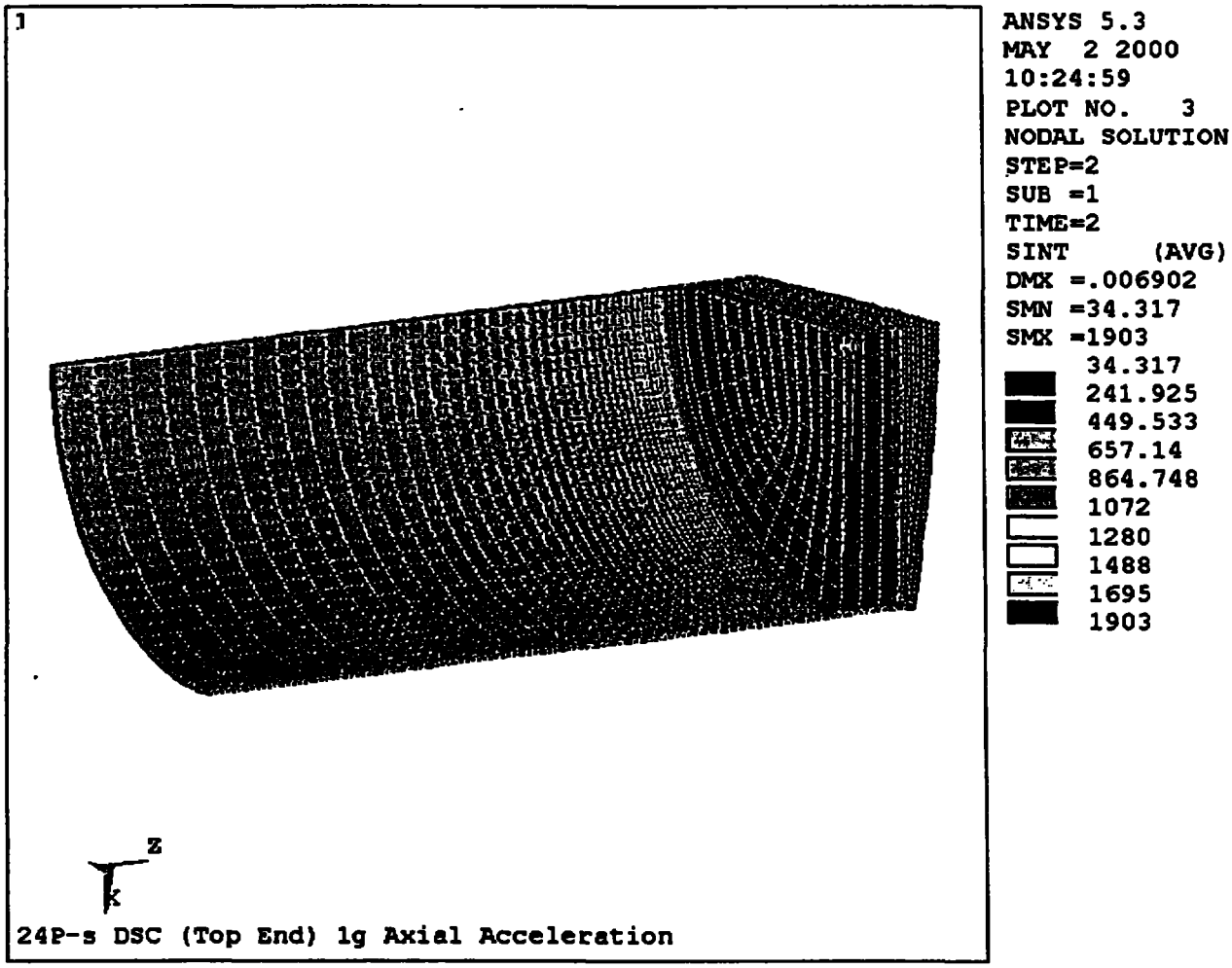

Figure B4-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

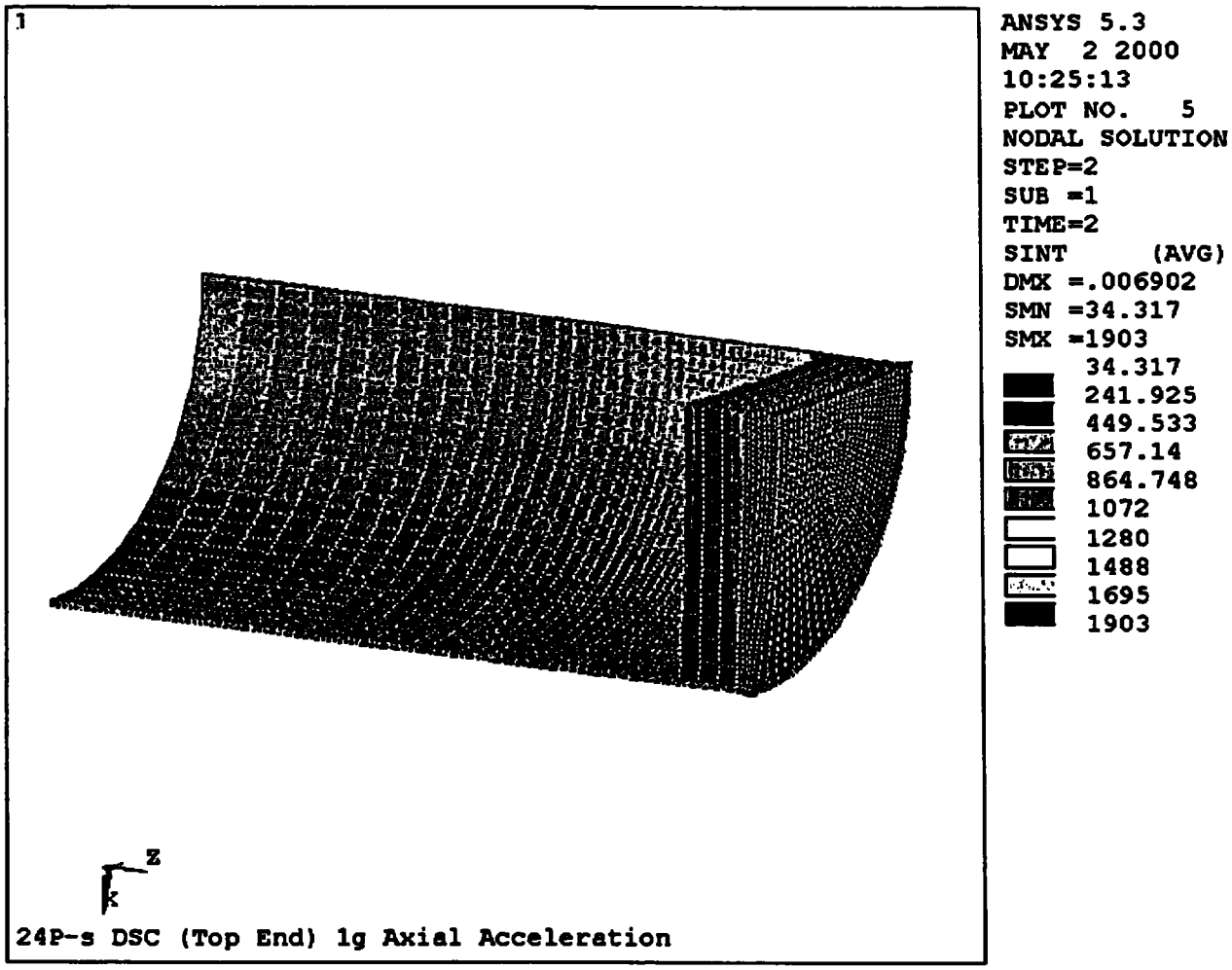

Figure B4-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

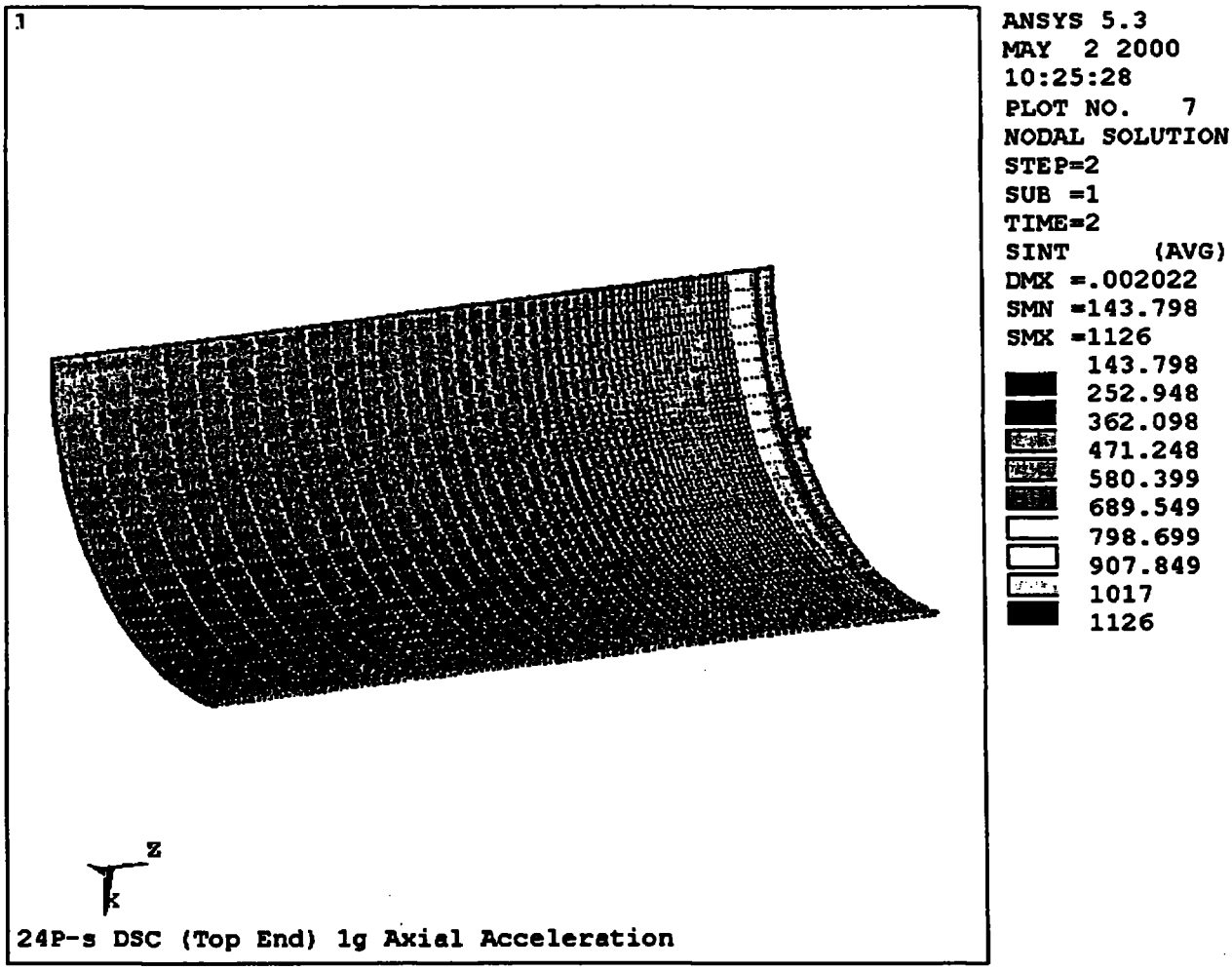

Figure B4-3

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

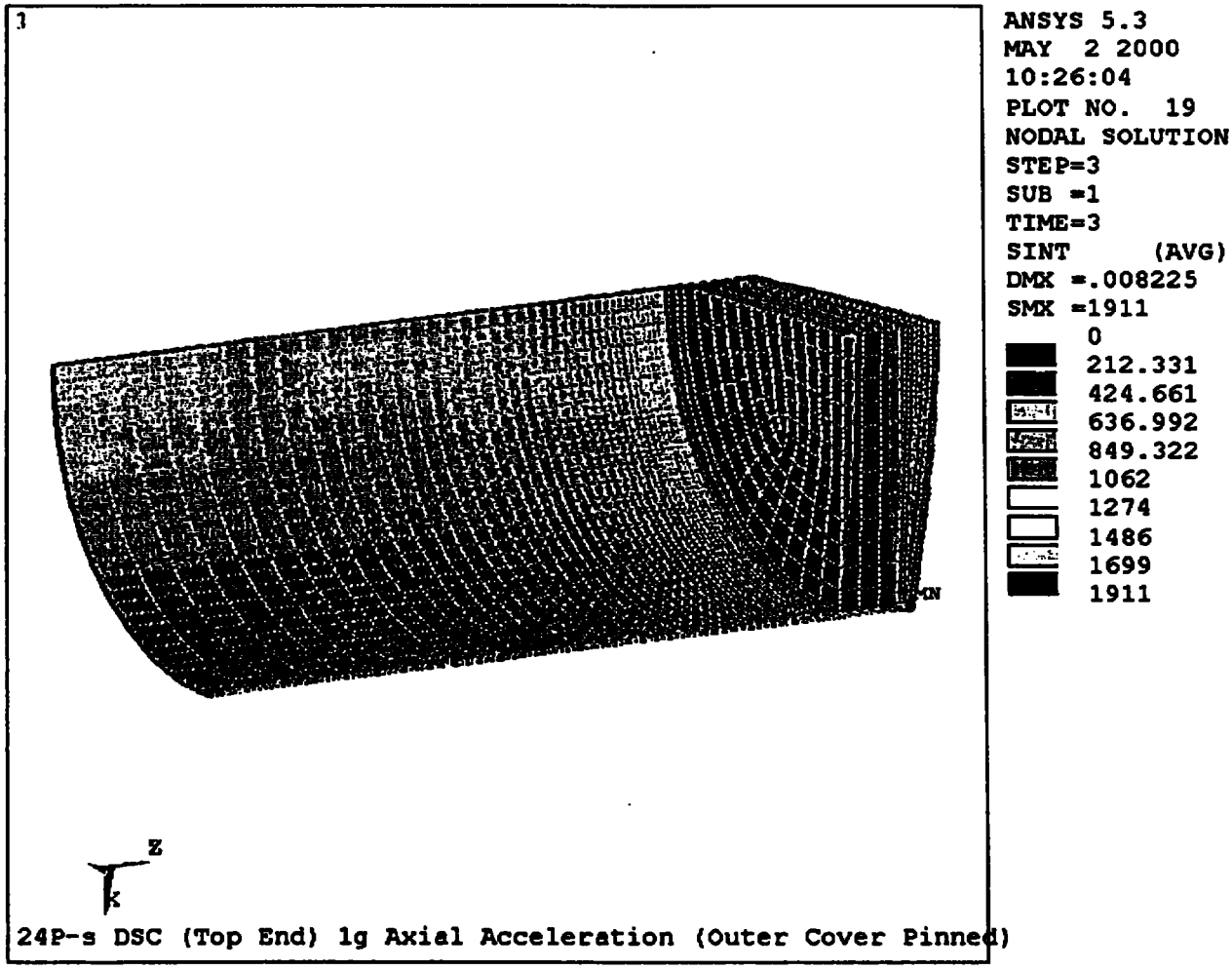

Figure B4-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

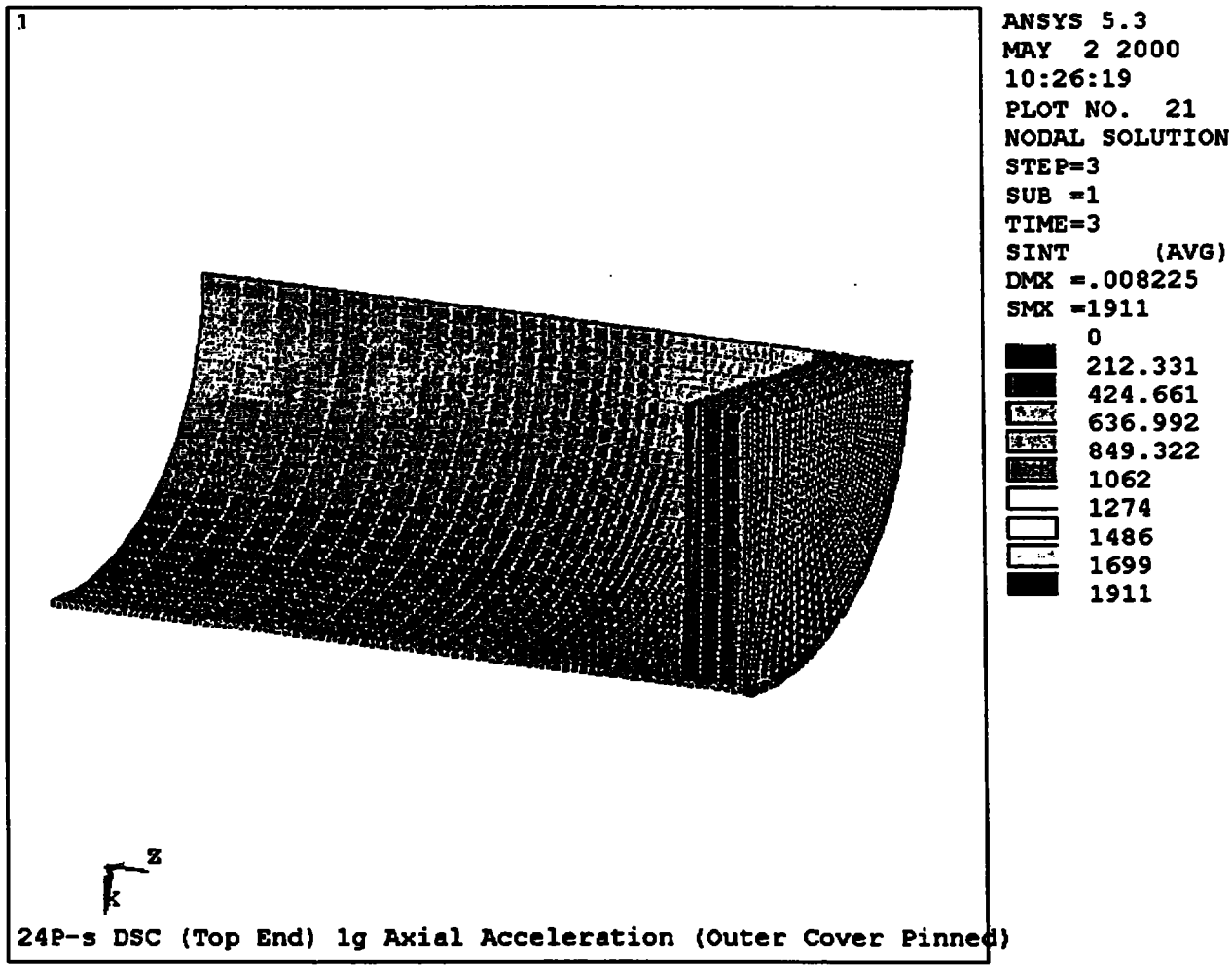

Figure B4-5

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

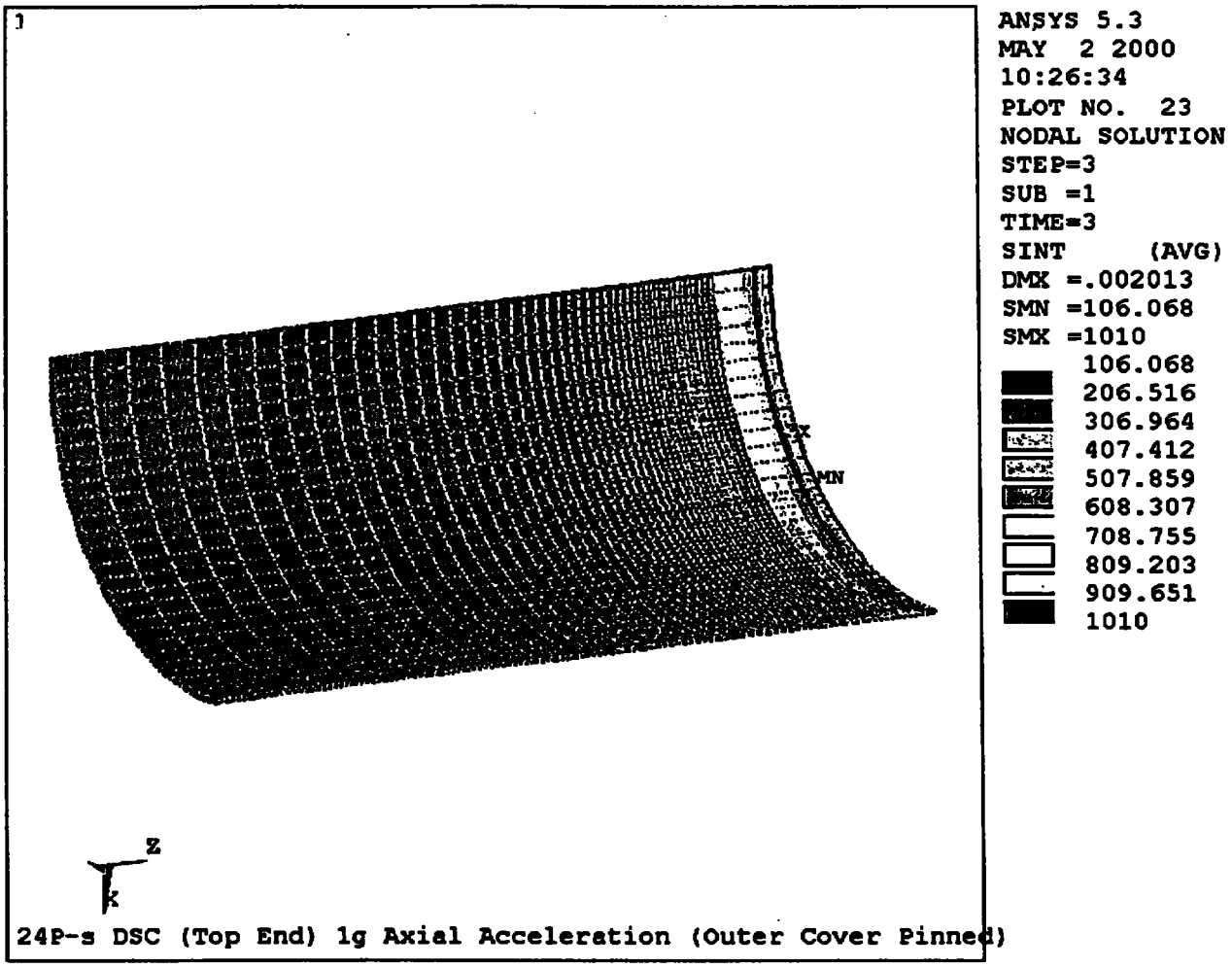

Figure B4-6

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

Appendix B5

ANSYS Stress Intensity Contour Plots for Run PT24PDW

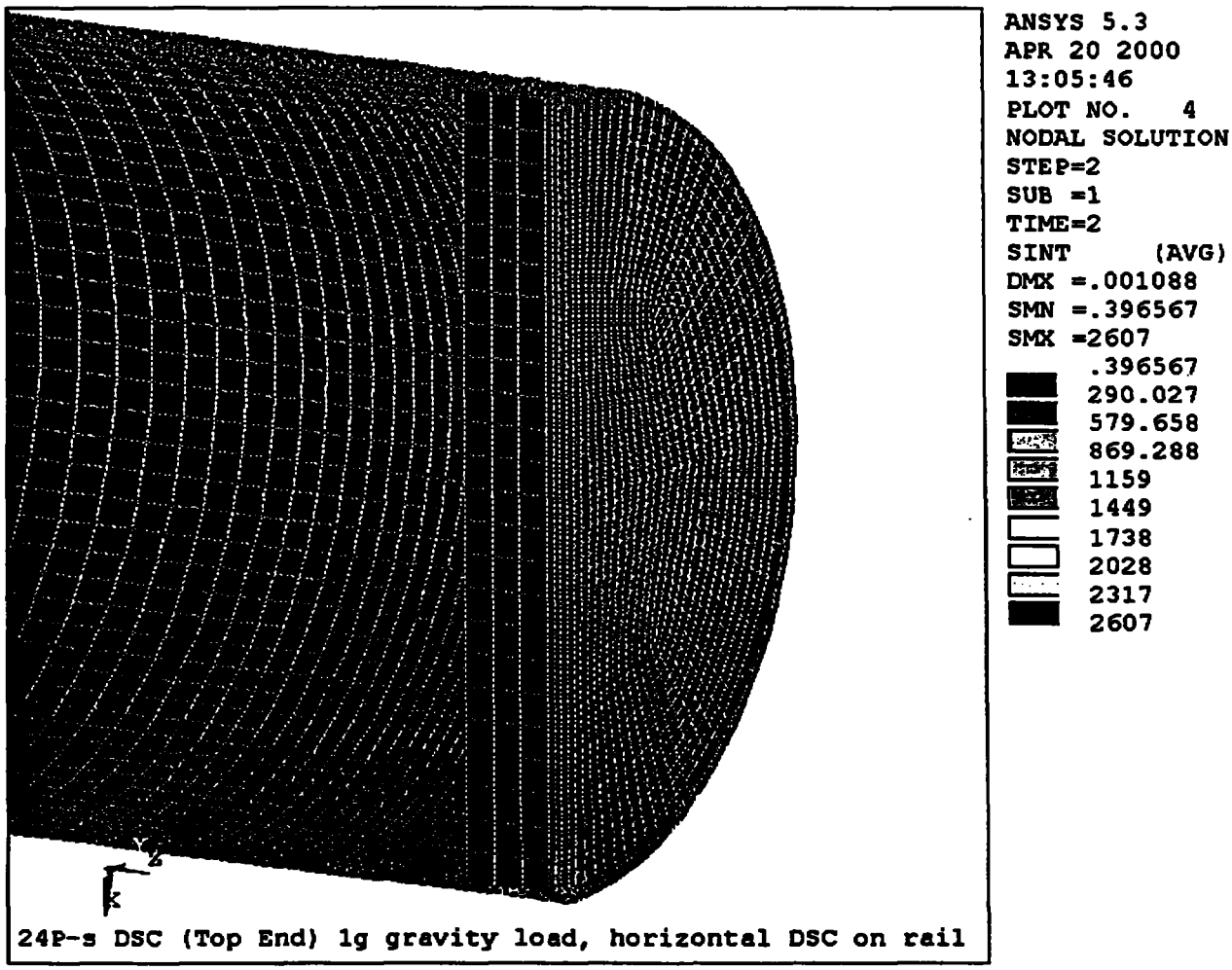

Figure B5-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

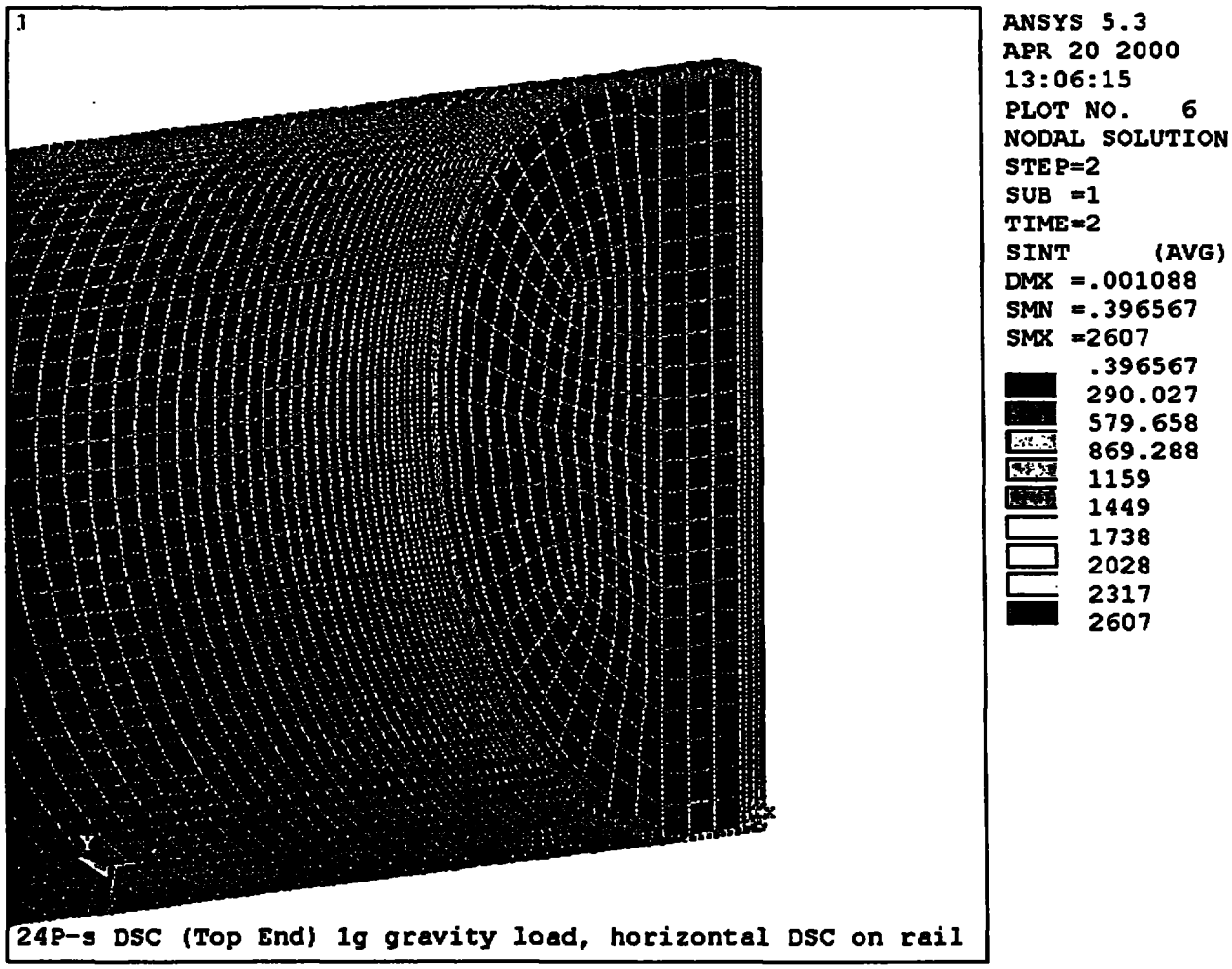

Figure B5-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

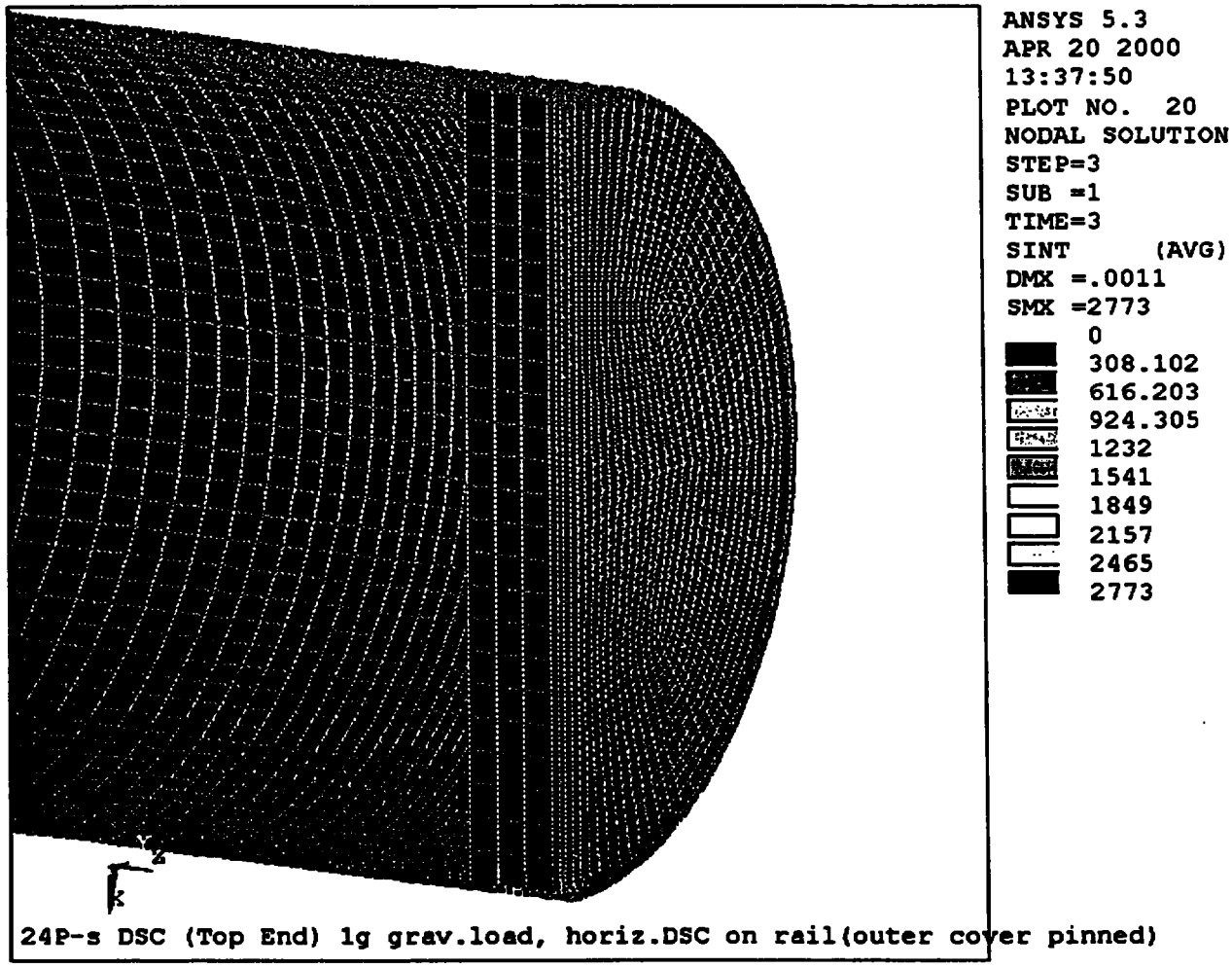

Figure B5-3

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

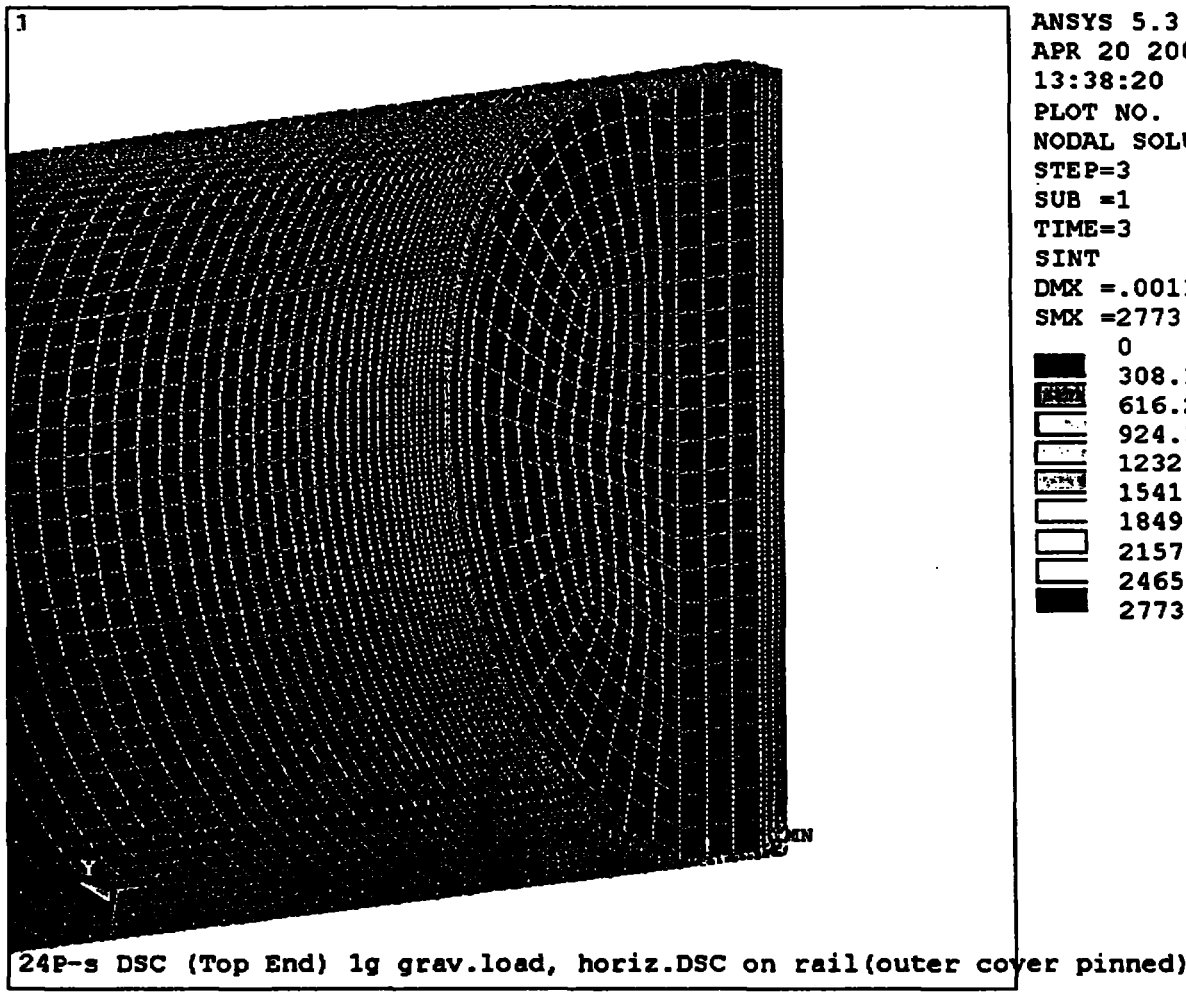

Figure B5-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

Appendix B6

ANSYS Temperature Contour Plots for Run PT24THRM

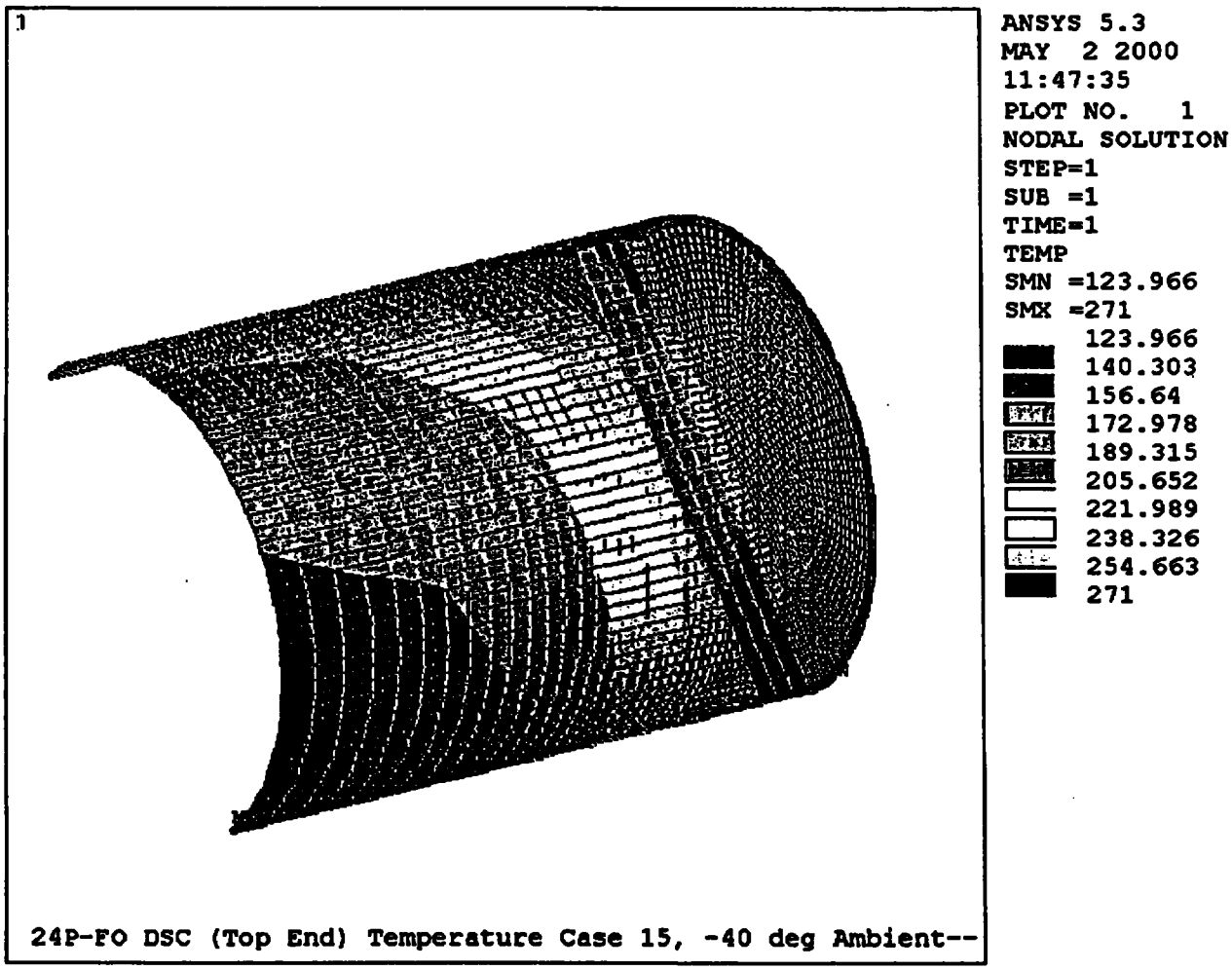

Figure B6-1

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

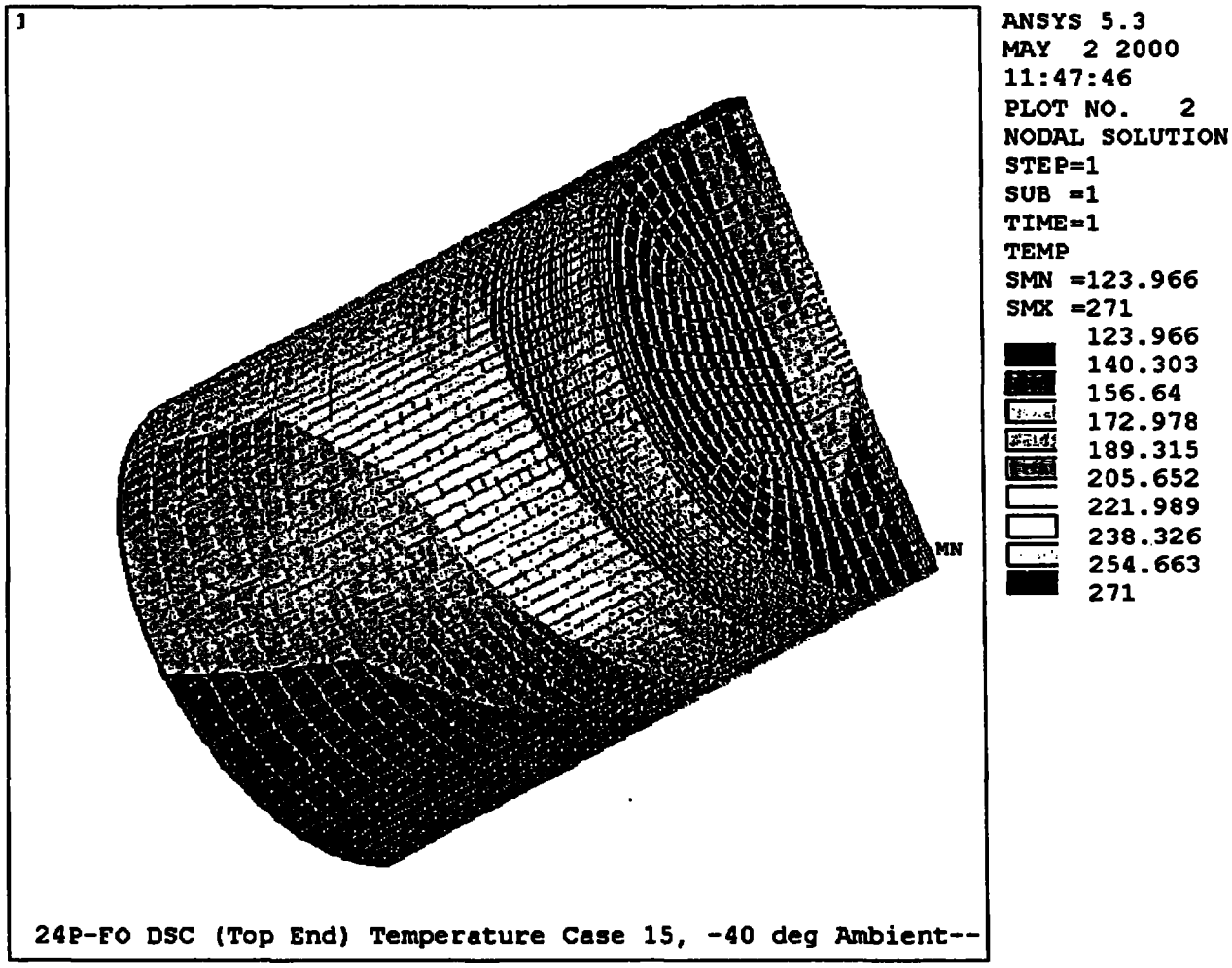

Figure B6-2

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

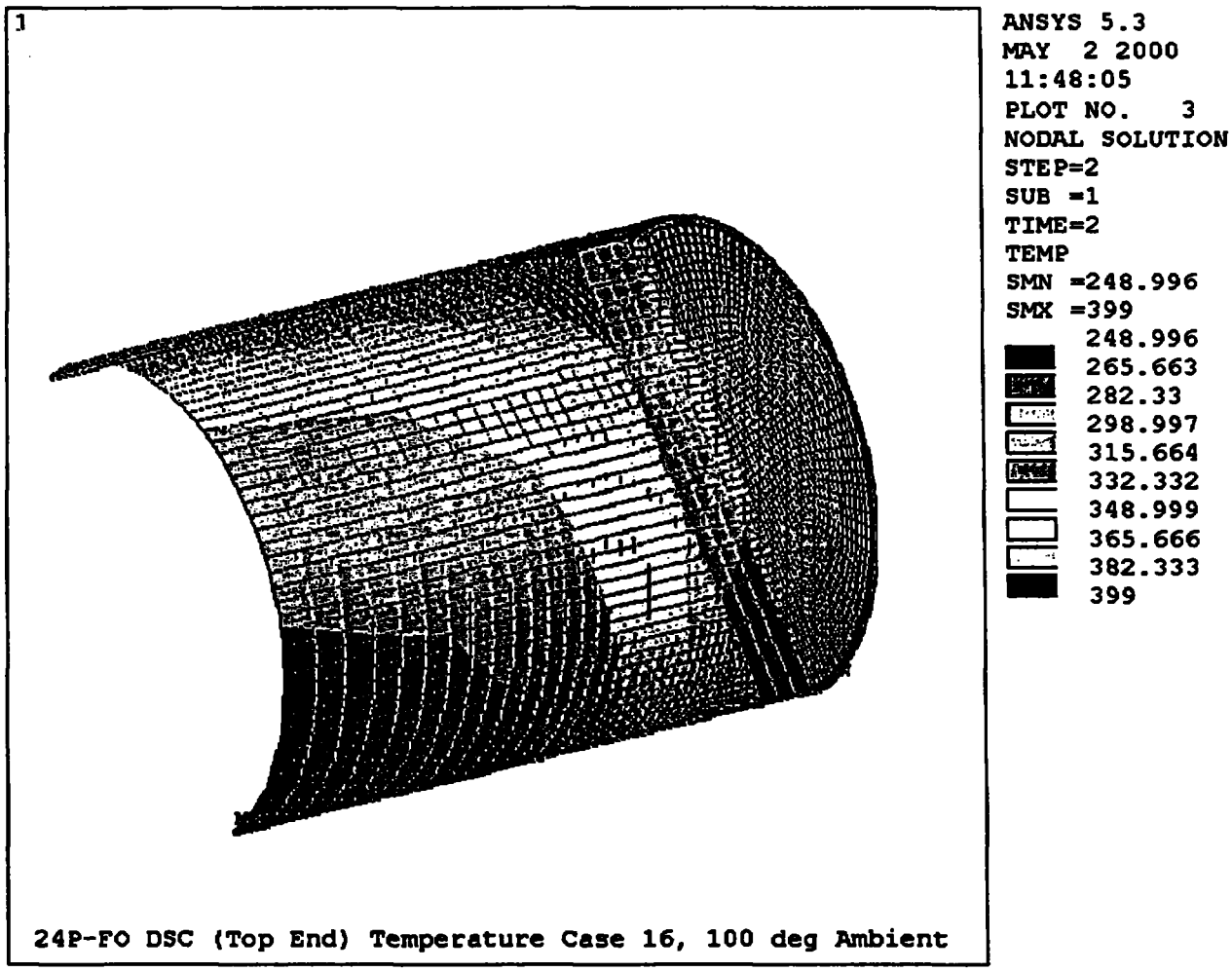

Figure B6-3

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

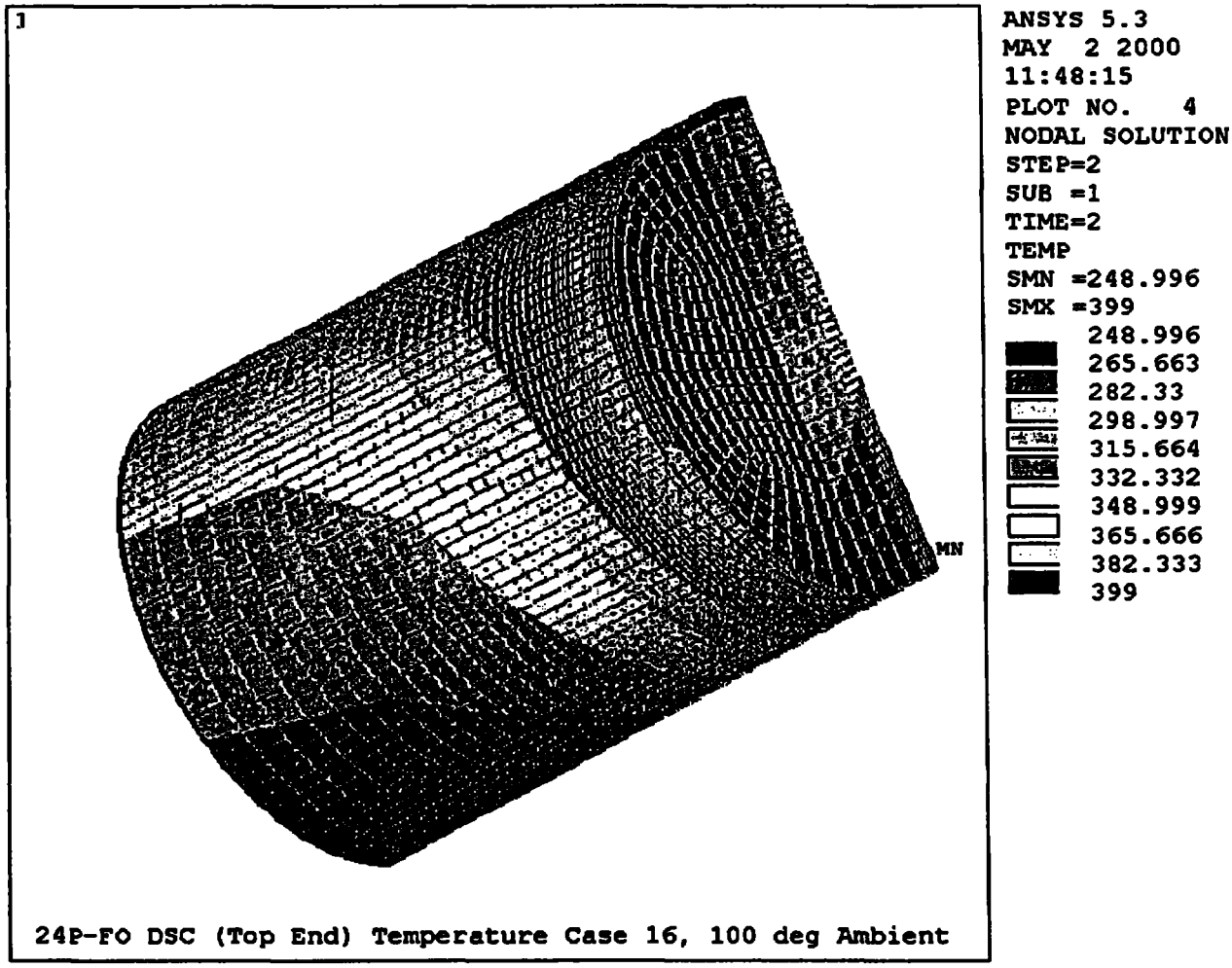

Figure B6-4

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

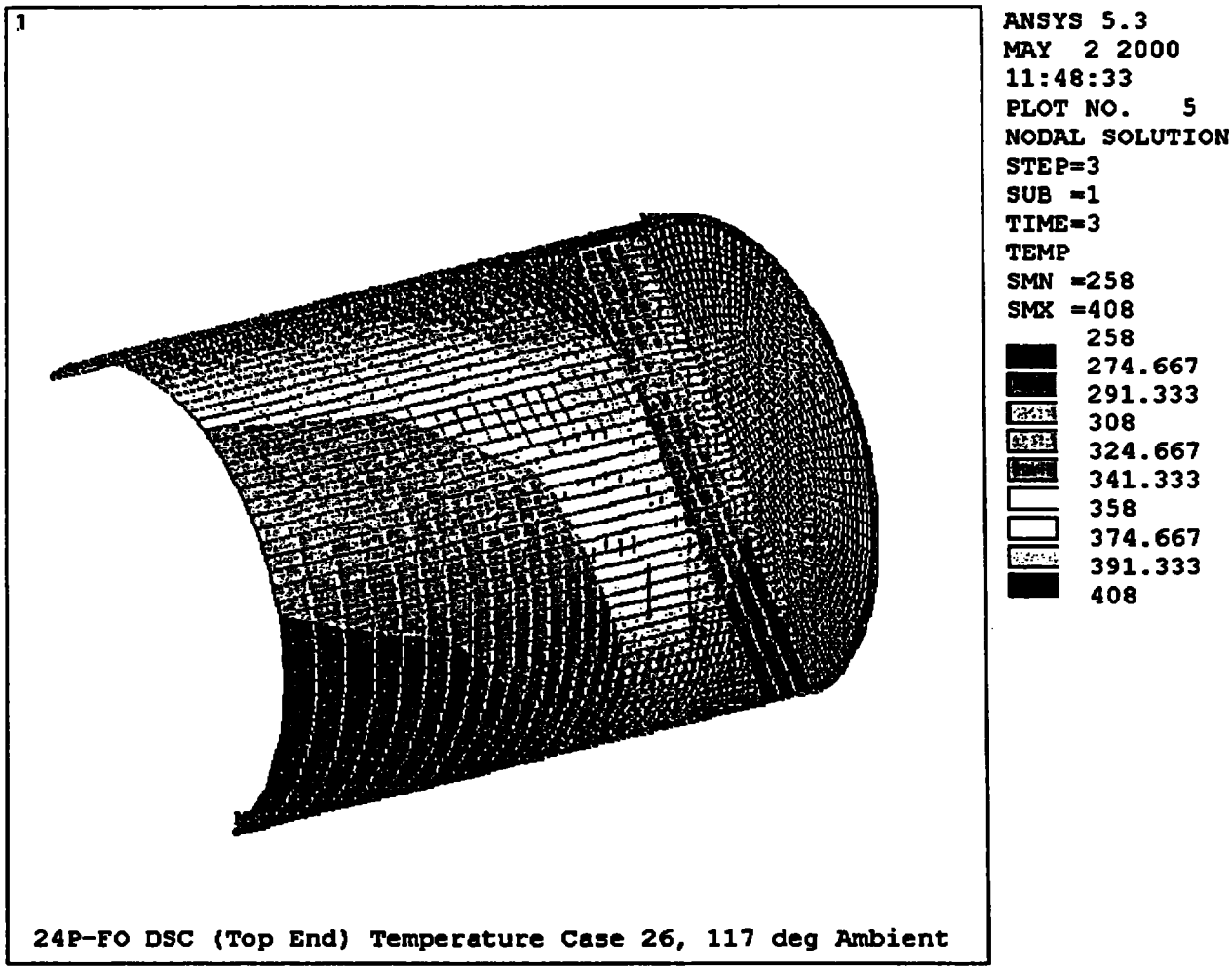

Figure B6-5

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

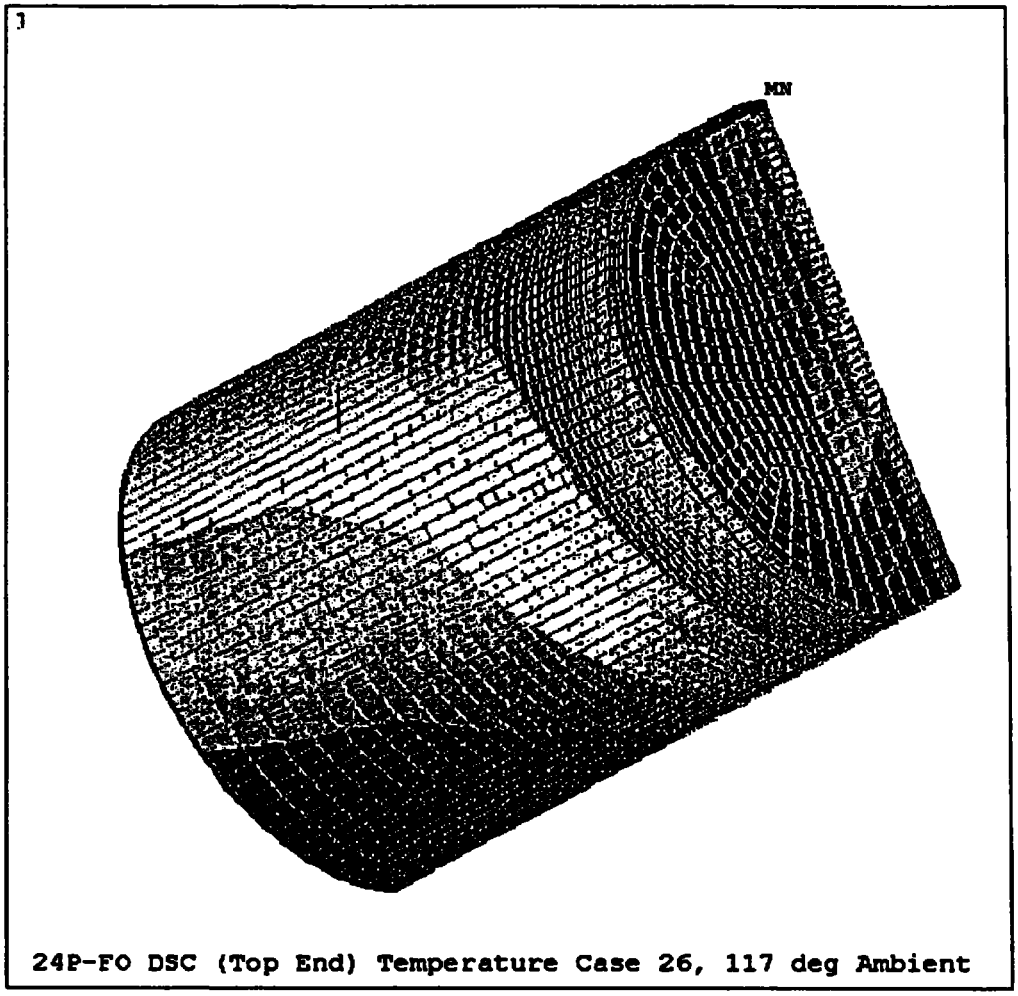

Figure B6-6

24P-FO DSC Shell Assembly, Top End Components

Temperature Contour

Appendix B7

ANSYS Stress Intensity Contour Plots for Run PT24PSD

Note:

The stress plots shown in Figures B7-3, B7-4, B7-5, B7-8, B7-9, and B7-10 exclude elements adjacent to the rail support (bottom centerline).

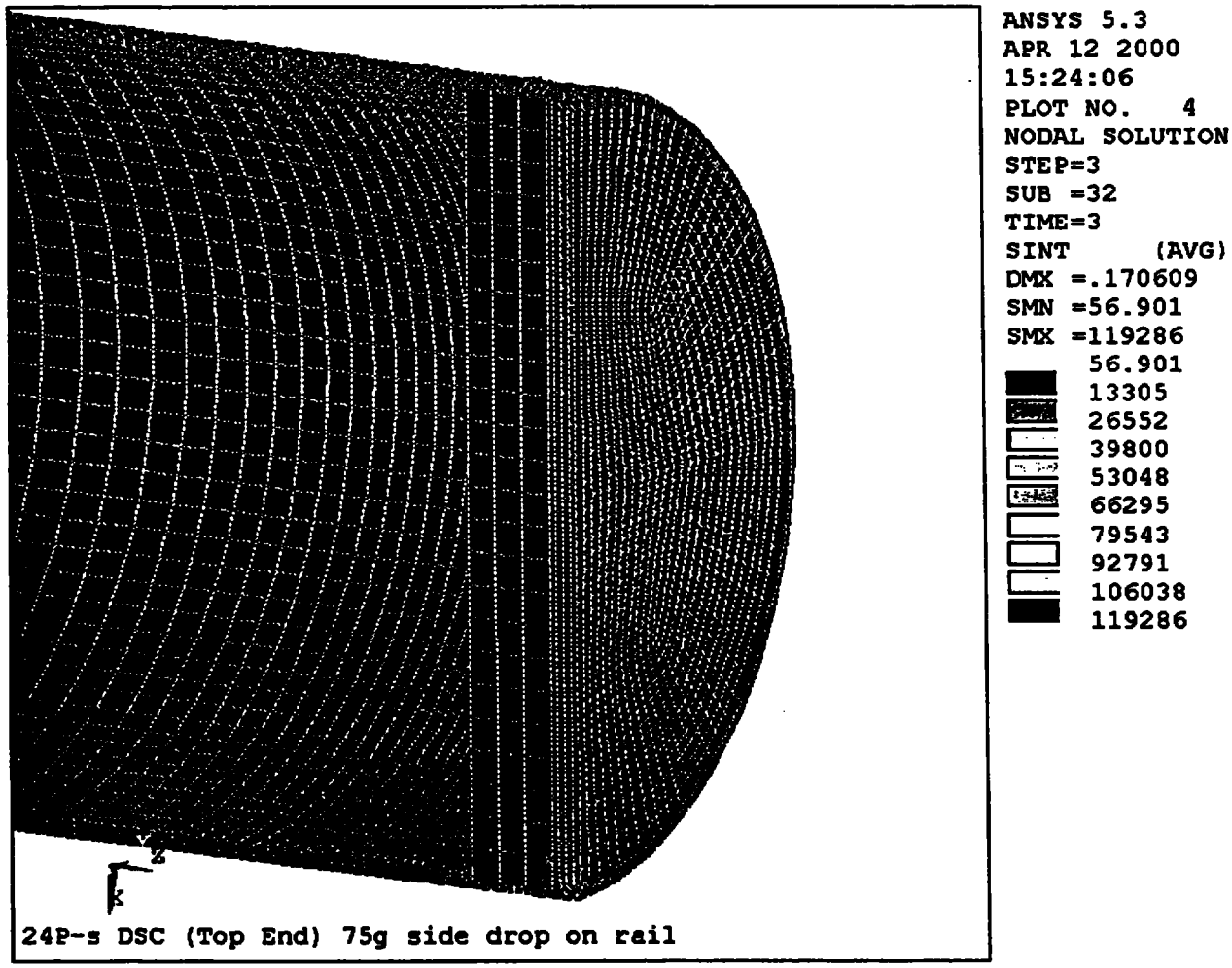

Figure B7-1

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

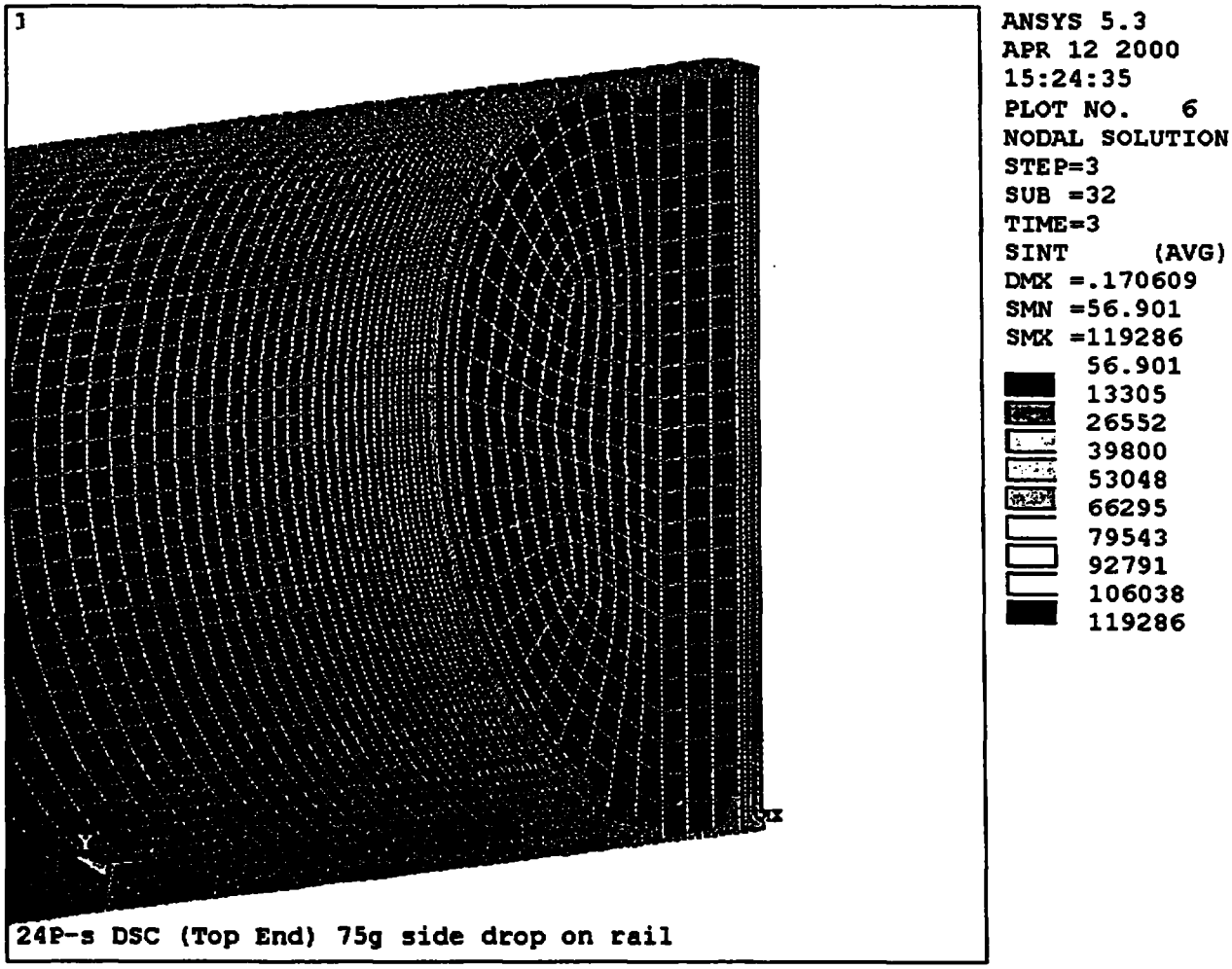

Figure B7-2

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

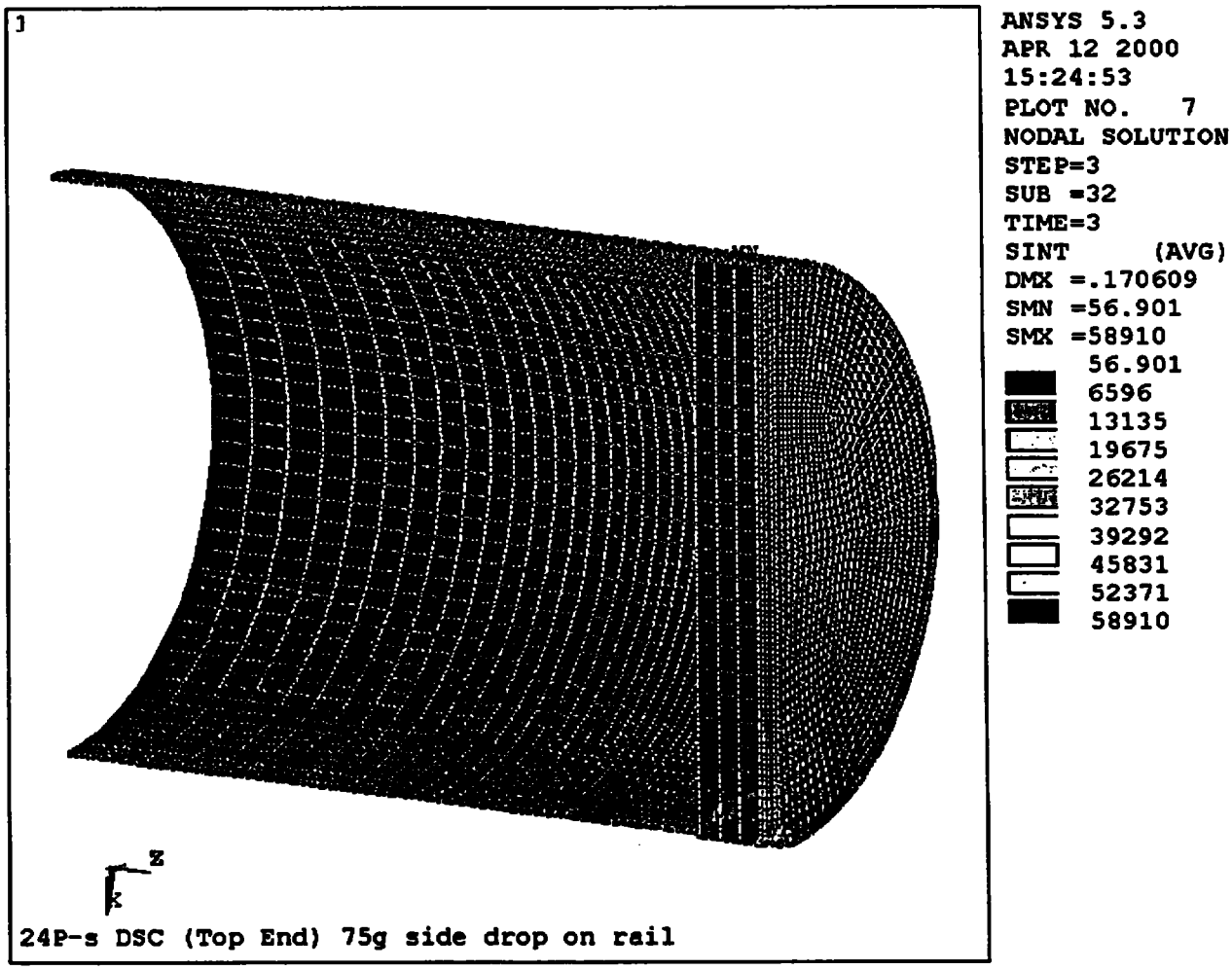

Figure B7-3

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

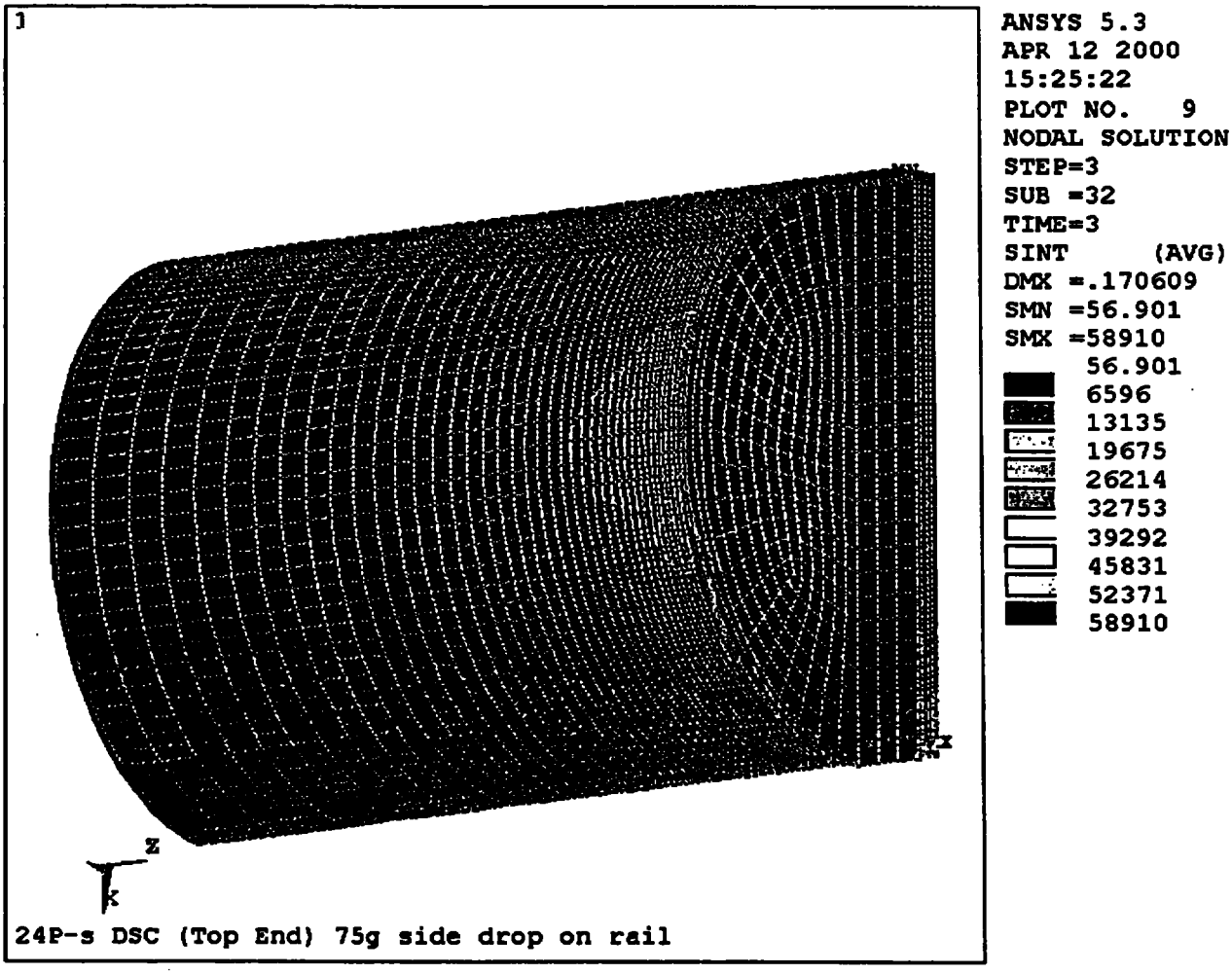

Figure B7-4

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

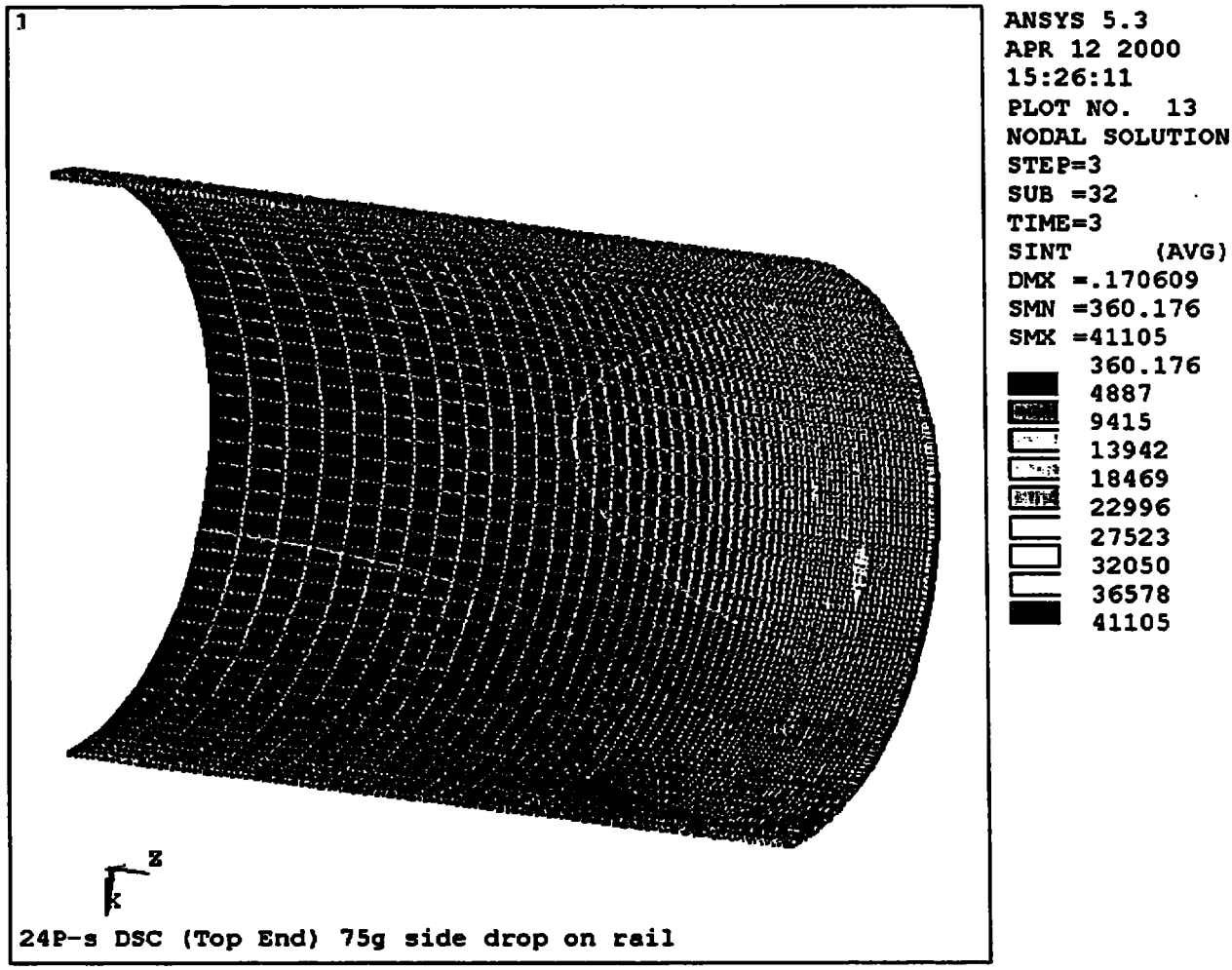

Figure B7-5

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour

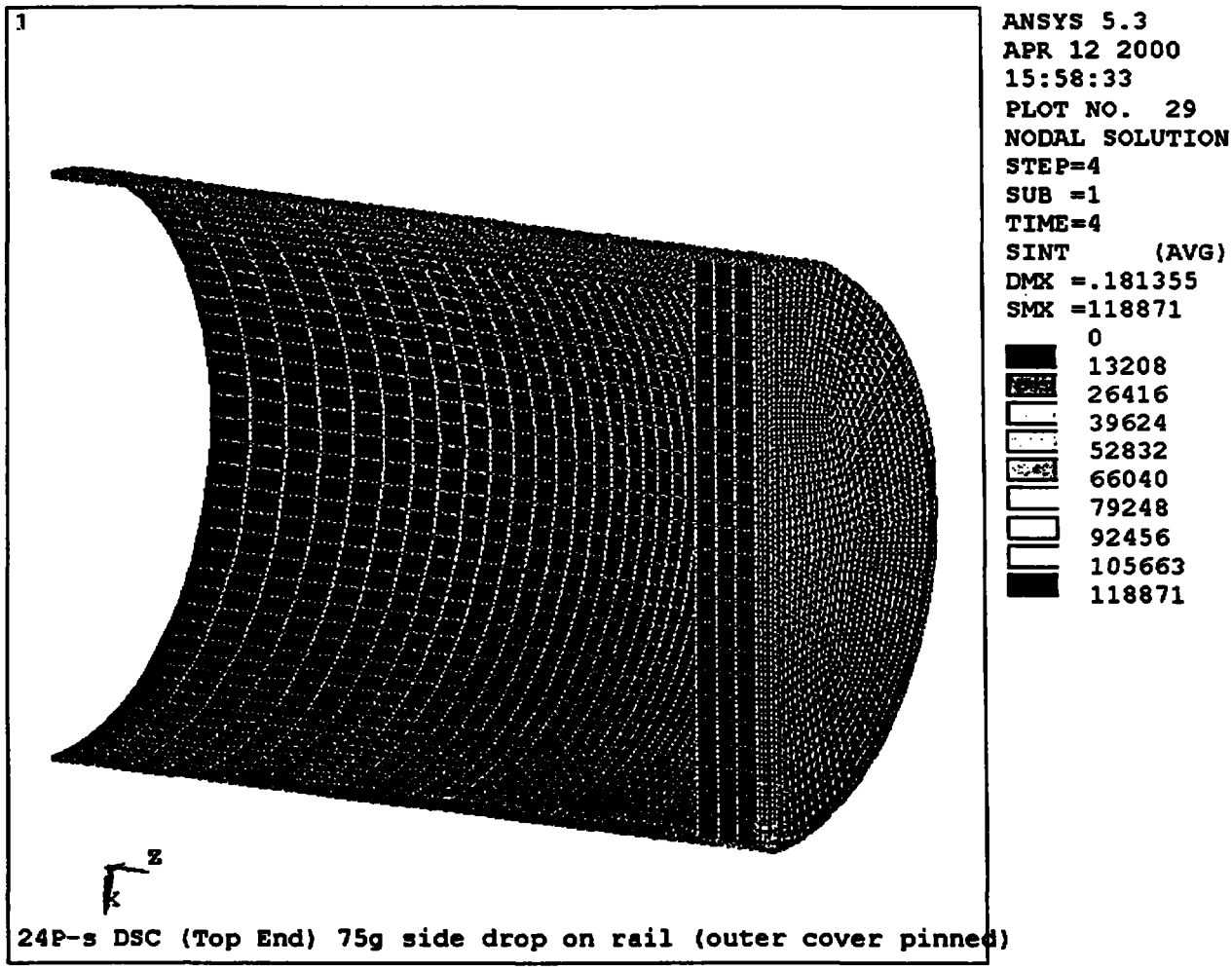

Figure B7-6

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

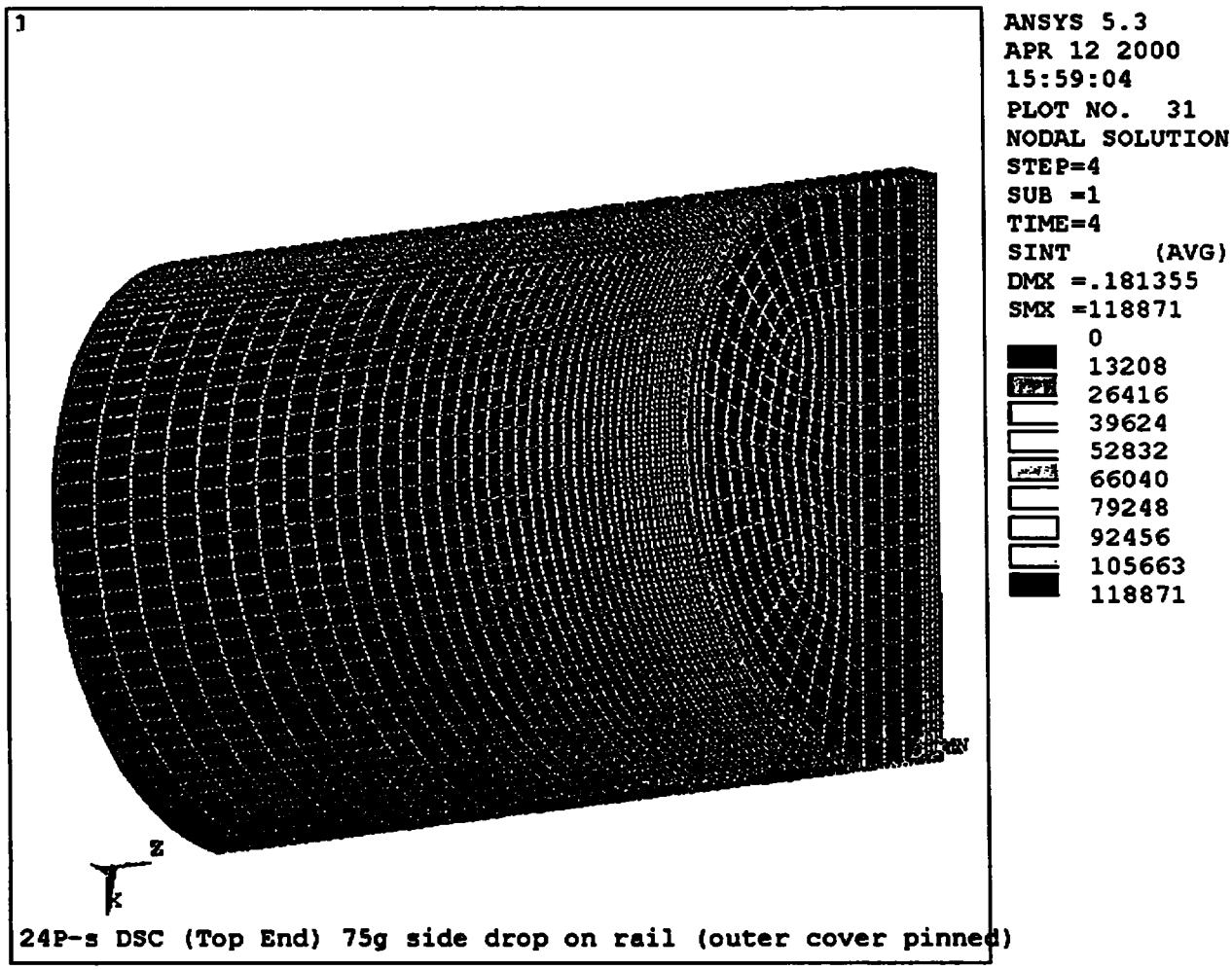

Figure B7-7

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

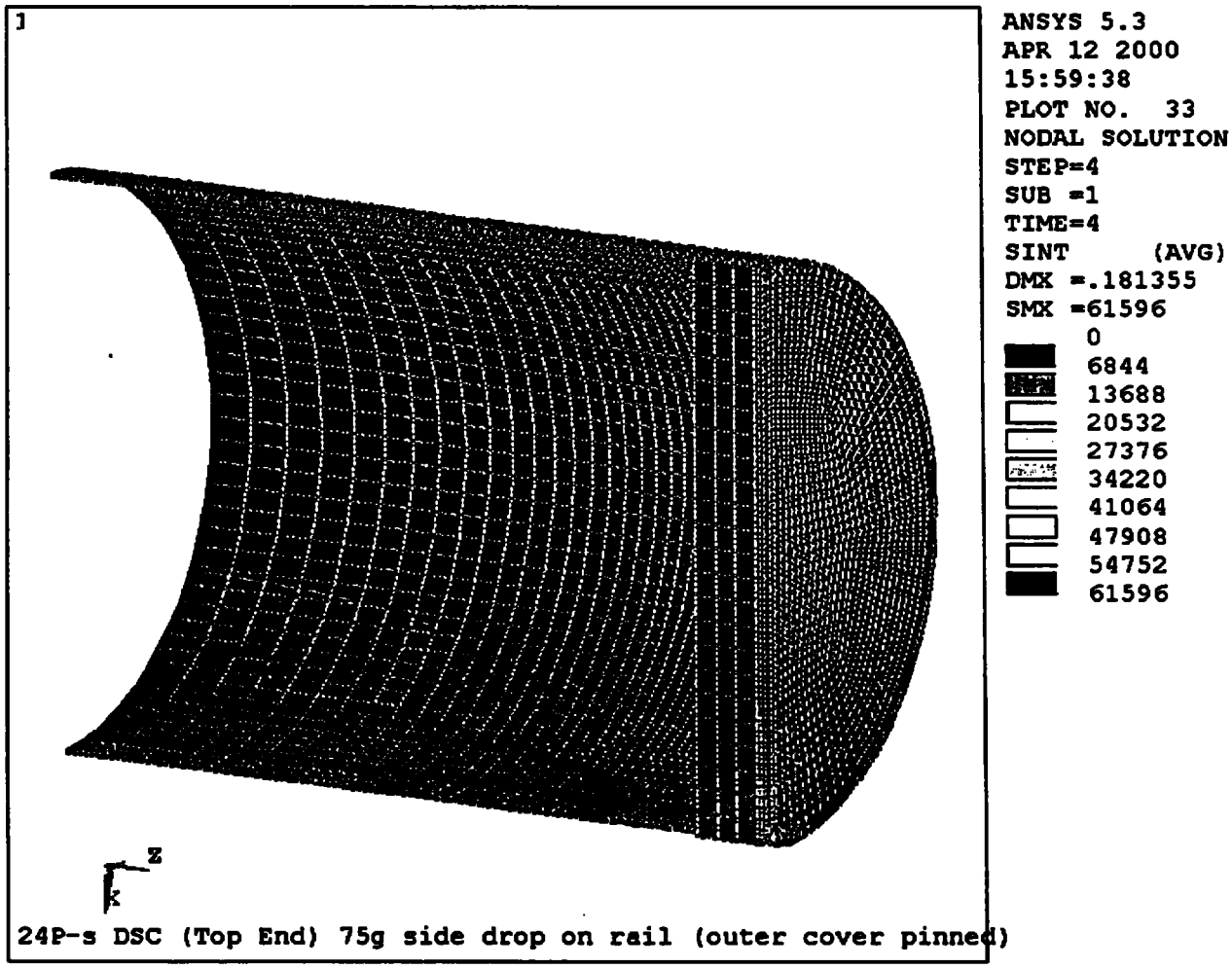

Figure B7-8

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

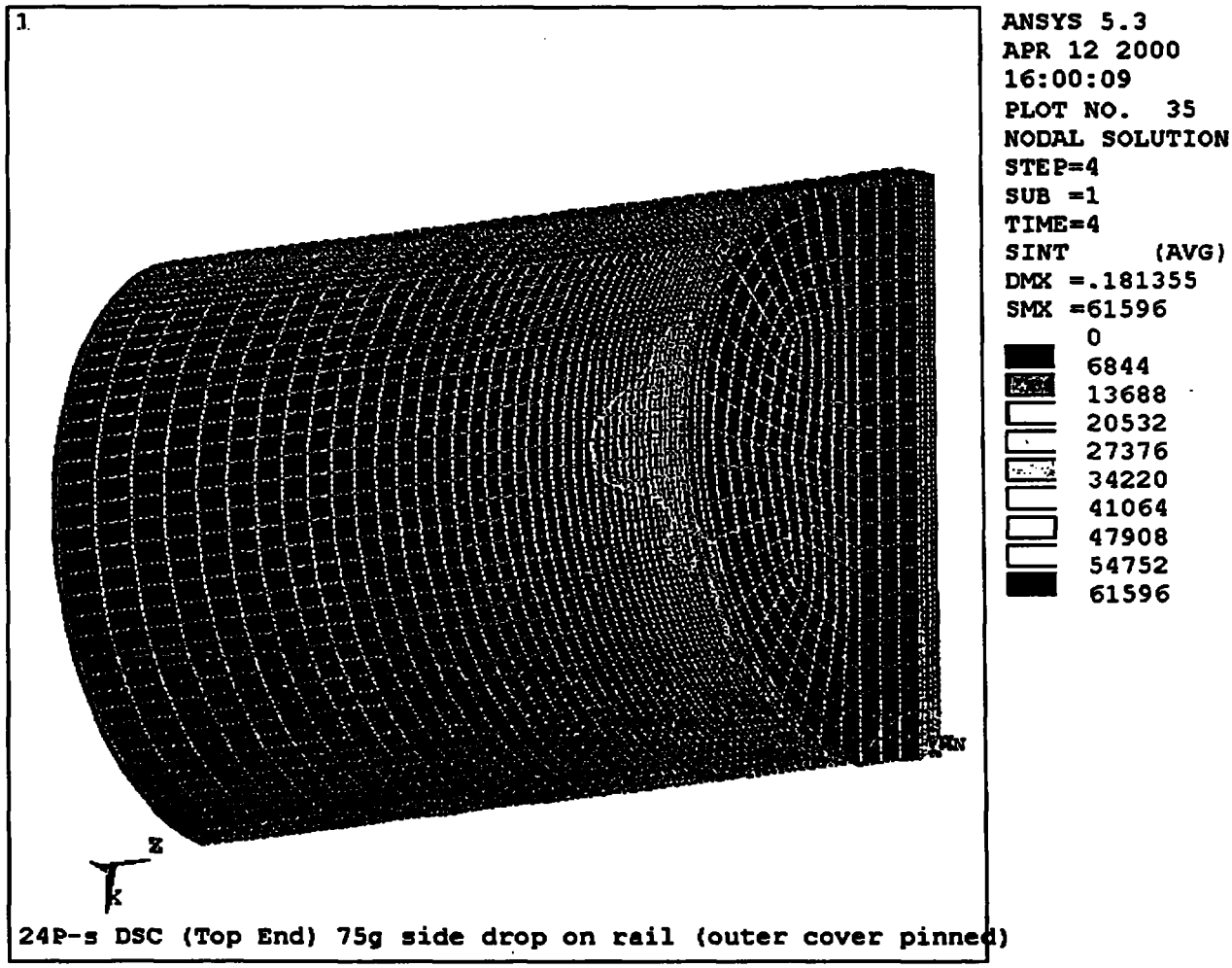

Figure B7-9

24P-FO DSC Shell Assembly, Top End Components

Stress Intensity Contour

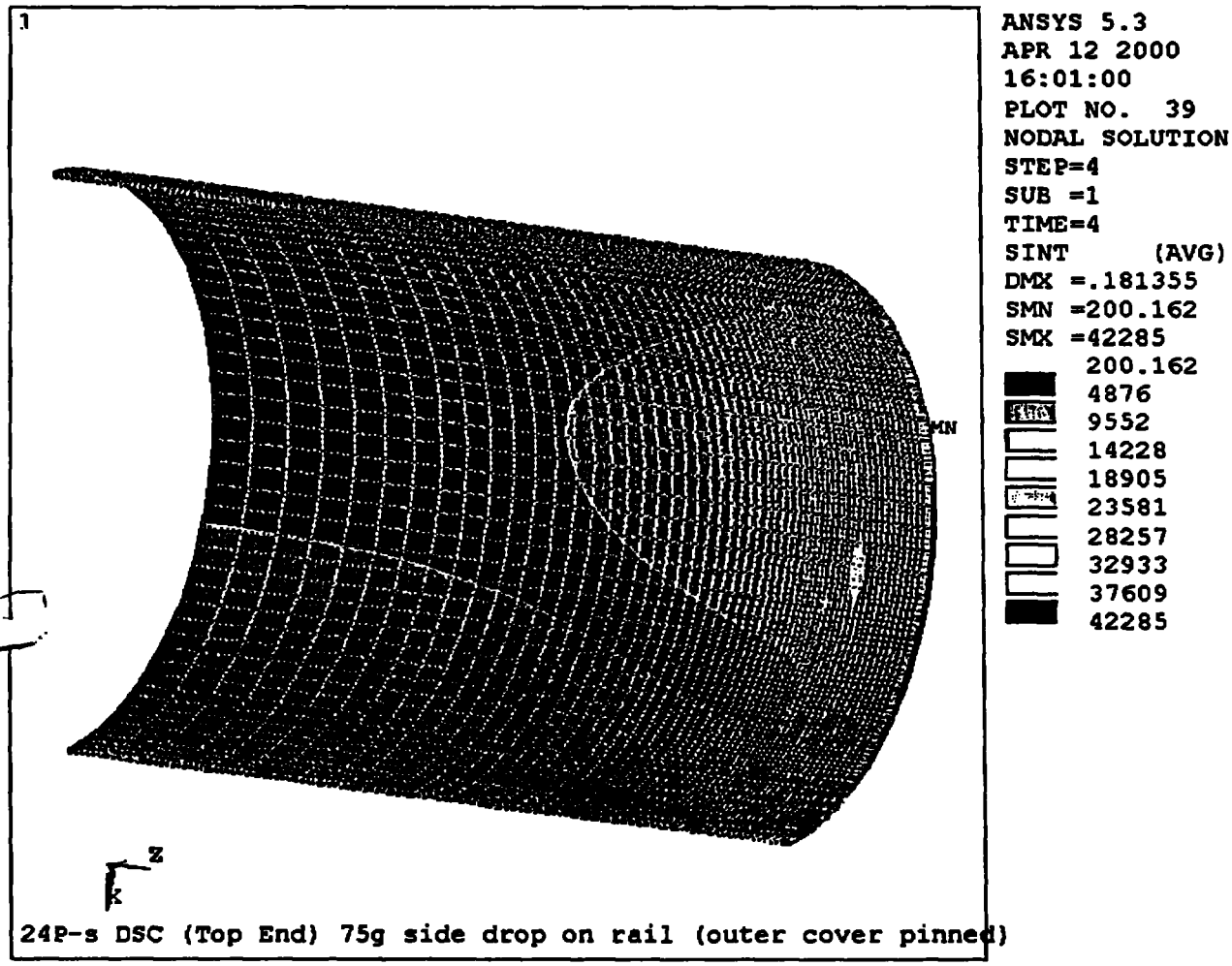

Figure B7-10

24P-FO DSC Shell Assembly, Cylindrical Shell (Top Half)

Stress Intensity Contour