Appendix A10

ANSYS Analysis Run Summary and Input Listings for T24PTH2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PTH2 (analysis) (1) PT24PTH2 (postprocessing) (1)

Date/Time: 6/1/00 6:58 PM 6/10/00 9:27 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 top end components

Loads Considered: Thermal 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

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

T24PTH2inp

```
/batch,list
/filname,t24pth2
/title,24P-Standard DSC Shell Assembly (Top End, 180 degree Model)
/prep7

/com shell assembly components
et,1,solid45            ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45           ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45           ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45           ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45           ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45           ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45           ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49          ! 3-D point to surface contact elements
!r,201,1.0E+07,,,,5     ! normal stiffness of gap elem btwn inner & outer plates
r,202,1.0E+06           ! normal stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07          ! normal stiffness of gap elem btwn plug and shell
r,204,1.0E+07           ! normal stiffness of gap elem btwn support ring & plug
keyopt,20,7,1           ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,70

/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

T_otc=1.3125            ! outer top cover plate thickness
T_itc=1.25              ! inner top cover plate thickness
T_tplug=7.625           ! top shield plug thickness
T_tw=.50                ! thickness of outer top cover plate weld (min.)

H_ring=2.00             ! height of support ring
T_ring=0.75             ! thickness of support ring

L_otc=H_dsc-0.12        ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc       ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc     ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug  ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75 ! lug location (top interface with shell)
```

```
B_lug=3.25                  ! base height of the lifting lug
! H_lug=4.13                 ! radial height of the lifting lug
! R_lug=1.75                 ! radius of lug curvature
! R_thru=1.38/2              ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                        ! shell outer bottom
k,2,IR                        ! shell inner bottom
k,6,IR,,H_dsc/2               ! mid-heght of DSC
k,7,OR,,H_dsc/2               ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug          ! bottom base of the lifting lug
k,71,IR,,L_lug                ! top base of the lifting lug
k,72,IR,,L_ring-H_ring        ! bottom of the support ring
k,73,IR,,L_ring               ! top of the support ring
k,74,IR,,L_itc                ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw           ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc           ! shell inner top
k,77,OR-0.19,,L_otc           ! shell outer top
k,78,OR,,H_dsc-0.59           ! upper chamfer
k,79,OR,,L_itc                ! line up with KP74
k,80,OR,,L_ring               ! line up with KP73
k,81,OR,,L_ring-H_ring        ! line up with KP72
k,82,OR,,L_lug                ! line up with KP71
k,83,OR,,L_lug-B_lug          ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc                ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc           ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc                 ! center of top surface
k,95,0,,L_itc                 ! center of bottom surface
k,96,IR-.44,,L_itc            ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc                ! center of top surface
k,102,0,,L_tplug              ! center of bottom surface
k,103,IR,,L_tplug             ! outer radius at bottom surface
k,104,IR-.44,,L_itc           ! radius at top cover plate contact
k,105,IR-.44,,L_tplug         ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug             ! outer radius at top surface
k,111,0,,L_tplug              ! center at top surface
k,112,0,,L_ring               ! center at bottom surface
k,113,IR,,L_ring              ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring                ! outer radius at top surface
k,121,IR-T_ring,,L_ring         ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring  ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring         ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

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 upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
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,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
```

```
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,                ! 1 division for horizontal lines
vdrag,all,,,,,1                ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                  ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,2             ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3                ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
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,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring            ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                         ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring     ! select lower radial line
```

```
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                          ! lines contained in above areas
vdrag,all,,,,,,1                ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                  ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                     ! upper shell to weld to outer top 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,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                     ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
```

```
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

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,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                   ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

/com define contact elements
/com top end plates

!esel,s,type,,11
!nsle
!cm,cont11,node                ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node               ! inner top cover plate top surface nodes
```

```
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,targ1413,node              ! top shield plug top surface nodes

csys,1                        ! cylindrical coordinates

!esel,s,type,,14
!nsle
!nsel,r,loc,x,IR-.01,IR+.01
!cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1         ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
! real,201
! gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
!real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)

!/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

!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
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to support ring for stability (one locations)
/com ********* valid only for temp & internal pressure loading **********

esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
cp,next,ux,all
```

```
allsel

vclear,12
esel,s,type,,14
edele,all
esel,s,type,,20
edele,all
alls

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

save

fini

/solution

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


/com Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Top End) Temperature Case 26, 117 deg Ambient
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,3,,,,t24therm,rth,d:\fo-dsc\newansys\top\

lswrite                        ! end of load step 1
save

solve
save

fini

/exit

/eof

*endif
```

PT24PTH2.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal loads
resume,t24pth2,db
/post1
file,t24pth2,rst

/com element plots ------------------------------------------------------------
/show,pt24pth2,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,0.03,0.75,0.94,-0.79
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

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

*do,iset,1,2                  ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
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,,11
   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,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   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 Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *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_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   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,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                       ! theta loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
*do,theta,0,180,90/26        ! sections at 3.46 degree intervals
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                       ! theta loop

/com DSC Inner Top Cover Plate Post1 Results -----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *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_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   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 Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *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_tplug)
   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,,14
   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 Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *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_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   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 Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
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

/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,bfe,temp              ! plot temperature distribution
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
```

```
/zoom,1,rect,0.03,0.75,0.94,-0.79
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
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,,12
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,,15
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,,13
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,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
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

/eof
```

Appendix A11

ANSYS Analysis Run Summary and Input Listings for T24PTHP

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PTHP (analysis) (1) PT24PTHP (postprocessing) (1)

Date/Time: 6/1/00 4:19 PM 6/10/00 9:52 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 top end components

Loads Considered: Thermal cases + 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 *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calc.
3. Of five load steps defined, only load steps 1 through 4 are valid.

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

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

T24PTHP.inp

```
/batch,list
/filname,t24pthp
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/config,ncont,1200
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1E5,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E6,1e7/100     ! norm/tan stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07        ! normal stiffness of gap elem btwn plug and shell
r,204,1E5,1e6/100     ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

tref,70

/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

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring

L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
```

```
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)

B_lug=3.25                ! base height of the lifting lug
! H_lug=4.13               ! radial height of the lifting lug
! R_lug=1.75               ! radius of lug curvature
! R_thru=1.38/2            ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                      ! shell outer bottom
k,2,IR                      ! shell inner bottom
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug        ! bottom base of the lifting lug
k,71,IR,,L_lug              ! top base of the lifting lug
k,72,IR,,L_ring-H_ring      ! bottom of the support ring
k,73,IR,,L_ring             ! top of the support ring
k,74,IR,,L_itc              ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw         ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc         ! shell inner top
k,77,OR-0.19,,L_otc         ! shell outer top
k,78,OR,,H_dsc-0.59         ! upper chamfer
k,79,OR,,L_itc              ! line up with KP74
k,80,OR,,L_ring             ! line up with KP73
k,81,OR,,L_ring-H_ring      ! line up with KP72
k,82,OR,,L_lug              ! line up with KP71
k,83,OR,,L_lug-B_lug        ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc              ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc         ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc               ! center of top surface
k,95,0,,L_itc               ! center of bottom surface
k,96,IR-.44,,L_itc          ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc              ! center of top surface
k,102,0,,L_tplug            ! center of bottom surface
k,103,IR,,L_tplug           ! outer radius at bottom surface
k,104,IR-.44,,L_itc         ! radius at top cover plate contact
k,105,IR-.44,,L_tplug       ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug           ! outer radius at top surface
k,111,0,,L_tplug            ! center at top surface
k,112,0,,L_ring             ! center at bottom surface
k,113,IR,,L_ring            ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring              ! outer radius at top surface
k,121,IR-T_ring,,L_ring       ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring       ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug
```

```
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 upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
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,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
```

```
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
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,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
a,120,121,122,123
lsel,r,loc,z,L_ring           ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
```

```
lsel,r,loc,z,L_ring-H_ring   ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2               ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                  ! upper shell to weld to outer top 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,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                  ! weld of inner cover plate to shell

esel,s,type,,11,16,5
```

```
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

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,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

/com define contact elements
/com top end plates

!esel,s,type,,11
!nsle
!cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
csys,0                         ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
```

```
cm,targ1312,node              ! inner top cover plate top surface nodes

csys,1                        ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
nsel,r,loc,x,10.5*IR/12,IR+.1
cm,targ1413,node              ! top shield plug top surface nodes

!esel,s,type,,14
!nsle
!nsel,r,loc,x,IR-.01,IR+.01
!cm,targ1411,node              ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1         ! mesh dependent
cm,targ1416,node              ! support ring inner top surface nodes

csys,0                        ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1       ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1       ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1       ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1       ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1      ! gen contact elem btwn support ring & plug (inner)

/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

!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
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to support ring for stability (one locations)
/com ********* valid only for temp & internal pressure loading **********
esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
```

```
cp,next,ux,all

allsel

vclear,12
esel,s,type,,14
edele,all
esel,s,type,,20
edele,all
alls

save

fini

/solution

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

/com 24P-FO DSC (Top End) Nonlinear Pressure Start, 1 psi
/title, 24P-FO DSC (Top End) Nonlinear Pressure Start, 1 psi
nsubst,1,8

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,1                   ! 1 psi
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,1
esel,s,type,,14

nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
sf,all,pres,.0001             ! Stability pressure for shield plug


allsel
csys,0

lswrite                         ! end of load step 1

save

solve
save


/com Temp Case 7, -40 deg Ambient + 10 psi
/title, 24P-FO DSC (Top End) Temp Case 7, -40 deg Ambient + 10 psi

r,201,1E6,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E7,1e7/100     ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1E6,1e6/100     ! norm/tan stiffness of gap elem btwn support ring & plug
```

```
nsubst,1,8
csys,1

/com Define temps for DSC shell in active fuel region
esel,s,type,,11
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 above active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,159.5,186.17
*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=-5.39*zt+.93*yt*zt-221.1*yt+1239.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for DSC Support Ring
esel,s,type,,16
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
   ntemp=-5.39*zt+.93*yt*zt-221.1*yt+1239.2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Inner & Outer Cover Plates, and Weld
esel,s,type,,12,15,1
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=-.1284*zt*xt+.0281*yt*zt*xt
    ntemp2=-6.7289*yt*xt+23.33*xt-1.15*zt+469.2
    ntemp=ntemp1+ntemp2
    bf,tnode,temp,ntemp
    nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                         ! end of load step 2
save

solve
save

fini

/exit

/eof
```

PT24PTHP.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal + pressure loads
resume,t24pthp,db
/post1
file,t24pthp,rst

/com element plots ------------------------------------------------------------
/show,pt24pthp,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,0.03,0.75,0.94,-0.79
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

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

*do,iset,2,4                  ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
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,,11
   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,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   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 Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *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_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   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,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                       ! theta loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
*do,theta,0,180,90/26        ! sections at 3.46 degree intervals
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                       ! theta loop

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *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_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   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 Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *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_tplug)
   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,,14
   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 Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *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_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   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 Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ----------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
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

/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,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
```

```
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
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,,12
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,,15
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,,13
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,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
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

/eof
```

Appendix A12

ANSYS Analysis Run Summary and Input Listings for T24PTP2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PTP2 (analysis) [1] PT24PTP2 (postprocessing) [1]

Date/Time: 6/2/20 12:14 PM 6/10/00 11:10 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 top end components

Loads Considered: Thermal cases + internal pressure [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: Steven R. Streutker Date: 6/19/00
Steven R. Streutker

T24PTP2.inp

```
/batch,list
/filname,t24ptp2
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/config,ncont,1200
/prep7

/com shell assembly components
et,1,solid45            ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45           ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45           ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45           ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45           ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45           ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45           ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49          ! 3-D point to surface contact elements
r,201,1E5,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E6,1e6/100       ! norm/tan stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07          ! normal stiffness of gap elem btwn plug and shell
r,204,1E5,1e6/100       ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1           ! keyopt (7)=1

! et,21,shell63           ! Elastic Shell - Lifting Lugs
! r,21,0.75/2             ! half-thickness of lug

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

/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

T_otc=1.3125              ! outer top cover plate thickness
T_itc=1.25                ! inner top cover plate thickness
T_tplug=7.625             ! top shield plug thickness
T_tw=.50                  ! thickness of outer top cover plate weld (min.)

H_ring=2.00               ! height of support ring
T_ring=0.75               ! thickness of support ring
```

```
L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)

B_lug=3.25                ! base height of the lifting lug
! H_lug=4.13               ! radial height of the lifting lug
! R_lug=1.75               ! radius of lug curvature
! R_thru=1.38/2            ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                      ! shell outer bottom
k,2,IR                      ! shell inner bottom
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug        ! bottom base of the lifting lug
k,71,IR,,L_lug              ! top base of the lifting lug
k,72,IR,,L_ring-H_ring      ! bottom of the support ring
k,73,IR,,L_ring             ! top of the support ring
k,74,IR,,L_itc              ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw         ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc         ! shell inner top
k,77,OR-0.19,,L_otc         ! shell outer top
k,78,OR,,H_dsc-0.59         ! upper chamfer
k,79,OR,,L_itc              ! line up with KP74
k,80,OR,,L_ring             ! line up with KP73
k,81,OR,,L_ring-H_ring      ! line up with KP72
k,82,OR,,L_lug              ! line up with KP71
k,83,OR,,L_lug-B_lug        ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc              ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc         ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc               ! center of top surface
k,95,0,,L_itc               ! center of bottom surface
k,96,IR-.44,,L_itc          ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc              ! center of top surface
k,102,0,,L_tplug            ! center of bottom surface
k,103,IR,,L_tplug           ! outer radius at bottom surface
k,104,IR-.44,,L_itc         ! radius at top cover plate contact
k,105,IR-.44,,L_tplug       ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug           ! outer radius at top surface
k,111,0,,L_tplug            ! center at top surface
k,112,0,,L_ring             ! center at bottom surface
k,113,IR,,L_ring            ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring              ! outer radius at top surface
k,121,IR-T_ring,,L_ring       ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring       ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
```

```
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

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 upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
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,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
```

```
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
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,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
```

```
a,120,121,122,123
lsel,r,loc,z,L_ring           ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring    ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                        ! lines contained in above areas
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2                ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug        ! define arc
! a,70,71,122,121,131,132,133   ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru   ! define circular area of thru hole
! wpstyle,defa                  ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                        ! cylindrical coordinates
! esel,s,type,,21               ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0   ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                        ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                   ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                   ! upper shell to weld to outer top 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,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                    ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

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,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

/com define contact elements
/com top end plates

!esel,s,type,,11
!nsle
!cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
```

```
csys,0                          ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node                ! inner top cover plate top surface nodes

csys,1                          ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
nsel,r,loc,x,10.5*IR/12,IR+.1
cm,targ1413,node                ! top shield plug top surface nodes

!esel,s,type,,14
!nsle
!nsel,r,loc,x,IR-.01,IR+.01
!cm,targ1411,node                ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1          ! mesh dependent
cm,targ1416,node                ! support ring inner top surface nodes

csys,0                          ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1         ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1         ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1         ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1         ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1        ! gen contact elem btwn support ring & plug (inner)

/com Define soft springs to stabilize shield plug (connect to support ring)
/com Valid for thermal + pressure
allsel
esel,s,type,,14
nsle
node1i=node(IR,0,L_ring)
node2i=node(-IR,0,L_ring)
esel,s,type,,16
nsle
node1j=node(IR,0,L_ring)
node2j=node(-IR,0,L_ring)
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

!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
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to support ring for stability (one locations)
/com ********* valid only for temp & internal pressure loading **********
esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
cp,next,ux,all

vclear,12
esel,s,type,,14
edele,all
esel,s,type,,20
edele,all
esel,s,type,,22
edele,all
alls

allsel

save

fini

/solution

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

/com 24P-FO DSC (Top End) Nonlinear Pressure Start, 1 psi
/title, 24P-FO DSC (Top End) Nonlinear Pressure Start, 1 psi
nsubst,1,8

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,1                  ! 1 psi
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,1
```

```
!esel,s,type,,14
!nsle
!nsel,r,loc,z,L_tplug-.01,L_tplug+.01
!sf,all,pres,.001            ! Stability pressure for shield plug

allsel
csys,0

lswrite                      ! end of load step 1

save

solve
save

/com Temp Case 8, 100 deg Ambient + 10 psi
/title, 24P-FO DSC (Top End) Temp Case 8, 100 deg Ambient + 10 psi
nsubst,5,20

r,201,1E6,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E6,1e6/100     ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1E6,1e6/100     ! norm/tan stiffness of gap elem btwn support ring & plug

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,10               ! 10 psi
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,10

/com Define temps for DSC shell in active fuel region
esel,s,type,,11
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 above active fuel region
esel,s,type,,11
nsle
nsel,r,loc,z,159.5,186.17
*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=-4.666*zt+.854*yt*zt-196.3*yt+1184
```

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

/com Define temps for DSC Support Ring
esel,s,type,,16
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
   ntemp=-4.666*zt+.854*yt*zt-196.3*yt+1184
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

/com Define temps for Top Shield Plug, Inner & Outer Cover Plates, and Weld
esel,s,type,,12,15,1
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=-.1077*zt*xt+.02588*yt*zt*xt
   ntemp2=-5.948*yt*xt+19.48*xt-1.113*zt+541.1
   ntemp=ntemp1+ntemp2
   bf,tnode,temp,ntemp
   nsel,u,node,,tnode
*enddo

allsel
csys,0

lswrite                        ! end of load step 2
save

solve
save

/com Temp Case 15, -40 deg Ambient + 10 psi
/title, 24P-FO DSC (Top End) Temp Case 15, -40 deg Ambient + 10 psi
nsubst,5,20
csys,1

/com read input from thermal results file
ldread,temp,1,,,,t24therm,rth,d:\fo-dsc\newansys\top\

allsel
csys,0

lswrite                        ! end of load step 3
save

solve
save
```

```
/com Temp Case 16, 104 deg Ambient + 10 psi
/title, 24P-FO DSC (Top End) Temp Case 16, 104 deg Ambient + 10 psi
nsubst,5,20
csys,1

/com read input from thermal results file
ldread,temp,2,,,,t24therm,rth,d:\fo-dsc\newansys\top\

allsel
csys,0

lswrite                        ! end of load step 4
save

solve
save


fini

/exit

/eof
```

PT24PTP2.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal + pressure loads
resume,t24ptp2,db
/post1
file,t24ptp2,rst

/com element plots ------------------------------------------------------------
/show,pt24ptp2,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,0.03,0.75,0.94,-0.79
/show,off                     ! discontinue plots to file
/auto,1                       ! zoom - fit

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

*do,iset,2,5                  ! define steps to postprocess
/go
set,iset

/com DSC Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
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,,11
   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,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   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 Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node             ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *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_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   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,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *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_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   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 Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *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_tplug)
   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,,14
   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 Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *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_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   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 Outer Top Cover Plate ----------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ----------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring -------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
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

/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,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
```

```
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
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,,12
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,,15
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,,13
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,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
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

/eof
```

Appendix A13

ANSYS Analysis Run Summary and Input Listings for T24PTP3

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: T24PTP3 (analysis) [1] PT24PTP3 (postprocessing) [1]

Date/Time: 6/19/00 8:37 AM 6/19/00 9:05 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 top end components

Loads Considered: Thermal cases + internal pressure [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: 6/19/00
Michael B. Cohen

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

T24PTP3.inp

```
/batch,list
/filname,t24ptp3
/title,24P-FO DSC Shell Assembly (Top End, 180 degree Model)
/config,ncont,1200
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell

et,11,solid45         ! 3-D Elastic/Plastic Solid - DSC Upper Shell
et,12,solid45         ! 3-D Elastic/Plastic Solid - DSC Outer Top Cover Pl
et,13,solid45         ! 3-D Elastic/Plastic Solid - DSC Inner Top Cover Pl
et,14,solid45         ! 3-D Elastic/Plastic Solid - DSC Top Shield Plug
et,15,solid45         ! 3-D Elastic/Plastic Solid - Top Plate Weld
et,16,solid45         ! 3-D Elastic/Plastic Solid - DSC Support Ring

et,20,contac49        ! 3-D point to surface contact elements
r,201,1E5,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E6,1e7/100     ! norm/tan stiffness of gap elem btwn plug & inner plate
!r,203,1.0E+07        ! normal stiffness of gap elem btwn plug and shell
r,204,1E5,1e6/100     ! norm/tan stiffness of gap elem btwn support ring & plug
keyopt,20,7,1         ! keyopt (7)=1

! et,21,shell63         ! Elastic Shell - Lifting Lugs
! r,21,0.75/2           ! half-thickness of lug

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

/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

T_otc=1.3125            ! outer top cover plate thickness
T_itc=1.25              ! inner top cover plate thickness
T_tplug=7.625           ! top shield plug thickness
T_tw=.50                ! thickness of outer top cover plate weld (min.)

H_ring=2.00             ! height of support ring
T_ring=0.75             ! thickness of support ring
```

```
L_otc=H_dsc-0.12          ! outer top cover plate location (top surface)
L_itc=L_otc-T_otc         ! inner top cover plate location (top surface)
L_tplug=L_itc-T_itc       ! top shield plug location (top surface)
L_ring=L_tplug-T_tplug    ! support ring location (top surface)
L_lug=L_ring-H_ring-0.75  ! lug location (top interface with shell)

B_lug=3.25                ! base height of the lifting lug
! H_lug=4.13               ! radial height of the lifting lug
! R_lug=1.75               ! radius of lug curvature
! R_thru=1.38/2            ! radius of lug thru hole


/com lower shell keypoints
k,1,OR                      ! shell outer bottom
k,2,IR                      ! shell inner bottom
k,6,IR,,H_dsc/2             ! mid-heght of DSC
k,7,OR,,H_dsc/2             ! mid-heght of DSC

/com upper shell keypoints
k,70,IR,,L_lug-B_lug        ! bottom base of the lifting lug
k,71,IR,,L_lug              ! top base of the lifting lug
k,72,IR,,L_ring-H_ring      ! bottom of the support ring
k,73,IR,,L_ring             ! top of the support ring
k,74,IR,,L_itc              ! top of the inner top cover plate
k,75,IR,,L_otc-T_tw         ! root of outer top cover plate weld
k,76,IR+0.21,,L_otc         ! shell inner top
k,77,OR-0.19,,L_otc         ! shell outer top
k,78,OR,,H_dsc-0.59         ! upper chamfer
k,79,OR,,L_itc              ! line up with KP74
k,80,OR,,L_ring             ! line up with KP73
k,81,OR,,L_ring-H_ring      ! line up with KP72
k,82,OR,,L_lug              ! line up with KP71
k,83,OR,,L_lug-B_lug        ! line up with KP70

/com outer top cover plate keypoints
k,90,IR,,L_otc              ! weld at inner radius of DSC
k,91,IR-0.49,,L_otc         ! weld interface at top surface
k,92,IR-0.9,,L_otc
k,93,0,,L_otc               ! center of top surface
k,95,0,,L_itc               ! center of bottom surface
k,96,IR-.44,,L_itc          ! outer radius (chamfer)at bottom surface

/com inner top cover plate keypoints
k,101,0,,L_itc              ! center of top surface
k,102,0,,L_tplug            ! center of bottom surface
k,103,IR,,L_tplug           ! outer radius at bottom surface
k,104,IR-.44,,L_itc         ! radius at top cover plate contact
k,105,IR-.44,,L_tplug       ! line up with KP104

/com top shield plug keypoints
k,110,IR,,L_tplug           ! outer radius at top surface
k,111,0,,L_tplug            ! center at top surface
k,112,0,,L_ring             ! center at bottom surface
k,113,IR,,L_ring            ! outer radius at bottom surface

/com support ring keypoints
k,120,IR,,L_ring              ! outer radius at top surface
k,121,IR-T_ring,,L_ring       ! inner radius at top surface
k,122,IR-T_ring,,L_ring-H_ring ! inner radius at bottom surface
k,123,IR,,L_ring-H_ring       ! outer radius at bottom surface

! /com lifting lug keypoints
! k,130,IR-H_lug+R_lug,,L_ring-R_lug
! k,131,IR-H_lug+R_lug,,L_ring
```

```
! k,132,IR-H_lug+(1-.707)*R_lug
! k,132,IR-H_lug+(1-.707)*R_lug,,L_ring-R_lug-.707*R_lug
! k,133,IR-0.6,,L_lug-B_lug

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 upper shell elements
lsel,none
asel,none
vsel,none
type,11
mat,1
a,6,70,83,7
a,70,71,82,83
a,71,72,81,82
a,72,73,80,81
a,73,74,79,80
a,74,75,78,79
a,75,76,77,78
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,,,6,70,64              ! select central shell line (inner)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,1/6.4       ! 4" to 0.625" element size
ksel,s,,,7,83,76              ! select central shell line (outer)
lslk,s,1                      ! lines containing selected keypoints
lesize,all,2.31,,,6.4         ! 0.5" to 4" element size
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
esize,0.75                    ! 0.75" element height for unmeshed lines
vmesh,all
cm,aushell,area
cm,vushell,volume
ksel,all

/com outer top cover plate elements
lsel,none
asel,none
vsel,none
type,12
mat,1
a,91,92,96,75
lsel,r,loc,x,IR-0.9,IR        ! select lines for dividing
llist
lesize,all,,,2                ! 2 divisions for selected lines
```

```
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,92,kp(0,IR-0.9,L_otc),93,93,96,kp(0,IR-0.44,L_itc),95,95
ksel,s,,,93,95,2              ! select centerline
lslk,s,1                      ! lines containing selected keypoints
lesize,all,,,2                ! 2 divisions thru plate thickness
vmesh,all
cm,aouttop,area
cm,vouttop,volume
ksel,all

/com inner top cover plate elements
lsel,none
asel,none
vsel,none
type,13
mat,1
ksel,s,kp,,74
ksel,a,kp,,101,105,1
a,74,104,105,103
lsel,s,loc,x,IR-.4,IR-.1
lesize,all,,,1,               ! 1 division for horizontal lines
vdrag,all,,,,,,1              ! generate volume along line 1 ("swp_arc1")
v,104,kp(0,IR-.44,L_itc),101,101,105,kp(0,IR-.44,L_tplug),102,102
esize,T_itc/2                 ! 2 elements thru plate
vmesh,all
cm,aintop,area
cm,vintop,volume
ksel,all

/com top shield plug elements
lsel,none
asel,none
vsel,none
type,14
mat,2
ksel,s,kp,,110,113,1
ldrag,110,113,,,,,2           ! generate lines along line 2 ("swp_arc2")
v,110,kp(0,IR,L_tplug),111,111,113,kp(0,IR,L_ring),112,112
esize,T_tplug/3               ! 3 elements thru plate
vmesh,all
cm,atopplug,area
cm,vtopplug,volume
ksel,all

/com weld of outer top cover plate
lsel,none
asel,none
vsel,none
type,15
mat,1
a,76,91,75,75
lsel,r,loc,z,L_otc
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,atopweld,area
cm,vtopweld,volume

/com support ring elements
lsel,none
asel,none
vsel,none
type,16
mat,1
```

```
a,120,121,122,123
lsel,r,loc,z,L_ring          ! select upper radial line
lesize,all,,,2,(T_ring-.40)/.40 ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
lsel,r,loc,z,L_ring-H_ring   ! select lower radial line
lesize,all,,,2,.40/(T_ring-.40) ! 2 divisions, gen node at shield plug chamfer
lsla,s                       ! lines contained in above areas
vdrag,all,,,,,,1             ! generate volume along line 1 ("swp_arc1")
esize,H_ring/2               ! 2 elements thru plate height
vmesh,all
cm,asupring,area
cm,vsupring,volume

! /com lifting lug elements
! lsel,none
! asel,none
! vsel,none
! type,21
! real,21
! mat,1
! larc,131,132,130,R_lug       ! define arc
! a,70,71,122,121,131,132,133  ! define gross area
! cm,a_gross,area
! asel,none
! wplane,,0,0,0,IR,0,0,0,0,L_otc ! workplane definition
! cyl4,kx(130),kz(130),R_thru  ! define circular area of thru hole
! wpstyle,defa                 ! return to default workplane
! cm,a_thru,area
! asel,a,area,,a_gross
! asba,a_gross,a_thru
! amesh,all
! csys,1                       ! cylindrical coordinates
! esel,s,type,,21              ! select lug elements & nodes
! allsel,below,elem
! *get,maxnode,node,,num,max
! ngen,2,maxnode,all,,,0,90,0  ! generate lug at 90 degrees
! egen,2,maxnode,all
! csys,0                       ! cartesian coordinates
! esel,s,type,,11,21,10
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to shell nodes
! esel,s,type,,16,21,5
! allsel,below,elem
! nummrg,node                  ! merge lug nodes to support ring nodes

! allsel

/com merge nodes for material continuity

esel,s,type,,11,12,1
esel,a,type,,15
nsle
nummrg,node                  ! upper shell to weld to outer top 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,,11,13,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,z,L_itc-.01,L_itc+.01
nummrg,node                    ! weld of inner cover plate to shell

esel,s,type,,11,16,5
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
nummrg,node                    ! upper (continuous) weld of support ring

nsel,s,loc,y,0,90/26
nsel,a,loc,y,5.9*90/26,7.1*90/26
nsel,a,loc,y,11.9*90/26,13.1*90/26
nsel,a,loc,y,18.9*90/26,20.1*90/26
nsel,a,loc,y,24.9*90/26,26*90/26
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
nummrg,node                    ! lower (intermittent) weld of support ring

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,11,16,1                  ! merge nodes at line of symmetry (top shell components)
   /gopr
    esel,s,type,,i
    nsle
    nummrg,node
*enddo

! esel,s,type,,21
! nsle
! nummrg,node                    ! merge nodes at line of symmetry (lifting lug nodes)
! allsel

/com define contact elements
/com top end plates

!esel,s,type,,11
!nsle
!cm,cont11,node                 ! nodes of upper shell

esel,s,type,,12
nsle
cm,cont12,node                 ! nodes of outer top cover plate

esel,s,type,,13
nsle
cm,cont13,node                 ! nodes of inner top cover plate

csys,1                         ! cylindrical coordinates
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring+.1,IR-.1
cm,cont16,node                 ! nodes of support ring at plug chamfer
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,IR-T_ring-.1,IR-T_ring+.1
cm,cont161,node                ! nodes of support ring at inner radius
```

```
csys,0                          ! cartesian coordinates

cmsel,s,cont13
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,targ1312,node                ! inner top cover plate top surface nodes

csys,1                          ! cylindrical coordinates

esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
nsel,r,loc,x,10.5*IR/12,IR+.1
cm,targ1413,node                ! top shield plug top surface nodes

!esel,s,type,,14
!nsle
!nsel,r,loc,x,IR-.01,IR+.01
!cm,targ1411,node                ! top shield plug circumferential nodes

esel,s,type,,14
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
nsel,r,loc,x,10.5*IR/12,IR+.1          ! mesh dependent
cm,targ1416,node                ! support ring inner top surface nodes

csys,0                          ! cartesian coordinates

allsel
type,20
real,201
gcgen,cont12,targ1312,1         ! generate contact elem btwn inner & outer plates
real,202
gcgen,cont13,targ1413,1         ! generate contact elem btwn plug & inner plate
! real,203
! gcgen,cont11,targ1411,1         ! generate contact elem btwn plug and shell
real,204
gcgen,cont16,targ1416,1         ! gen contact elem btwn support ring & plug (outer)
gcgen,cont161,targ1416,1        ! gen contact elem btwn support ring & plug (inner)

/com Define soft springs to stabilize shield plug (connect to support ring)
/com Valid for thermal + pressure
allsel
esel,s,type,,14
nsle
node1i=node(IR,0,L_ring)
node2i=node(-IR,0,L_ring)
esel,s,type,,16
nsle
node1j=node(IR,0,L_ring)
node2j=node(-IR,0,L_ring)
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

!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
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0,.01
d,all,ux
allsel

/com ux couple shield plug to support ring for stability (one locations)
/com ********* valid only for temp & internal pressure loading **********
esel,s,type,,14,16,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
cp,next,ux,all

allsel

vclear,12
esel,s,type,,14
edele,all
esel,s,type,,20
edele,all
esel,s,type,,22
edele,all
alls


save

fini

/solution

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

/com 24P-FO DSC (Top End) Nonlinear Pressure Start, 1 psi
/title, 24P-S DSC (Top End) Nonlinear Pressure Start, 1 psi
nsubst,1,8

!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,1                 ! 1 psi
!nsle
!nsel,r,loc,z,L_tplug-.01,L_itc+.01
!nsel,r,loc,x,IR-.01,IR+.01
!sf,all,pres,1
```

```
!esel,s,type,,14
!nsle
!nsel,r,loc,z,L_tplug-.01,L_tplug+.01
!sf,all,pres,.001            ! Stability pressure for shield plug

allsel
csys,0

!lswrite                      ! end of load step 1

save

!solve
save

r,201,1E6,1e6/100,,,5 ! norm/tan stiffness of gap elem btwn inner & outer plates
r,202,1E6,1e7/100     ! norm/tan stiffness of gap elem btwn plug & inner plate
r,204,1E6,1e6/100     ! norm/tan stiffness of gap elem btwn support ring & plug


/com Temperature Case 26, 117 deg Ambient + 10 psi
/title, 24P-FO DSC (Top End) Temp Case 26, 117 deg Ambient + 10 psi
nsubst,2,10
csys,1

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,10                ! 10 psi
nsle
nsel,r,loc,z,L_tplug-.01,L_itc+.01
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,10
alls

/com read input from thermal results file
ldread,temp,3,,,,t24therm,rth,d:\fo-dsc\newansys\top\

allsel
csys,0

lswrite                       ! end of load step 3
save


solve
save

fini

/exit

/eof
```

PT24PTP3.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, top end
/com  thermal + pressure loads
resume,t24ptp3,db
/post1
file,t24ptp3,rst

/com element plots ------------------------------------------------------------
/show,pt24ptp3,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,0.03,0.75,0.94,-0.79
/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 Upper Shell Post1 Results ---------------------------------------------
esel,s,type,,11
nsle
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
cm,outer,node                 ! outer surface nodes
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-H_ring-5,H_dsc-.7
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,,11
   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,,11
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,11
 nsle
 *do,ix,IR+.21,OR-.19,OR-.19-(IR+.21)
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
 *do,iz,L_otc-.47/2,L_otc-.47,-.47/2
   inode=node(IR,theta,L_otc-T_tw)
   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 Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,12
nsle
nsel,r,loc,z,L_otc-.01,L_otc+.01
nsel,r,loc,x,0,IR-0.8
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
nsel,r,loc,x,0,IR-0.4
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_itc)
   *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_otc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,12
   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,,12
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,12
 nsle
   inode=node(IR-.22,theta,185.17)
   onode=node(IR-.70,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(IR-.49,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
*enddo                         ! theta loop

/com DSC Outer Top Cover Plate Weld Post1 Results ------------------------------
*do,theta,0,180,90/26          ! sections at 3.46 degree intervals
 esel,s,type,,15
 nsle
 nsel,r,loc,y,theta-1,theta+1
 esln
 esel,r,type,,15
 nsle
 *do,ix,IR-.49,IR+.21,(.49+.21)/2
   inode=node(IR,theta,L_otc-T_tw)
   onode=node(ix,theta,L_otc)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 *enddo
*enddo                         ! theta loop

/com DSC Inner Top Cover Plate Post1 Results ----------------------------------
esel,s,type,,13
nsle
nsel,r,loc,z,L_itc-.01,L_itc+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_tplug)
   *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_itc)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,13
   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 Top Shield Plug Post1 Results ----------------------------------------
esel,s,type,,14
nsle
nsel,r,loc,z,L_tplug-.01,L_tplug+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring)
   *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_tplug)
   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,,14
   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 Support Ring Post1 Results ------------------------------------
esel,s,type,,16
nsle
nsel,r,loc,z,L_ring-.01,L_ring+.01
cm,outer,node                  ! outer surface nodes
nsle
nsel,r,loc,z,L_ring-H_ring-.01,L_ring-H_ring+.01
cm,reminner,node               ! inner surface nodes
*get,totnode,node,,count
*do,i,1,totnode,1
   !/gopr
   inode=node(0,0,L_ring-H_ring)
   *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_ring)
   nsel,s,node,,inode
   nsel,a,node,,onode
   esln
   esel,r,type,,16
   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 Outer Top Cover Plate ---------------------------
esel,s,type,,12,15,3
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_otc-T_tw-.01,L_otc-T_tw+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Inner Top Cover Plate ---------------------------
/com
/com top row of nodes (pinned weld)
esel,s,type,,13
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_itc-.01,L_itc+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce

/com Nodal Forces for Weld of Support Ring ------------------------------------
/com
/com top row of nodes (continuous weld)
esel,s,type,,16
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,z,L_ring-.01,L_ring+.01
spoint,,.01,.01,0            ! summation in cylindrical coordinate system
nlist
nforce
/com
/com bottom row of nodes (intermittent weld)
nsle
nsel,r,loc,x,IR-.1,IR+.1
nsel,r,loc,z,L_ring-H_ring-.1,L_ring-H_ring+.1
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

/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,-0.02,0.60,0.93,-0.86
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,-0.5
/replot
/zoom,1,rect,0.03,0.75,0.94,-0.79
```

```
/auto,1                         ! zoom - fit

/dscale,,1                      ! displacement scale

/com shell elements
esel,s,type,,11
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,,12
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,,15
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,,13
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,,14
nsle
/view,,-0.2,-0.8,-0.5
plnsol,s,int,0                  ! plot stress intensity
/view,,0.2,0.8,0.5
/replot

/com support ring elements
esel,s,type,,16
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

/eof
```

Appendix A14

ANSYS Analysis Run Summary and Input Listings for QB24PLT

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QB24PLT (analysis) (1) PB24PLT (postprocessing) (1)

Date/Time: 3/7/00 11:15 PM 4/12/00 12:17 AM

ANSYS Version: 5.3 PC386/486

Hardware Summary:

Operating System: Windows NT Ver. 4.0

CPU: Dual Pentium-II 450 MHz

Analysis Modules Used: ❊PREP7 ❊SOLUTION ❊POST1

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

Loads Considered: Leak test pressure and axial 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: Michael E. Gohen Date: 6/19/00

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

QB24PLT.inp

```
/batch,list
/filname,qb24plt
/title,24P-short DSC (Bottom End, Shell & Inner Cover Only, 90 Degree Model)
/prep7

/com shell assembly components
et,1,solid45          ! 3-D Elastic/Plastic Solid - DSC Lower Shell
et,4,solid45          ! 3-D Elastic/Plastic Solid - DSC Inner Bottom Pl

tref,450              ! 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

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 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

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 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
```

```
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 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

save

fini

/solution

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

/com load step 1 - 155k axial + 14.7 psi ext.pressure on shell & inner cover
/title,24P-s DSC (Bot.End) 155k Axial + 14.7 psi External Pressure
csys,1                        ! cylindrical coordinates
esel,s,type,,1
nsle
```

```
nsel,r,loc,z,L_ibc,H_dsc/2   ! shell from inner cover plate and up
nsel,r,loc,x,OR-.01,OR+.01
sf,all,pres,14.7             ! full vacuum pressure
esel,s,type,,4
nsle
nsel,r,loc,z,L_bplug-.1,L_bplug+.01 ! inner cover plate
sf,all,pres,14.7             ! full vacuum pressure
esel,s,type,,1
nsle
nsel,r,loc,z,0
Pload=155000                          ! total axial load
Aload=3.14159*((OR-.25)**2-(IR+.21)**2) ! load area at bottom edge of shell
sf,all,pres,Pload/Aload      ! axial compression load on shell
csys,0                       ! cartesian coordinates
allsel
lswrite
save
solve
save

fini

/exit

/eof
```

PB24PLT.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  leak test
resume,qb24plt,db
/post1
file,qb24plt,rst

/com element plots ------------------------------------------------------------
/show,pb24plt,pic,1          ! plot to file
/triad,lbot                  ! triad in lower corner
/device,vector,1             ! vector plots
/num,2                       ! numbers, no colors
/vup,1,z                     ! z-axis up
/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,-.40,-.13,.39,-.90
/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,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 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 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 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
! esel,u,type,,20                ! unselect contact elements
/view,,-0.2,-0.9,0.3
plnsol,s,int,0                 ! plot stress intensity
/zoom,1,rect,-.40,-.13,.39,-.90
/auto,1                        ! zoom - fit
/view,,-0.2,-0.9,-0.3
/replot
/zoom,1,rect,-.40,-.13,.39,-.90
/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 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

dsys,1

*enddo                         ! end load step loop

allsel

fini

exit,nosave
```

Appendix A15

ANSYS Analysis Run Summary and Input Listings for QB24PIP

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QB24PIP (analysis) (1) PB24PIP (postprocessing) (1)

Date/Time: 4/26/20 6:37 AM 4/22/20 11:13 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: Internal pressure on inner pressure boundary (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 *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Step 5 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 5 are not used.

Run By: MBCohen Date: 6/15/00
Michael E. Cohen

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

QB24PIP.inp

```
/batch,list
/filname,qb24pip
/title,24P-FO 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 - .0005 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Bottom End) .0005 psi Pressure on Shell & Inner Cover
nsubst,1,10
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,.0005
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 10 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Bottom End) 10 psi Pressure on Shell & Inner Cover
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
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,10
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
/title,24P-FO DSC (Bot.End) 10 psi on Shell & Inner Cover (Outer Cover Pinned)
nsubst,1,20
esel,s,type,,5
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
lswrite
save
solve
save

/com load step 4 - 60 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Bot.End) 60 psi on Shell & Inner Cover (Outer Cover Pinned)
nsubst,1,20
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,60
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 5 - unpin outer cover plate weld
/title,24P-FO DSC (Bot.End) 60 psi Pressure on Shell & Inner Cover
nsubst,1,20
ealive,all                      ! unkill weld elements
lswrite
save
```

```
solve
save

fini

/exit

/eof
```

PB24PIP.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  internal pressure load
resume,qb24pip,db
/post1
file,qb24pip,rst

/com element plots ------------------------------------------------------------
/show,pb24pip,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,-0.890177,0.220652,-0.254692,-0.483152
/show,off                    ! discontinue plots to file
/auto,1                      ! zoom - fit

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

*do,iset,2,5                 ! 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,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.890,0.221,-0.255,-0.483
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.982,0.517,-0.327,-0.373
/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 A16

ANSYS Analysis Run Summary and Input Listings for QB24PFL

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QB24PFL (analysis) [1] PB24PFL (postprocessing) [1]

Date/Time: 4/20/20 6:35 AM 4/26/20 6:42 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: External flood pressure, 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 *.pic* extensions.
2. Specific load values are tabulated in an ANSYS Run Summary Table in the body of the calculation.
3. Load Step 5 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 5 are not used.

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

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

QB24PFL.inp

```
/batch,list
/filname,qb24pfl
/title,24P-FO 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+05           ! normal stiffness of gap elem btwn plug & shell
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
keyopt,20,7,1           ! keyopt (7)=1


tref,450                ! 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,1,200,300,400,500,600,700
dens,2,490/1728
mpdata,ex,2,1,28.8E+06,28.3E+06,27.7E+06,27.3E+06,26.7E+06,25.5E+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

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

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
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 couple UZ center inner bottom cover plate node at
!/com surface in contact with bottom shield plug
csys,1                          ! cylindrical coordinates
esel,s,type,,3,4
nsle
nsel,r,loc,x,0
nsel,r,loc,z,L_bplug
cp,next,uz,all
csys,0
allsel


!/com couple UZ center outer bottom cover plate node at
!/com surface in contact with bottom shield plug
!csys,1                          ! cylindrical coordinates
csys,1                          ! cylindrical coordinates
esel,s,type,,2,3
nsle
nsel,r,loc,x,0
nsel,r,loc,z,T_obc
cp,next,uz,all
csys,0
allsel

stop=0
*if,stop,eq,0,then
/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 - .0005 psi external pressure on shell & outer cover plate
/title,24P-FO DSC (Bot.End) .0005 psi External Pressure
nsubst,1,10
csys,1                          ! cylindrical coordinates
esel,s,type,,2,5,3
esel,a,type,,1
nsle
nsel,r,loc,z,-.01,.01           ! outer cover plate & weld
nsel,a,loc,x,OR-.26,OR+.01      ! shell
sf,all,pres,.0005
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - 22 psi external pressure on shell & outer cover plate
/title,24P-FO DSC (Bot.End) 22 psi External Pressure
nsubst,1,20
r,202,1.0E+07,1E7/100           ! norm/tan stiff. of gap elem btwn plug & outer plate
r,203,1.0E+07,1E7/100           ! norm/tan stiff. of gap elem btwn plug & inner plate
csys,1                          ! cylindrical coordinates
esel,s,type,,2,5,3
esel,a,type,,1
nsle
nsel,r,loc,z,-.01,.01           ! outer cover plate & weld
nsel,a,loc,x,OR-.26,OR+.01      ! shell
sf,all,pres,22
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - pin outer cover plate weld
/title,24P-FO DSC (Bot.End) 22 psi External Pressure (Outer Cover Pinned)
nsubst,1,20
esel,s,type,,5
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
lswrite
save
solve
save

/com load step 4 - add 10 psi internal pressure on shell & inner cover plate
/title,24P-FO DSC (Bot.End) 22 psi Ext. +.10 psi Int. (Outer Cover Pinned)
```

```
nsubst,1,20
csys,1                          ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,10
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 5 - unpin outer cover plate weld
/title,24P-FO DSC (Bot.End) 21.7 psi External + 10 psi Internal Pressure
nsubst,1,20
ealive,all                      ! unkill weld elements
lswrite
save
solve
save

fini

/exit

/eof
*endif
```

PB24PFL.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  flood load
resume,qb24pfl,db
/post1
file,qb24pfl,rst

/com element plots ------------------------------------------------------------
/show,pb24pfl,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,-0.890177,0.220652,-0.254692,-0.483152
/show,off                      ! discontinue plots to file
/auto,1                        ! zoom - fit

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

*do,iset,2,5                   ! 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,,500                 ! 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,-0.890,0.221,-0.255,-0.483
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.982,0.517,-0.327,-0.373
/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 A17

ANSYS Analysis Run Summary and Input Listings for QB24P1G

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: QB24P1G (analysis) [1] PB24P1G (postprocessing) [1]

Date/Time: 3/7/00 11:11 PM 5/2/00 9:29 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: 1g axial outward acceleration, fuel inertial pressure [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

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

QB24P1G.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  1g axial handling load
resume,qb24p1g,db
/post1
file,qb24p1g,rst

/com element plots ------------------------------------------------------------
/show,pb24p1g,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,-0.89,0.22,-0.25,-0.48
/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,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,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.89,0.22,-0.26,-0.48
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.98,0.52,-0.33,-0.37
/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
```

PB24P1G.inp

```
/batch,list
/com
/com postprocessing input file for quarter model of DSC shell, bottom end
/com  1g axial handling load
resume,qb24p1g,db
/post1
file,qb24p1g,rst

/com element plots ------------------------------------------------------------
/show,pb24p1g,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,-0.89,0.22,-0.25,-0.48
/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,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,-0.8,-0.5
plnsol,s,int,0               ! plot stress intensity
/zoom,1,rect,-0.89,0.22,-0.26,-0.48
/auto,1                      ! zoom - fit
/view,,-0.2,-0.8,0.5
/replot
/zoom,1,rect,-0.98,0.52,-0.33,-0.37
/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 A18

ANSYS Analysis Run Summary and Input Listings for B24PDW

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PDW (analysis) (1) PB24PDW (postprocessing) (1)

Date/Time: 3/7/00 8:07 PM 4/12/00 1:39 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: Deadweight acceleration on horizontal DSC (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: Michael E. Cohen Date: 6/19/00

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

B24PDW.inp

```
/batch,list
/filname,b24pdw
/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+07         ! norm/tan stiffness of gap elem btwn plug & outer plate
! r,203,1.0E+07         ! norm/tan stiffness of gap elem btwn plug & inner plate
! keyopt,20,7,1         ! keyopt (7)=1


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,,,26,2.67/1.5 ! 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

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
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 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 ends at mid-height
d,all,uz,0                ! restrain point at far end, away from grapple ring

/com radial restraint along 2 longitudinal lines of shell nodes at perimeter
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 2" from symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc-0.3,T_obc+T_bplug/6          !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/6,T_obc+T_bplug/2    !6 & 2 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/2,L_bplug-T_bplug/6 !2 & 6 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_bplug-T_bplug/6,L_bplug+.01      !6 is mesh dependent
cp,next,ux,all

allsel

/com uz couple a shield plug node to an inner cover plate node for stability
/com ***** valid for independent grapple pull-out and side drop ! *******
nsel,s,loc,x,0,0.1
nsel,r,loc,y,0,0.1
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,uz,all

allsel

save

fini

/solution
antype,static
eqslv,pcg,1e-7
nropt,auto
! pred,on,,on
! autots,on
nlgeom,on
! neqit,100

/com load step 1 - 1g gravity load, horizontal DSC on rail
/title,24P-s DSC (Bot.End) 1g gravity load, horizontal DSC on rail
```

```
/com analysis parameters
nsubst,1,8
acel,-1.
lswrite
save
solve
save

/com load step 2 - pin outer cover plate weld
/title,24P-s DSC (Bot.End) 1g grav.load, horiz DSC (outer cover pinned)
nsubst,1,8
esel,s,type,,5
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                   ! unkill weld elements for postprocessing
save

fini

/exit

/eof
```

PB24PDW.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  horizontal deadweight
resume,b24pdw,db
/post1
file,b24pdw,rst

/com element plots ------------------------------------------------------------
/show,pb24pdw,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,1,2                 ! 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
theta=0
sf=1.02325
dtheta=2.5561/sf
*do,i,1,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
theta=0
sf=1.02325
dtheta=2.5561/sf
```

```
*do,i,1,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i 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
 theta=0
 sf=1.02325
 dtheta=2.5561/sf
 *do,i,1,27                   ! 26+1 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                        ! end i loop

 theta=94.550
 sf=1/1.02325
 dtheta=4.550
 *do,i,1,26                    ! 26 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                        ! end i loop

 /com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
 theta=0
 sf=1.02325
 dtheta=2.5561/sf
 *do,i,1,27                    ! 26+1 nodes of graduated distribution
  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
dtheta=sf*dtheta
theta=theta+dtheta
*enddo                          ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                      ! 26 nodes of graduated distribution
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                          ! end i 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,,100                ! 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 A19

ANSYS Analysis Run Summary and Input Listings for B24THERM

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24THERM (analysis) (1) PB24THRM (analysis) (1)

Date/Time: 6/14/00 12:19 PM 6/19/00 1:15 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)

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

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

B24THERM.inp

```
/batch,list
/filname,b24therm
/title,24P-FO 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+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,70               ! 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
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_arcl,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

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 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
```

```
/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
!nropt,auto
!neqit,50
!pred,on,,on
!autots,on
!nlgeom,on
!eqslv,pcg,1e-9
!nsubst,10

/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 A20

ANSYS Analysis Run Summary and Input Listings for B24PSID2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PSID2 (analysis) [1] PB24PSD2 (postprocessing) [1]

Date/Time: 1/13/00 6:04 PM 4/20/20 12:17 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: 75g side drop acceleration [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: M.E. Cohen Date: 6/19/00
Michael E. Cohen

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

B24PSID2.inp

```
/batch,list
/filname,b24psid2
/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+07           ! norm/tan stiffness of gap elem btwn plug &
outer plate
! r,203,1.0E+07           ! norm/tan stiffness of gap elem btwn plug &
inner plate
! keyopt,20,7,1           ! keyopt (7)=1


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 non-linear properties - Type 316
etan1=.05                          ! slope of tangent modulus
tb,bkin,1,6
tbtemp,70
tbdata,,30000,etan1*28.3E+06       ! c1=sy, c2=tangent modulus
tbtemp,200
```

```
tbdata,,25800,etan1*27.6E+06     ! c1=sy, c2=tangent modulus
tbtemp,300
tbdata,,23300,etan1*27.0E+06     ! c1=sy, c2=tangent modulus
tbtemp,400
tbdata,,21400,etan1*26.5E+06     ! c1=sy, c2=tangent modulus
tbtemp,500
tbdata,,19900,etan1*25.8E+06     ! c1=sy, c2=tangent modulus
tbtemp,600
tbdata,,18800,etan1*25.3E+06     ! c1=sy, c2=tangent modulus

/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,,,26,2.67/1.5 ! 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

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
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 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 ends at mid-height
d,all,uz,0                ! restrain point at far end, away from
grapple ring

/com radial restraint along 2 longitudinal lines of shell nodes at
perimeter
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at
x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 2" from
symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc-0.3,T_obc+T_bplug/6          !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/6,T_obc+T_bplug/2    !6 & 2 are mesh
dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
```

```
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/2,L_bplug-T_bplug/6 !2 & 6 are mesh
dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_bplug-T_bplug/6,L_bplug+.01     !6 is mesh dependent
cp,next,ux,all

allsel

/com uz couple a shield plug node to an inner cover plate node for
stability
/com ***** valid for independent grapple pull-out and side drop !
*******
nsel,s,loc,x,0,0.1
nsel,r,loc,y,0,0.1
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,uz,all

allsel

save

fini

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

/solution
antype,static
eqslv,pcg,1e-7
nropt,auto
pred,on,,on
autots,on
nlgeom,on
neqit,100

/com load step 1 - 75g side drop on rail w/plasticity & nlgeom
/title,24P-s DSC (Bot.End) 75g side drop on rail
/com analysis parameters
nsubst,10,160
acel,-75.
lswrite
save
solve
save
```

```
/com load step 2 - pin outer cover plate weld
/title,24P-s DSC (Bot.End) 75g side drop on rail (outer cover
pinned)
nsubst,1,8
esel,s,type,,5
nsle
ekill,all                    ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all                   ! unkill weld elements for
postprocessing
save

fini

*endif

/exit

/eof
```

PB24PSD2.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  side drop
resume,b24psid2,db
/post1
file,b24psid2,rst

/com element plots ------------------------------------------------------------
/show,pb24psd2,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,1,2                  ! 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,0,3
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,0,3
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
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
theta=5.1719
```

```
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i 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
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com DSC Outer Bottom Cover Plate Weld Post1 Results ------------------------
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 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
  dtheta=sf*dtheta
  theta=theta+dtheta
*enddo                          ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                      ! 26 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
*enddo                          ! end i 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_ibc+.01
nsel,r,loc,x,IR-.3,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cmsel,u,unnode
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cmsel,u,unnode
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
   cmsel,u,unnode
   esln,,1
   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

/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

/com all elements except contact elements and shell elements above rail
esel,s,type,,1
nsle
nsel,r,loc,y,0,3
cm,unnode,node
allsel
esel,u,type,,20
cmsel,u,unnode
esln,,1
/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 shell elements excluding those directly above rail
esel,s,type,,1
nsle
nsel,u,loc,y,0,3
esln,,1
/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 elements excluding those in direct contact with shell
esel,s,type,,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/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 inner cover plate elements excluding those in direct contact with shell
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.3,IR+.01
```

```
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/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 A21

ANSYS Analysis Run Summary and Input Listings for B24PSID3

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PSID3 (analysis) (1) PB24PSD3 (postprocessing) (1)

Date/Time: 4/25/00 7:13 PM 4/26/20 7:52 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: 75g side drop acceleration with internal pressure (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

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

B24PSID3.inp

```
/batch,list
/filname,b24psid3
/title,24P-FO 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+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
keyopt,20,7,1         ! keyopt (7)=1


tref,500

/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 non-linear properties - Type 316
etan1=.05                       ! slope of tangent modulus
tb,bkin,1,6
tbtemp,70
tbdata,,30000,etan1*28.3E+06    ! c1=sy, c2=tangent modulus
tbtemp,200
tbdata,,25800,etan1*27.6E+06    ! c1=sy, c2=tangent modulus
tbtemp,300
tbdata,,23300,etan1*27.0E+06    ! c1=sy, c2=tangent modulus
tbtemp,400
tbdata,,21400,etan1*26.5E+06    ! c1=sy, c2=tangent modulus
tbtemp,500
tbdata,,19900,etan1*25.8E+06    ! c1=sy, c2=tangent modulus
tbtemp,600
tbdata,,18800,etan1*25.3E+06    ! c1=sy, c2=tangent modulus

/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,20,IR                       ! weld at inner radius of DSC
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,25,OR_load                  ! radius of the ram load
k,26,0,0,0                    ! center at bottom surface
! k,27,0,,T_bw                  ! center of plate, internal
k,28,0,,T_obc                 ! center at top surface
! k,29,OR_load,,T_obc           ! line up with KP25
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
! k,43,IR-0.25,,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+0.21,,L_otc           ! shell inner top
! k,77,OR-0.19,,L_otc           ! shell outer top
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,,,26,2.67/1.5 ! 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,2.0,,,8            ! 0.5" to 4" element size
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,2.0,,,1/8          ! 4" to 0.5" element size
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
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


/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

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
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,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 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 ends at mid-height
d,all,uz,0                ! restrain point at far end, away from grapple ring

/com radial restraint along 2 longitudinal lines of shell nodes at perimeter
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,-.01,.01
d,all,ux,0                ! restrain a longitudinal line of nodes at x=OR
csys,1                    ! cylindrical
nsel,s,loc,x,OR-.01,OR+.01
nsel,r,loc,y,2.4,2.8      ! mesh dependent
nrotat,all
d,all,ux,0                ! restrain a long. line of nodes 2" from symm. line
csys,0                    ! cartesian
allsel

/com ux-couple shield plug & shell nodes along drop contact line
/com valid for side loading only!
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc-0.3,T_obc+T_bplug/6          !6 is mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/6,T_obc+T_bplug/2    !6 & 2 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,T_obc+T_bplug/2,L_bplug-T_bplug/6 !2 & 6 are mesh dependent
cp,next,ux,all
nsel,s,loc,x,IR-.01,IR+.01
nsel,r,loc,y,-.01,.01
nsel,r,loc,z,L_bplug-T_bplug/6,L_bplug+.01      !6 is mesh dependent
cp,next,ux,all

allsel

/com uz couple a shield plug node to an inner cover plate node for stability
/com ***** valid for independent grapple pull-out and side drop ! *******
```

```
nsel,s,loc,x,0,0.1
nsel,r,loc,y,0,0.1
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,uz,all

allsel

save

fini

/solution
antype,static
eqslv,pcg,1e-7
nropt,auto
pred,on,,on
autots,on
nlgeom,on
neqit,100

/com load step 1 - (75g+20psi)/2000 side drop on rail w/plast. & nlgeom
/title,24P-FO DSC (Bot.End) (75g+20psi)/2000 side drop on rail
/com analysis parameters
nsubst,1,8
acel,-75/2000
csys,1                        ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,20/2000
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 2 - (75g+20psi)/10 side drop on rail w/plast. & nlgeom
/title,24P-FO DSC (Bot.End) (75g+20psi)/10 side drop on rail
/com analysis parameters
nsubst,1,8
r,202,1e6,1e7/100
r,203,1e6,1e7/100
acel,-75/10
csys,1                        ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
sf,all,pres,2
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 3 - 75g+20psi side drop on rail w/plasticity & nlgeom
/title,24P-FO DSC (Bot.End) 75g+20psi side drop on rail
/com analysis parameters
nsubst,8,50
r,202,1e7,1e7/100
r,203,1e7,1e7/100
acel,-75.
csys,1                        ! cylindrical coordinates
nsel,s,loc,z,L_ibc-.01,H_dsc/2
nsel,r,loc,x,0,IR+.01
```

```
sf,all,pres,20
csys,0                          ! cartesian coordinates
allsel
lswrite
save
solve
save

/com load step 4 - 75g+20psi side drop on rail w/plasticity & nlgeom (outer cover pinned)
/title,24P-FO DSC (Bot.End) 75g+20psi side drop on rail (outer cover pinned)
/com analysis parameters
nsubst,1,8
esel,s,type,,5
nsle
ekill,all                       ! kill weld elements
esel,all
nsle
lswrite
save
solve
ealive,all
save

fini

/exit

/eof
```

PB24PSD3.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  side drop + internal pressure
resume,b24psid3,db
/post1
file,b24psid3,rst

/com element plots ------------------------------------------------------------
/show,pb24psd3,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,3,4                  ! 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
nsel,u,loc,y,0,3
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,0,3
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
theta=5.1719
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,T_obc
 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
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

/com
/com shell at mid-height
theta=5.1719
```

```
sf=1.02325
dtheta=2.5561*sf
*do,i,3,27                    ! 26+1 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i loop

theta=94.550
sf=1/1.02325
dtheta=4.550
*do,i,1,26                    ! 26 nodes of graduated distribution
 esel,s,type,,1
 nsle
 nsel,r,loc,y,theta-1,theta+1
 nsel,r,loc,z,0,H_dsc/2-5,H_dsc/2+.01
 esln
 esel,r,type,,1
 nsle
   inode=node(IR,theta,H_dsc/2)
   onode=node(OR,theta,H_dsc/2)
   nlist,inode,onode,onode-inode
   lpath,inode,onode
   prsect
 dtheta=sf*dtheta
 theta=theta+dtheta
*enddo                        ! end i 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
 theta=5.1719
 sf=1.02325
 dtheta=2.5561*sf
 *do,i,3,27                   ! 26+1 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                       ! end i loop

 theta=94.550
 sf=1/1.02325
 dtheta=4.550
 *do,i,1,26                   ! 26 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                       ! end i loop

 /com DSC Outer Bottom Cover Plate Weld Post1 Results ---------------------------
 theta=5.1719
 sf=1.02325
 dtheta=2.5561*sf
 *do,i,3,27                   ! 26+1 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                          ! end i loop

 theta=94.550
 sf=1/1.02325
 dtheta=4.550
 *do,i,1,26                      ! 26 nodes of graduated distribution
  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
  dtheta=sf*dtheta
  theta=theta+dtheta
 *enddo                          ! end i 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_ibc+.01
nsel,r,loc,x,IR-.3,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cmsel,u,unnode
cm,outer,node                ! outer surface nodes
nsle
nsel,r,loc,z,L_ibc-.01,L_ibc+.01
cmsel,u,unnode
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
   cmsel,u,unnode
   esln,,1
   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

/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

/com all elements except contact elements and shell elements above rail
esel,s,type,,1
nsle
nsel,r,loc,y,0,3
cm,unnode,node
allsel
esel,u,type,,20
cmsel,u,unnode
esln,,1
/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 shell elements excluding those directly above rail
esel,s,type,,1
nsle
nsel,u,loc,y,0,3
esln,,1
/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 elements excluding those in direct contact with shell
esel,s,type,,2
nsle
nsel,r,loc,x,IR-.01,IR+.01
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/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 inner cover plate elements excluding those in direct contact with shell
esel,s,type,,4
nsle
nsel,r,loc,x,IR-.3,IR+.01
```

```
nsel,r,loc,y,0,3
cm,unnode,node
nsle
cmsel,u,unnode
esln,,1
/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 A22

ANSYS Analysis Run Summary and Input Listings for B24PTH

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTH (analysis) (1) PB24PTH (postprocessing) (1)

Date/Time: 6/14/00 3:29 PM 6/14/00 7:54 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: 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

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

B24PTH.inp

```
/batch,list
/filname,b24pth
/title,24P-FO 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+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,70               ! 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
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

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 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

/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 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
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 only for temp & internal pressure 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
alls

vclear,7
esel,s,type,,3
edele,all
esel,s,type,,20
edele,all

save

fini

/solution

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


/com Temperature Case 7, -40 deg Ambient
/title, 24P-FO DSC (Bottom End) Temperature 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 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 3
save

solve
save

/com Temperature Case 8, 100 deg Ambient
/title, 24P-FO DSC (Bottom End) Temperature 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 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 4
save

solve
save

/com Temperature Case 15, -40 deg Ambient
/title, 24P-FO DSC (Bottom End) Temperature Case 15, -40 deg Ambient
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,1,,,,b24therm,rth,t:\fo-dsc\NewANSYS\bot\

lswrite                        ! end of load step 5
save
```

```
solve
save

/com Temperature Case 16, 104 deg Ambient
/title, 24P-FO DSC (Bottom End) Temperature Case 16, 104 deg Ambient
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,2,,,,b24therm,rth,t:\fo-dsc\NewANSYS\bot\


allsel
csys,0

lswrite                        ! end of load step 6
save

solve
save


fini

/exit

/eof
```

PB24PTH.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  thermal loads
resume,b24pth,db
/post1
file,b24pth,rst

/com element plots ------------------------------------------------------------
/show,pb24pth,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,1,7                 ! 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,bfe,temp                 ! plot temperature distribution
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 A23

ANSYS Analysis Run Summary and Input Listings for B24PTH2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PTH2 (analysis) [1] PB24PTH2 (postprocessing) [1]

Date/Time: 6/14/00 3:27 PM 6/14/00 5:57 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: 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

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: SR Strut Date: 6/19/00
Steven R. Streutker

B24PTH2.inp

```
/batch,list
/filname,b24pth2
/title,24P-FO 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+06         ! normal stiffness of gap elem btwn plug & shell
r,202,1.0E+05,1E6/100 ! norm/tan stiffness of gap elem btwn plug & outer plate
r,203,1.0E+05,1E6/100 ! norm/tan stiffness of gap elem btwn plug & inner plate
keyopt,20,7,1         ! keyopt (7)=1

tref,70               ! 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
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

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 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

/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)

!/om 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
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 only for temp & internal pressure 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

vclear,7
esel,s,type,,3
edele,all
esel,s,type,,20
edele,all

save

fini

/solution

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

!/com load step 1, Temperature Case 22, 100 deg Ambient
!/title, 24P-FO DSC (Bottom End) Temperature Case 22, 100 deg Ambient
!nsubst,1,8
!csys,1

!/com Define temps for DSC shell in cavity region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,8.75,175.92
!*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=1.206e-10*zt**6-7.413e-8*zt**5
!    ntemp2=1.651e-5*zt**4-1.658e-3*zt**3
!    ntemp3=6.341e-2*zt**2+.7352*zt+350.8
!    ntemp=ntemp1+ntemp2+ntemp3
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for DSC shell below cavity region
!esel,s,type,,1
!nsle
!nsel,r,loc,z,0,8.75
!*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=-6.947e-3*zt**4+.1138*zt**3
!    ntemp2=-.7334*zt**2+2.427*zt+360.7
!    ntemp=ntemp1+ntemp2
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Outer Cover Plate, Weld & Grapple Ring
!esel,s,type,,2
!esel,a,type,,5,7,1
!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=(-5.040e-6*zt+5.398e-5)*xt**4
!    ntemp2=( 6.331e-4*zt-4.030e-3)*xt**3
!    ntemp3=(-1.749e-2*zt+5.638e-2)*xt**2
!    ntemp4=( 5.931e-2*zt-2.652e-1)*xt
!    ntemp5=( 1.6*zt+389.5)
!    ntemp=ntemp1+ntemp2+ntemp3+ntemp4+ntemp5
!    bf,tnode,temp,ntemp
!    nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Shield Plug
!esel,s,type,,3
!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=(-5.590e-6*zt+5.494e-5)*xt**4
!    ntemp2=( 3.379e-4*zt-3.513e-3)*xt**3
```

```
!   ntemp3=(-6.686e-3*zt+3.748e-2)*xt**2
!   ntemp4=( 2.262e-2*zt-2.010e-1)*xt
!   ntemp5=( .96*zt+390.6)
!   ntemp=ntemp1+ntemp2+ntemp3+ntemp4+ntemp5
!   bf,tnode,temp,ntemp
!   nsel,u,node,,tnode
!*enddo

!/com Define temps for Bottom Inner Cover Plate
!esel,s,type,,4
!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=(-4.221e-5*zt+3.479e-4)*xt**4
!   ntemp2=( 2.188e-3*zt-1.831e-2)*xt**3
!   ntemp3=(-3.581e-2*zt+2.705e-1)*xt**2
!   ntemp4=( 1.576e-1*zt-1.281)*xt
!   ntemp5=(2.933*zt+374.8)
!   ntemp=ntemp1+ntemp2+ntemp3+ntemp4+ntemp5
!   bf,tnode,temp,ntemp
!   nsel,u,node,,tnode
!*enddo

!allsel
!csys,0

!lswrite                        ! end of load step 1
!save

!solve
!save

/com load step 2, Temperature Case 26, 117 deg Ambient
/title, 24P-FO DSC (Bottom End) Temp Case 26, 117 deg Ambient
nsubst,1,8
csys,1

/com read input from thermal results file
ldread,temp,3,,,,b24therm,rth,t:\fo-dsc\NewANSYS\bot\

allsel
csys,0

lswrite                         ! end of load step 2
save

solve
save

fini

/exit

/eof
```

PB24PTH2.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of DSC shell, bottom end
/com  thermal loads
resume,b24pth2,db
/post1
file,b24pth2,rst

/com element plots ------------------------------------------------------------
/show,pb24pth2,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,1,2                  ! 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,bfe,temp               ! plot temperature distribution
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 A24

ANSYS Analysis Run Summary and Input Listings for B24PGP1

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PGP1 (analysis) (1) PB24PGP1 (postprocessing) (1)

Date/Time: 3/10/20 1:08 PM 4/12/00 4:30 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: Grapple assembly only

Loads Considered: Grapple pull loads (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: Michael E. Cohen Date: 6/19/00

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

B24PGP1.inp

```
/batch,list
/filname,b24pgp1
/title,24P-short DSC Grapple Ring Only (180 Degree Refined Model)
/com model of the grapple ring only is obtained by selecting only the grapple...
/com ring assembly elements prior to ANSYS solve.
/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         ! norm stiffness of gap elem btwn plug & outer plate
! r,203,1.0E+07         ! norm stiffness of gap elem btwn plug & inner plate
! keyopt,20,7,1         ! keyopt (7)=1


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

/com ux/uz couple a shield plug node to an inner cover plate node for stability (center)
/com ***** valid for grapple pull *******
nsel,s,loc,x,0,0.1
nsel,r,loc,y,0,0.1
nsel,r,loc,z,L_bplug-.01,L_bplug+.01
cp,next,ux,all
cp,next,uz,all
allsel

/com following lines to make grapple ring only model
esel,s,type,,6,7
nsle
nsel,r,loc,z,-.01,.01
d,all,ux,0,0,,,uy,uz
nsle

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 tension load at grapple ring
/title,24P-s DSC Grapple Assy.Only, 60k Pull-Out Load
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
csys,0                            ! cartesian
nsle
lswrite
save
solve
save
```

```
/com load step 2 - 80 kip tension load at grapple ring
/title,24P-s DSC Grapple Assy.Only, 80k Pull-Out Load
pload=-80000/2
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
csys,0                              ! cartesian
nsle
lswrite
save
solve
save

fini

/exit

/eof
```

PB24PGP1.inp

```
/batch,list
/com
/com postprocessing input file for half (180 deg) model of grapple assembly
/com  grapple pull for primary stress
resume,b24pgp1,db
/post1
file,b24pgp1,rst

/com element plots ------------------------------------------------------------
/show,pb24pgp1,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,1,2                  ! define steps to postprocess
/go
set,iset

/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

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 grapple ring assembly elements
esel,s,type,,6,7               ! grapple assembly components
nsle
/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 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 A25

ANSYS Analysis Run Summary and Input Listings for B24PGP2

ANSYS Analysis Summary & Computer Run Coversheet

Calculation Number: SCE-01.0204

Run ID: B24PGP2 (analysis) (1) PB24PGP2 (postprocessing) (1)

Date/Time: 4/26/00 9:09 AM 4/26/20 1:04 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 w/o grapple

Loads Considered: Grapple pull loads, internal pressure on outer pressure boundary (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: Michael E. Cohen Date: 6/14/00

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

B24PGP2.inp

```
/batch,list
/filname,b24pgp2
/title,24P-FO 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-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 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 shell boundary conditions
nsel,s,loc,z,H_dsc/2      ! shell ends at mid-height
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0
d,all,ux,0,,,,uz          ! restrain point at far end, away from grapple ring
nsel,s,loc,z,0.75
nsel,r,loc,x,OR-.01,OR+.01
nsel,r,loc,y,0
d,all,ux,0                ! restrain point at near end, near grapple ring
allsel

/com uz/ux 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/ far end rest.
/title,24P-FO 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

/com load step 2 - 80 kip tens. load at grap.ring suppt w/ far end rest.
/title,24P-FO DSC (Bot.End) 80k at grap.ring suppt (outer cover pinned)
! nsubst,1,8
csys,1                        ! cylindrical coordinates
```

```
load=-80000/2
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

/com load step 3 - add 20 psi to outer cover plate
/title,24P-FO DSC (Bot.End) 80k at grap.ring suppt + 20psi out.cover (pinned)
! nsubst,1,8
csys,1                        ! cylindrical coordinates
esel,s,type,,1
nsle
nsel,r,loc,z,T_bw-.01,H_dsc/2
nsel,r,loc,x,IR-.01,IR+.01
sf,all,pres,20
esel,s,type,,2
nsle
nsel,r,loc,z,T_bw-.01,T_obc+.01
nsel,u,loc,z,T_obc/2-.01,T_obc/2+.01
sf,all,pres,20
esel,s,type,,1
nsle
nsel,r,loc,z,H_dsc/2-.01,H_dsc/2+.01
sf,all,pres,-522.4             ! balancing pressure load at far end of shell
csys,0                        ! cartesian coordinates
allsel
lswrite
save
solve
save

fini

/exit

/eof
```

PB24PGP2.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,b24pgp2,db
/post1
file,b24pgp2,rst

/com element plots ------------------------------------------------------------
/show,pb24pgp2,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
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 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
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 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
```