Table 17 (2pp.) nasaortho.OPT (Wimp = ± 0.125 inch)

```
      n            $ Do you want a tutorial session and tutorial output?
  -2219.000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
         0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
         0         $ In-plane shear in load set A,                        Nxy( 1)
      n            $ Does the axial load vary in the L2 direction?
         0         $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
         0         $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
      y            $ Want to include effect of transverse shear deformation?
         0         $ IQUICK = quick analysis indicator (0 or 1)
      y            $ Do you want to vary M for minimum local buckling load?
      n            $ Do you want to choose a starting M for local buckling?
      y            $ Do you want to perform a "low-axial-wavenumber" search?
  0.9990000        $ Factor of safety for general instability, FSGEN( 1)
  0.9990000        $ Factor of safety for panel (between rings) instability, FSPAN( 1)
  0.9990000        $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
   1.000000        $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
   1.000000        $ Factor of safety for stress, FSSTR( 1)
      y            $ Do you want "flat skin" discretized module for local buckling?
      n            $ Do you want wide-column buckling to constrain the design?
   0.000000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
   0.000000        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
         0         $ Axial load applied along the (0=neutral plane), (1=panel skin)
   0.000000        $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
   0.000000        $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
   0.125000        $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
   0.000000        $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
 0.1000000E-06     $ Initial local imperfection amplitude (must be positive), Wloc( 1)
      n            $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
      y            $ Do you want PANDA2 to find the general imperfection shape?( 1)
   1.000000        $ Maximum allowable average axial strain (type H for HELP)( 1)
      N            $ Is there any thermal "loading" in this load set (Y/N)?
      Y            $ Do you want a "complete" analysis (type H for "Help")?
      y            $ Want to provide another load set ?
  -2219.000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
         0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
         0         $ In-plane shear in load set A,                        Nxy( 1)
      n            $ Does the axial load vary in the L2 direction?
         0         $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
         0         $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
      y            $ Want to include effect of transverse shear deformation?
         0         $ IQUICK = quick analysis indicator (0 or 1)
      y            $ Do you want to vary M for minimum local buckling load?
      n            $ Do you want to choose a starting M for local buckling?
      y            $ Do you want to perform a "low-axial-wavenumber" search?
  0.9990000        $ Factor of safety for general instability, FSGEN( 1)
  0.9990000        $ Factor of safety for panel (between rings) instability, FSPAN( 1)
  0.9990000        $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
   1.000000        $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
   1.000000        $ Factor of safety for stress, FSSTR( 1)
      y            $ Do you want "flat skin" discretized module for local buckling?
      n            $ Do you want wide-column buckling to constrain the design?
   0.000000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
   0.000000        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
         0         $ Axial load applied along the (0=neutral plane), (1=panel skin)
   0.000000        $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
   0.000000        $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
  -0.125000        $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
   0.000000        $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
 0.1000000E-06     $ Initial local imperfection amplitude (must be positive), Wloc( 1)
      n            $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
      y            $ Do you want PANDA2 to find the general imperfection shape?( 1)
   1.000000        $ Maximum allowable average axial strain (type H for HELP)( 1)
      N            $ Is there any thermal "loading" in this load set (Y/N)?
      Y            $ Do you want a "complete" analysis (type H for "Help")?
      N            $ Want to provide another load set ?
      N            $ Do you want to impose minimum TOTAL thickness of any segment?
      N            $ Do you want to impose maximum TOTAL thickness of any segment?
      N            $ Do you want to impose minimum TOTAL thickness of any segment?
      N            $ Do you want to impose maximum TOTAL thickness of any segment?
      N            $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
         0         $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
         1         $ Index for type of shell theory (0 or 1 or 2), ISAND
      Y            $ Does the postbuckling axial wavelength of local buckles change?
      Y            $ Want to suppress general buckling mode with many axial waves?
      N            $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
         1         $ Choose (0=transverse inextensional; 1=transverse extensional)
         1         $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
         1         $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
```

Wimp = ± 0.125"

Two load sets: 1 = +0.125 = Wimp
2 = −0.125 = Wimp

Table 17 (p. 2 of 2)

```
    Y          $ Do you want to prevent secondary buckling (mode jumping)?
    N          $ Do you want to use the "alternative" buckling solution?
      5        $ How many design iterations permitted in this run (5 to 25)?
1.000000       $ MAXMAR. Plot only those margins less than MAXMAR (Type H)
    N          $ Do you want to reset total iterations to zero (Type H)?
      1        $ Index for objective (1=min. weight, 2=min. distortion)
1.000000       $ FMARG (Skip load case with min. margin greater than FMARG)
```

Input for mainsetup

Use 2 load sets when you have a general buckling modal imperfection

Load Set 1 = + Wimp

Load Set 2 = − Wimp

Table 18 nasaortho.CPL

```
n        $ Do you want a tutorial session and tutorial output?
n        $ Any design variables to be plotted v. iterations (Y or N)?
n        $ Any design margins to be plotted (Y or N)?
y        $ Do you want a plot of the objective v. iterations (Y/N)?
n        $ Do you want to get more plots before your next "SUPEROPT"?
```

Input for CHOOSEPLOT

(plot only the objective when you use SUPEROPT)

Output from DIPLOT = nasaortho.5.ps

Output from SUPEROPT

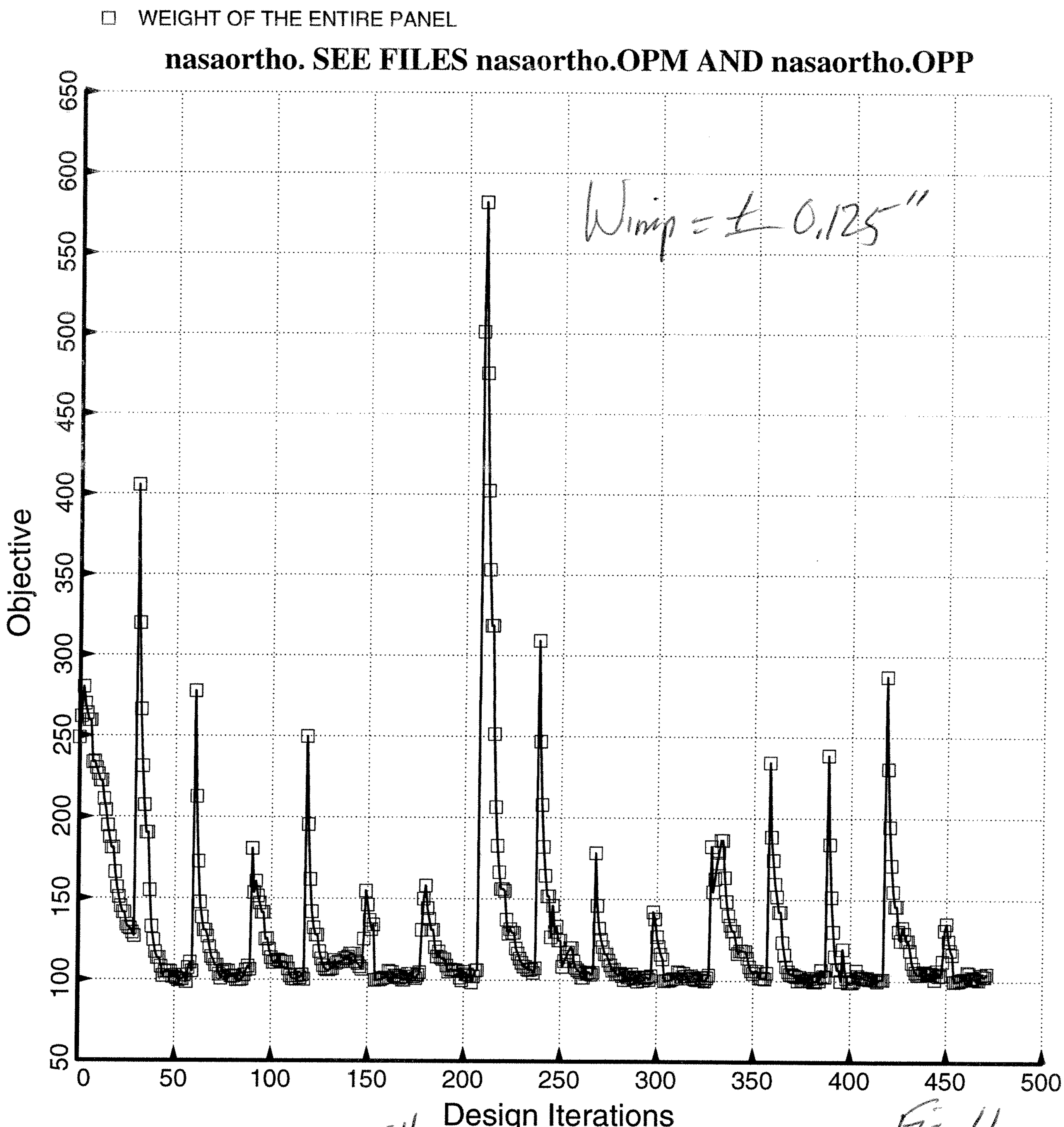


Fig. 11

Table 19 (3pp.) nasaortho.OPM (abridged)

nasaortho.wimp0.125.superopt1.opm (abridged)

critical or nearly critical

Wimp = ± 0.125"

```
 *************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0666E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0414E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE              DEFINITION
 1   5.16E-02 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
 2   4.25E-02 Bending-torsion buckling; M=5  ;FS=0.999
 3   6.76E-02 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
 4   2.56E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 5   2.63E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 6   1.62E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7   1.16E-01 Ring sidesway buk., discrete model, n=48  circ.halfwaves;FS=0.999
 8   1.14E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-MID.;FS=1.
 9   2.77E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
10   3.96E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  -5.66E-03 buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
12  -2.82E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
13   5.06E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
14   1.59E+01 buck.(SAND);rolling with smear rings; M=171;N=1;slope=0.;FS=0.999
15   6.68E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
16   1.46E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
17   6.31E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.

 *************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0915E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0752E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE              DEFINITION
 1   8.55E-02 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
 2   7.52E-02 Bending-torsion buckling; M=5  ;FS=1.
 3   9.26E-02 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
 4   2.52E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=-0.0248; RNGS;FS=1.
 5   3.28E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; RNGS;FS=1.
 6   1.98E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7   1.46E-01 Inter-ring bucklng, discrete model, n=60  circ.halfwaves;FS=0.999
 8   1.13E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-RNGS;FS=1.
 9   3.56E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
10   3.93E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11   3.55E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .RNGS;FS=1.
12   1.31E+00 buck.(SAND);rolling with smear string;M=1;N=13;slope=0.;FS=0.999
13   1.58E+01 buck.(SAND);rolling with smear rings; M=171;N=1;slope=0.;FS=0.999
14   7.34E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
15  -1.88E-02 buck.(SAND);rolling only of   rings;  M=0;N=50;slope=0.;FS=1.4
16   1.46E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
17   6.05E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

Table 19 (p.2 of 3)

```
 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 2;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0984E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1206E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1  1.24E-01 Local buckling from discrete model-1.,M=6   axial halfwaves;FS=0.99
 2  1.32E-01 Long-axial-wave bending-torsion buckling; M=1  ;FS=0.999
 3  9.95E-02 Local buckling from Koiter theory,M=6   axial halfwaves;FS=0.999
 4  1.18E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; MID.;FS=1.
 5  2.57E+06 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  1.26E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0403; MID.;FS=1.
 7  8.59E-03 (m=1   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.68E-01 Inter-ring bucklng, discrete model, n=60  circ.halfwaves;FS=0.999
 9  1.14E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0248;-MID.;FS=1.
10  2.77E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  3.96E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  7.36E+00 buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
13 -2.82E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
14  5.06E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
15  4.19E-03 buck.(SAND);rolling with smear string;M=1;N=60;slope=0.;FS=0.999
16  1.01E+01 buck.(SAND);rolling with smear rings; M=170;N=1;slope=0.;FS=0.999
17  6.68E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
18 -1.88E-02 buck.(SAND);rolling only of   rings;  M=0;N=50;slope=0.;FS=1.4
19  1.46E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
20  3.43E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.

 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 2;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0781E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1129E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1  1.16E-01 Local buckling from discrete model-1.,M=7   axial halfwaves;FS=0.99
 2  1.03E-01 Long-axial-wave bending-torsion buckling; M=1  ;FS=1.
 3  7.91E-02 Local buckling from Koiter theory,M=7   axial halfwaves;FS=0.999
 4  1.12E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; RNGS;FS=1.
 5  1.98E+06 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6  1.21E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0403; RNGS;FS=1.
 7 -9.24E-04 (m=1   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.16E-01 Ring sidesway buk., discrete model, n=48  circ.halfwaves;FS=0.999
 9  1.12E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0248;-RNGS;FS=1.
10  3.56E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11  3.93E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
12  1.16E+01 buckling margin stringer Iseg.3 . Local halfwaves=5  .RNGS;FS=1.
13  1.01E+01 buck.(SAND);rolling with smear rings; M=170;N=1;slope=0.;FS=0.999
14  7.34E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
15  1.46E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
16  3.35E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 2 LOAD SETS PROCESSED  ***********
 ************************************************
```

Wimp = 0.125

Table 19 (p.3 of 3)

```
         SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER     CURRENT     UPPER        DEFINITION
  NO. VAR.  VAR.  VAR.    TO    CONSTANT   BOUND      VALUE      BOUND
   1   Y     N     N      0    0.00E+00  1.00E+00 1.8594E+00  1.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y      1    3.33E-01  0.00E+00 6.1973E-01  0.00E+00       B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N      0    0.00E+00  1.00E-02 8.8811E-01  2.00E+00        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N      0    0.00E+00  1.00E-02 4.9565E-02  1.00E+00    T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N      0    0.00E+00  1.00E-02 8.0641E-02  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   6   Y     N     N      0    0.00E+00  1.00E+00 1.1772E+01  3.00E+01        B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
   7   N     N     N      0    0.00E+00  0.00E+00 0.0000E+00  0.00E+00       B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
   8   Y     N     N      0    0.00E+00  1.00E-02 1.7544E+00  2.00E+00        H(RNG):height of s»
tiffener (type H for sketch), h:
   9   Y     Y     N      0    0.00E+00  1.00E-02 8.9081E-02  1.00E+00    T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE          DEFINITION
            0     0   9.983E+01   WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                                  =     4.8816E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                         =     0.0000E+00
  TOTAL WEIGHT OF STRINGERS                             =     3.7935E+01
  TOTAL WEIGHT OF RINGS                                 =     1.3075E+01
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=     9.6290E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ********************* END OF nasaortho.OPM FILE *****************
```

optimum design with Wimp = ± 0.125"

Output from PANDAOPT with ITYPE = 2

There is an unanswered question here: If the shell is formed by cold-rolling the hogged-out flat plate into a cylindrical panel, won't the slender rings buckle? There probably should have been an inequality constraint introduced in DECIDE that forced H(RNG) < CT(3), in which C is a fairly small number like 5.0. (p.57)

Table 20 nasaortho.OPT (Wimp = 0.)

```
        n          $ Do you want a tutorial session and tutorial output?
  -2219.000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
           0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
           0       $ In-plane shear in load set A,                         Nxy( 1)
        n          $ Does the axial load vary in the L2 direction?
           0       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
           0       $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
        y          $ Want to include effect of transverse shear deformation?
           0       $ IQUICK = quick analysis indicator (0 or 1)
        y          $ Do you want to vary M for minimum local buckling load?
        n          $ Do you want to choose a starting M for local buckling?
        y          $ Do you want to perform a "low-axial-wavenumber" search?
  0.9990000        $ Factor of safety for general instability, FSGEN( 1)
  0.9990000        $ Factor of safety for panel (between rings) instability, FSPAN( 1)
  0.9990000        $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
   1.000000        $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
   1.000000        $ Factor of safety for stress, FSSTR( 1)
        y          $ Do you want "flat skin" discretized module for local buckling?
        n          $ Do you want wide-column buckling to constrain the design?
   0.000000        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
   0.000000        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
           0       $ Axial load applied along the (0=neutral plane), (1=panel skin)
   0.000000        $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
   0.000000        $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
Wimp → 0.000000    $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
   0.000000        $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
  0.1000000E-06    $ Initial local imperfection amplitude (must be positive), Wloc( 1)
        n          $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
        y          $ Do you want PANDA2 to find the general imperfection shape?( 1)
   1.000000        $ Maximum allowable average axial strain (type H for HELP)( 1)
        N          $ Is there any thermal "loading" in this load set (Y/N)?
        Y          $ Do you want a "complete" analysis (type H for "Help")?
        N          $ Want to provide another load set ?
        N          $ Do you want to impose minimum TOTAL thickness of any segment?
        N          $ Do you want to impose maximum TOTAL thickness of any segment?
        N          $ Do you want to impose minimum TOTAL thickness of any segment?
        N          $ Do you want to impose maximum TOTAL thickness of any segment?
        N          $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
           0       $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
           1       $ Index for type of shell theory (0 or 1 or 2), ISAND
        Y          $ Does the postbuckling axial wavelength of local buckles change?
        Y          $ Want to suppress general buckling mode with many axial waves?
        N          $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
           1       $ Choose (0=transverse inextensional; 1=transverse extensional)
           1       $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
           2       $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
        Y          $ Do you want to prevent secondary buckling (mode jumping)?
        N          $ Do you want to use the "alternative" buckling solution?
           5       $ How many design iterations permitted in this run (5 to 25)?
   1.000000        $ MAXMAR. Plot only those margins less than MAXMAR (Type H)
        N          $ Do you want to reset total iterations to zero (Type H)?
           1       $ Index for objective (1=min. weight, 2=min. distortion)
   1.000000        $ FMARG (Skip load case with min. margin greater than FMARG)
```

Input for mainsetup
The design is that obtained with Wimp = ±0.125", but Wimp is set to zero in this ITYPE=2 run.

Table 21 (2 pp.) nasaortho.OPM (abridged)

nasaortho.wimp0.000.superopt1.opm

Wimp = 0.0

```
************************************************************
CHAPTER 28 Present design, loading, and margins for the
           current load set and subcase. See Table 6 in
Bushnell, D.
"Optimization of an axially compressed ring and stringer
stiffened cylindrical shell with a general buckling modal
imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
Honolulu, Hawaii, April 2007

ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
         Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
 Local buckling load factor from KOITER theory =  1.3649E+00 (flat skin)
 Local buckling load factor from BOSOR4 theory =  1.3451E+00 (flat skin)
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
MAR. MARGIN
NO.  VALUE                DEFINITION
 1  3.51E-01 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  3.46E-01 Bending-torsion buckling; M=4  ;FS=0.999
 3  3.66E-01 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  1.84E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 5  1.71E+00 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 6  3.57E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7  9.42E-01 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
 8  1.84E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=-0.0248;-MID.;FS=1.
 9  1.71E+00 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
10  1.08E+01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  9.94E-01 buckling margin stringer Iseg.3 . Local halfwaves=6  .MID.;FS=1.
12  9.94E-01 buckling margin stringer Iseg.3 . Local halfwaves=6  .NOPO;FS=1.
13  1.19E+00 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
14  1.55E+01 buck.(SAND);rolling with smear rings; M=170;N=1;slope=0.;FS=0.999
15  2.00E+00 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
16  4.45E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.

************************************************************
CHAPTER 28 Present design, loading, and margins for the
           current load set and subcase. See Table 6 in
Bushnell, D.
"Optimization of an axially compressed ring and stringer
stiffened cylindrical shell with a general buckling modal
imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
Honolulu, Hawaii, April 2007

ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 2:
LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
         Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
 Local buckling load factor from KOITER theory =  1.3802E+00 (flat skin)
 Local buckling load factor from BOSOR4 theory =  1.3766E+00 (flat skin)
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
MAR. MARGIN
NO.  VALUE                DEFINITION
 1  3.83E-01 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
 2  3.77E-01 Bending-torsion buckling; M=5  ;FS=1.
 3  3.82E-01 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
 4  1.78E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; RNGS;FS=1.
 5  1.76E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=-0.0403; RNGS;FS=1.
 6  3.76E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7  9.38E-01 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
 8  1.83E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=0.0248;-RNGS;FS=1.
 9  1.81E+00 eff.stress:matl=2,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
10  1.06E+01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11  1.15E+00 buckling margin stringer Iseg.3 . Local halfwaves=6  .RNGS;FS=1.
12  1.54E+01 buck.(SAND);rolling with smear rings; M=170;N=1;slope=0.;FS=0.999
13  2.15E+00 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
14  4.31E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
***********  ALL 1 LOAD SETS PROCESSED  ***********
****************************************************

         SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER    CURRENT    UPPER       DEFINITION
 NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND     VALUE     BOUND
```

Table 21 (p. 2 of 2)

```
   1   Y     N     N     0    0.00E+00   1.00E+00  1.8594E+00   1.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y     1    3.33E-01   0.00E+00  6.1973E-01   0.00E+00       B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N     0    0.00E+00   1.00E-02  8.8811E-01   2.00E+00        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N     0    0.00E+00   1.00E-02  4.9565E-02   1.00E+00    T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N     0    0.00E+00   1.00E-02  8.0641E-02   1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   6   Y     N     N     0    0.00E+00   1.00E+00  1.1772E+01   3.00E+01        B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
   7   N     N     N     0    0.00E+00   0.00E+00  0.0000E+00   0.00E+00       B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
   8   Y     N     N     0    0.00E+00   1.00E-02  1.7544E+00   2.00E+00        H(RNG):height of s»
tiffener (type H for sketch), h:
   9   Y     Y     N     0    0.00E+00   1.00E-02  8.9081E-02   1.00E+00    T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER    CURRENT
 NO.  RNG  NO.   NO.      VALUE            DEFINITION
            0     0    9.983E+01    WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                              =    4.8816E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                     =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                         =    3.7935E+01
  TOTAL WEIGHT OF RINGS                             =    1.3075E+01
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=      9.6290E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF nasaortho.OPM FILE ****************
```

Same optimum design as in Table 19.

Output from PANDAOPT

Wimp = 0., ITYPE = 2

Table 22 nasaortho.CHG

```
    n         $ Do you want a tutorial session and tutorial output?
    y         $ Do you want to change any values in Parameter Set No. 1?
        1     $ Number of parameter to change (1, 2, 3, . .)
 1.859400     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        2     $ Number of parameter to change (1, 2, 3, . .)
0.6197300     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        3     $ Number of parameter to change (1, 2, 3, . .)
0.8881100     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        4     $ Number of parameter to change (1, 2, 3, . .)
0.4956500E-01 $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        5     $ Number of parameter to change (1, 2, 3, . .)
0.8064100E-01 $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        6     $ Number of parameter to change (1, 2, 3, . .)
 11.77200     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        7     $ Number of parameter to change (1, 2, 3, . .)
 0.000000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        8     $ Number of parameter to change (1, 2, 3, . .)
 1.754400     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
        9     $ Number of parameter to change (1, 2, 3, . .)
0.8908100E-01 $ New value of the parameter
    n         $ Want to change any other parameters in this set?
    n         $ Do you want to change values of "fixed" parameters?
    n         $ Do you want to change values of allowables?
```

Input for CHANGE
(in order to save the optimum design listed in Table 19)

Table 23 (2pp.) Some knockdown factors (Wimp = 0.0) used in PANDA2 other than those for imperfections

```
nasaortho.knockdown.factors

VARIOUS KNOCKDOWN FACTORS USED IN THIS CASE IN PANDA2
OTHER THAN KNOCKDOWN FACTORS FOR IMPERFECTIONS
======================================================================
Local buckling (IQUICK = 0 discretized single module model):

 BUCKLING LOAD FACTORS FROM BOSOR4-TYPE DISCRETIZED MODEL...
         (skin-stringer discretized module of local buckling)
  AXIAL     BUCKLING        KNOCKDOWN FOR    KNOCKDOWN FOR       BUCKLING
  HALF-    LOAD FACTOR    TRANSVERSE SHEAR   IN-PLANE SHEAR    LOAD FACTOR
  WAVES  BEFORE KNOCKDOWN    DEFORMATION     LOADING AND/OR  AFTER KNOCKDOWN
                                               ANISOTROPY
    M        EIGOLD             KSTAR            KNOCK      EIGOLD*KSTAR*KNOCK
    8      1.52654E+00       1.00000E+00      1.00000E+00     1.52654E+00
    9      1.60180E+00       1.00000E+00      1.00000E+00     1.60180E+00
    7      1.46193E+00       1.00000E+00      1.00000E+00     1.46193E+00
    6      1.40658E+00       1.00000E+00      1.00000E+00     1.40658E+00
    5      1.36690E+00       1.00000E+00      1.00000E+00     1.36690E+00
    4      1.36316E+00       1.00000E+00      1.00000E+00     1.36316E+00
    3      1.44458E+00       1.00000E+00      1.00000E+00     1.44458E+00
 Buckling load factor before t.s.d.=  1.3632E+00 After t.s.d.=  1.3500E+00
    4      1.36316E+00       9.90376E-01      1.00000E+00     1.35004E+00
------------------------------------------------------------------------

Local buckling (IQUICK = 1 PANDA-type "closed form" solution):

 EIGMNC=  1.49E+00  1.00E+17  1.07E+00  1.00E+17  1.00E+17  1.07E+00  1.00E+17
 SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
 MWAVEX=     3         0         6         0         0         6         0
 NWAVEX=     1         0         1         0         0         1         0

 Buckling load factor before t.s.d.=  1.0724E+00 After t.s.d.=  1.0642E+00
------------------------------------------------------------------------

Inter-ring buckling (discretized "skin"-ring single module model):

*** BEGIN "SKIN"-RING BUCKLING, DISCRETE MODEL) **
 *** BEGIN SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **
 Buckling load factor from SUB. LOCAL, EIGITR(16)=  2.4157E+00
 Number of axial halfwaves between rings, NSTART=   17
 *** END   SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **

 knockdown for smeared stringers from SUB.EIGMOD,
                                        SMRFAC=  8.2997E-01
 knockdown for transverse shear deformation (t.s.d.) from SUB.SHRRED,
                                        SHRFAC=  9.6[illegible]E-01
 Buckling load factor BEFORE knockdown for smeared stringers=  2.4157E+00
 Buckling load factor AFTER  knockdown for smeared stringers=  2.0050E+00
 NOTE: The buckling load factor,  2.0050E+00, has not yet been
 further reduced by the "shear/anisotropy" factor, FKNSRG(1)=  1.0000E+00

                            LOCAL      INTER-RING      GENERAL
                          BUCKLING      BUCKLING       BUCKLING
 RATIOS OF BUCKLING LOADS FROM ARBOCZ THEORY TO THOSE FROM
 PANDA2 THEORY FOR THE PERFECT STRUCTURE:
    (ARBOCZ/PANDA2):    1.0000E+00   9.6767E-01    1.0000E+00

 THE GOVERNING KNOCKDOWN FACTOR FOR EACH TYPE OF BUCKLING
 (LOCAL, INTER-RING, GENERAL) IS SET EQUAL TO THE MINIMUM
 KNOCKDOWN FACTOR FOR THAT TYPE OF BUCKLING, REDUCED
 FURTHER BY THE RATIO (ARBOCZ/PANDA2) FOR THE PERFECT PANEL
 IF THE RATIO (ARBOCZ/PANDA2) IS LESS THAN UNITY:
 The ARBOCZ theory is used only if ICONSV=1. ICONSV= 1

 USED NOW IN PANDA2:   1.0000E+00   9.6767E-01   1.0000E+00


 Margin=  9.4207E-01  Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
-------------------------------------------------------------------------------

Inter-ring buckling (PANDA-type "closed form" solution):

 EIGMNC=  2.46E+00  2.46E+00  2.46E+00  1.00E+17  1.00E+17  2.46E+00  5.53E+00
 SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
 MWAVEX=     1         1         1         0         0         1         1
```

Knockdown for t.s.d.

Compare with STAGS (Fig. 26)

Compare knockdowns!

knockdown for smeared stringers

for t.s.d

Compare with BIGBOSOR4 in Fig. 13

knockdown: for ARBOCZ theory / PANDA2 theory

Wimp = 0.0 here.

Table 23 (p. 2 of 2)

Knockdowns:

```
NWAVEX=   18        18        18         0         0        18         0

Buckling load factor before t.s.d.=  2.4628E+00 After t.s.d.=  2.3881E+00
Buckling load factor BEFORE knockdown for smeared stringers=  2.3881E+00
Buckling load factor AFTER  knockdown for smeared stringers=  1.9813E+00
-------------------------------------------------------------------------------
```

for t.s.d.

for smeared stringers

```
General buckling (PANDA-type "closed form" solution):

EIGMNC=  2.61E+00  2.61E+00  2.61E+00  1.00E+17  1.00E+17  2.61E+00  6.19E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    3         3         3         0         0         3         4
NWAVEX=    6         6         6         0         0         6         0

Buckling load factor before t.s.d.=  2.6111E+00 After t.s.d.=  2.4667E+00
Buckling load factor BEFORE knockdown for smeared stringers=  2.4667E+00
Buckling load factor AFTER  knockdown for smeared stringers=  2.3132E+00
General buckling load factor before and after knockdown:
EIGGEN(before modification by 5 factors below)      =  2.3132E+00
Knockdown factor from modal imperfection(s)         =  1.0000E+00
Knockdown factor for smearing rings on cyl. shell   =  9.4556E-01
Knockup factor to avoid twice accounting for t.s.d.=  1.0000E+00
1st modifying factor, FKNMOD=1 or 1/(EIG9X*FMDKD9) =  1.0000E+00
2nd modifying factor, EIGMR9=1 or EIGGNX/EIGGEN    =  1.0000E+00
After knockdn,EIGGEN*FKNOCK(9)*(RNGKNK/SHRFCT)*FKNMOD*EIGMR9=  2.1873E+00
    13      2.18728E+00   buckling load factor simp-support general buck;M=3;N=6;slope=0.
Margin=  1.1895E+00  buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
=================================================================================
```

for t.s.d.

for smeared stringers

for smeared rings

compare with BIGBOSOR4 in Fig. 16; with STAGS in Fig. 27 & 20.

Parts of nasaortho.OPM generated when NPRINT=2 in the nasaortho.OPT file.

Table 24 knockdowns for imperfections (Wimp = 0.125")

```
nasaortho.imperfect.knockdown.factors

KNOCKDOWN FACTORS USED IN THIS CASE IN PANDA2
ONLY CORRESPONDING TO THE GENERAL BUCKLING MODAL
IMPERFECTION SHAPE WITH AMPLITUDE, WIMP = 0.125 INCH.
 ==========================================================
 BUCKLING LOAD FACTORS AND IMPERFECTION SENSITIVITY SUMMARY
 ----------------------------------------------------------
                         LOCAL      INTER-RING     GENERAL
                       BUCKLING     BUCKLING      BUCKLING
 RATIOS OF BUCKLING LOADS FROM ARBOCZ THEORY TO THOSE FROM
 PANDA2 THEORY FOR THE PERFECT STRUCTURE:
    (ARBOCZ/PANDA2):   1.0000E+00   9.7738E-01   1.0000E+00
 ----------------------------------------------------------
 KNOCKDOWN FACTORS FOR IMPERFECTIONS DERIVED FROM
 PANDA2 THEORY VS THOSE FROM ARBOCZ 1992 UPDATE OF KOITERs
 1963 SPECIAL THEORY:
 FROM PANDA2 THEORY:   9.9216E-01   1.0000E+00   7.0929E-01
 FROM ARBOCZ THEORY:   9.9706E-01   1.0000E+00   6.8804E-01
 THE GOVERNING KNOCKDOWN FACTOR FOR EACH TYPE OF BUCKLING
 (LOCAL, INTER-RING, GENERAL) IS SET EQUAL TO THE MINIMUM
 KNOCKDOWN FACTOR FOR THAT TYPE OF BUCKLING, REDUCED
 FURTHER BY THE RATIO (ARBOCZ/PANDA2) FOR THE PERFECT PANEL
 IF THE RATIO (ARBOCZ/PANDA2) IS LESS THAN UNITY:
 The ARBOCZ theory is used only if ICONSV=1. ICONSV= 1

 USED NOW IN PANDA2:   9.9216E-01   9.7738E-01   6.8804E-01

 FACTOR APPLIED TO   6.8804E-01 FOR ALTERNATIVE SOLUTION FOR
 GENERAL    BUCKLING WITH DISCRETE STIFFENERS, FKNMLT=  1.0000E+00
 FACTOR APPLIED TO   9.7738E-01 FOR ALTERNATIVE SOLUTION FOR
 INTER-RING BUCKLING WITH DISCRETE STIFFENERS, FKNMLS=  1.0000E+00

 ***NOTE*** IF THERE IS INTERNAL PRESSURE THESE KNOCKDOWN
            FACTORS MAY BE CHANGED AS NOTED BELOW.
 ==========================================================
```

Output included in nasaortho.OPM when NPRINT = 2 in the nasaortho.OPT file.

Table 25 nasacortho.PAN

```
       n          $ Do you want a tutorial session and tutorial output?
74.37600          $ Panel length in the plane of the screen, L2
       0          $ Enter control (0 or 1) for stringers at panel edges
       2          $ Enter control (1=sym; 2=s.s.) for boundary condition
       1          $ Enter ILOCAL=0 for panel buckling; 1 for local buckling, ILOCAL
       6          $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
       3          $ How many eigenvalues (get at least 3) do you want?
```

note

Input for PANEL.

PANEL generates an input file, nasacortho.ALL, for BIGBOSOR4

exactly 40 stringer spacings:

$$74.376 = 40 \times \underbrace{1.8594}_{\text{Tables 21 \& 19 \& 22}}$$

Table 26(2pp) input to resetup & output from BIGRESTART

nasaortho.RES (input for BIGBOSOR4 processor called resetup):

```
    N         $ Do you want response at resonance to base excitation?
      1       $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
      0       $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
      0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
    N         $ Are there any regions for which you want expanded plots?
    100       $ NOB   = starting number of circ. waves (buckling analysis)
    100       $ NMINB = minimum number of circ. waves  (buckling analysis)
   1000       $ NMAXB = maximum number of circ. waves  (buckling analysis)
    100       $ INCRB = increment in number of circ. waves (buckling)
      3       $ NVEC  = number of eigenvalues for each wave number
    Y         $ Do you want to suppress listing the prebuckling resultants?
    Y         $ Do you want to suppress listing the buckling modes?
```

---

nasaortho.OUT (abridged output from BIGBOSOR4 processor, bigrestart):

```
BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      100

EIGENVALUES =
   2.01122E+00    2.02759E+00    2.04606E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      200

EIGENVALUES =
   1.72948E+00    1.76521E+00    1.79184E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      300

EIGENVALUES =
   1.47490E+00    1.49292E+00    1.50631E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      400

EIGENVALUES =
   1.41494E+00    1.42184E+00    1.42794E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      500

EIGENVALUES =
   1.41971E+00    1.42349E+00    1.42823E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      600

EIGENVALUES =
   1.44791E+00    1.45361E+00    1.45930E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      700

EIGENVALUES =
   1.48842E+00    1.49484E+00    1.50118E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      800

EIGENVALUES =
   1.53717E+00    1.54400E+00    1.55072E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =      900

EIGENVALUES =
   1.59638E+00    1.60354E+00    1.61058E+00

BUCKLING LOADS FOLLOW
CIRCUMFERENTIAL WAVE NUMBER, N =     1000

EIGENVALUES =
   1.66975E+00    1.67714E+00    1.68440E+00
```

Handwritten annotations beside the output:

N = 100: means "m=1 axial halfwaves between adjacent rings"

N = 200: "m=2 axial halfwaves" (See Appendix 1)

N = 400: "m=4 axial halfwaves"

1.41494E+00: critical value — local buckling, Fig. 12

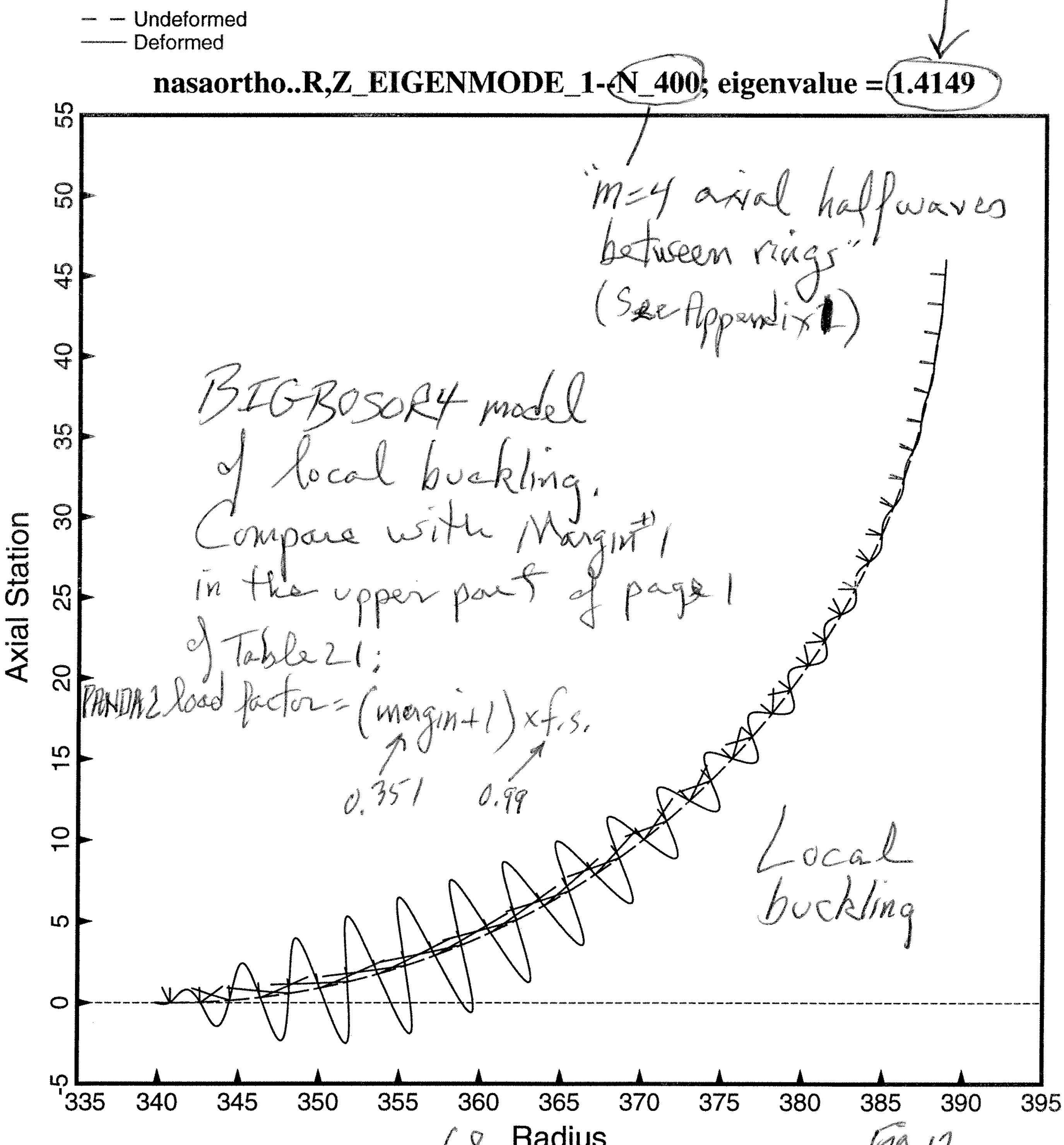
Table 26 (p. 2 of 2)

```
**** CRITICAL EIGENVALUE AND WAVENUMBER ****
EIGCRT=  1.4149E+00; NO. OF CIRC. WAVES, NWVCRT=  400
**************************************************

***** EIGENVALUES AND MODE SHAPES *****
 EIGENVALUE(CIRC. WAVES)
======================================
   2.0112E+00( 100)
   1.7295E+00( 200)
   1.4749E+00( 300)
   1.4149E+00( 400) <--critical value
   1.4197E+00( 500)
   1.4479E+00( 600)
   1.4884E+00( 700)
   1.5372E+00( 800)
   1.5964E+00( 900)
   1.6698E+00(1000)
======================================
```

(400) means "m = 4 axial halfwaves between rings"
(See Appendix 1)

BIGBOSOR4 buckling load factor



"m=4 axial halfwaves between rings" (See Appendix 1)

BIGBOSOR4 model of local buckling. Compare with Margin #1 in the upper part of page 1 of Table 21;

PANDA2 load factor = (margin+1) x f.s.

0.351 0.99

Local buckling

Fig. 12

Table 27 nasaortho.PAN

```
   n          $ Do you want a tutorial session and tutorial output?
74.37600      $ Panel length in the plane of the screen, L2
      0       $ Enter control (0 or 1) for stringers at panel edges
      2       $ Enter control (1=sym; 2=s.s.) for boundary condition
      0       $ Enter ILOCAL=0 for panel buckling; 1 for local buckling, ILOCAL
      1       $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
      1       $ How many eigenvalues (get at least 3) do you want?
```

note

input to PANEL to generate BIGBOSOR4 huge torus model

exactly 40 stringer spacings.

Table 28 (2 pages) input to resetup & output from bigrestart

nasaortho.RES (input for BIGBOSOR4 processor called resetup):

```
     N         $ Do you want response at resonance to base excitation?
        1      $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
        0      $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
        0      $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
     N         $ Are there any regions for which you want expanded plots?
      100      $ NOB   = starting number of circ. waves (buckling analysis)
      100      $ NMINB = minimum number of circ. waves  (buckling analysis)
     1000      $ NMAXB = maximum number of circ. waves  (buckling analysis)
      100      $ INCRB = increment in number of circ. waves (buckling)
        3      $ NVEC  = number of eigenvalues for each wave number
     Y         $ Do you want to suppress listing the prebuckling resultants?
     Y         $ Do you want to suppress listing the buckling modes?
----------------------------------------------------------------------
```

nasaortho.OUT (abridged output from BIGBOSOR4 processor called bigrestart):

```
 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      100

 EIGENVALUES =
    2.01057E+00    2.02945E+00    2.04959E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      200

 EIGENVALUES =
    1.73259E+00    1.76990E+00    1.79792E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      300

 EIGENVALUES =
    1.46254E+00    1.48117E+00    1.49508E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      400

 EIGENVALUES =
    1.39769E+00    1.40499E+00    1.41118E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      500

 EIGENVALUES =
    1.40030E+00    1.40385E+00    1.40849E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      600

 EIGENVALUES =
    1.42664E+00    1.43215E+00    1.43767E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      700

 EIGENVALUES =
    1.46551E+00    1.47177E+00    1.47794E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      800

 EIGENVALUES =
    1.51262E+00    1.51930E+00    1.52587E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      900

 EIGENVALUES =
    1.57007E+00    1.57707E+00    1.58396E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =     1000

 EIGENVALUES =
    1.64144E+00    1.64868E+00    1.65578E+00
```

Handwritten notes: at N = 100: means "m=1 axial halfwaves"; at first eigenvalue for N = 100: inter-ring buckling; at N = 400: means "m=4 axial halfwaves"; at first eigenvalue for N = 400: critical value

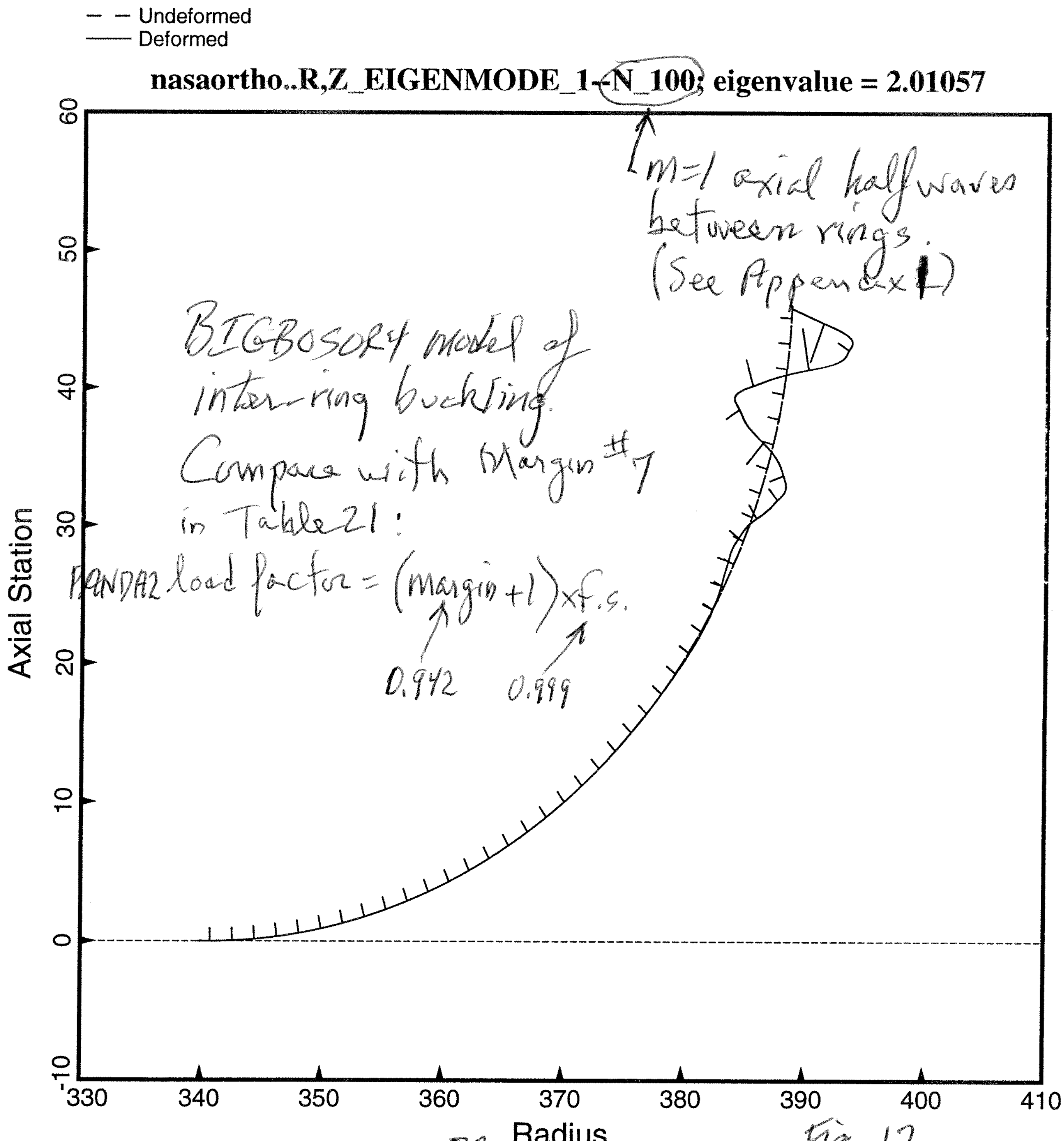
Table 28 (p. 2 of 2)

```
**** CRITICAL EIGENVALUE AND WAVENUMBER ****
EIGCRT=  1.3977E+00; NO. OF CIRC. WAVES, NWVCRT=  400
***************************************************

***** EIGENVALUES AND MODE SHAPES *****
 EIGENVALUE(CIRC. WAVES)
=======================================
   2.0106E+00( 100)
   1.7326E+00( 200)
   1.4625E+00( 300)
   1.3977E+00( 400) <--critical value
   1.4003E+00( 500)
   1.4266E+00( 600)
   1.4655E+00( 700)
   1.5126E+00( 800)
   1.5701E+00( 900)
   1.6414E+00(1000)
=======================================
```

← inter-ring buckling. (m=1 axial halfwaves)

Output from BIGRESTART



Undeformed
Deformed
nasaortho..R,Z_EIGENMODE_1--N_100; eigenvalue = 2.01057
m=1 axial halfwaves between rings. (See Appendix
BIGBOSOR4 model of inter-ring buckling. Compare with Margin #7 in Table 21:
PANDA2 load factor = (margin+1) x f.s.
0.942
0.999
Axial Station
Radius

Fig. 13

Table 29 nasacortho.PAN

```
     n        $ Do you want a tutorial session and tutorial output?
68.75000      $ Length of the ring-stiffened cylindrical shell, L1
      1       $ Choose BOSOR4 model: INDIC=1 or INDIC=4; INDIC
  -2219       $ Axial resultant Nx in Load Set A, Nx
      0       $ Axial resultant Nxo in Load Set B, Nxo
      0       $ Normal pressure p
      1       $ IABP = 1 if pressure in Load Set A; IABP=0 otherwise. IABP
      3       $ Enter control (1=sym; 2=s.s.; 3=clamp) for buckling b.c.
      2       $ Starting number of circumferential waves [see H(elp)],N0B
     20       $ Ending number of circumferential waves [see H(elp)],NMAXB
      1       $ Increment in number of circumferential waves, INCRB
      1       $ Number of eigenvalues for each circ. wavenumber, NVEC
```

Input for PANEL2.
Generates BIGBOSOR4 model
of the entire shell with
smeared stringers & rings as
shell branches.

Table 30 nasaortho.OUT

nasaortho.OUT (abridged output from BIGBOSOR4)

```
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    4.8485E+00(   2)
    4.4486E+00(   3)
    3.7108E+00(   4)
    3.0393E+00(   5)
    2.8031E+00(   6) <--general buckling
    2.8772E+00(   7)
    3.1000E+00(   8)
    3.1632E+00(   9)
    3.1132E+00(  10)
    3.0608E+00(  11)
    3.0170E+00(  12)
    2.9829E+00(  13)
    2.9587E+00(  14)
    2.9434E+00(  15)
    2.9363E+00(  16)
    2.9362E+00(  17) <--inter-ring buckling
    2.9420E+00(  18)
    2.9527E+00(  19)
    2.9672E+00(  20)
 =======================================
```

(Compare with Table 31)

(Compare with Table 31)

Output from bigbosorall

Clamped shell.

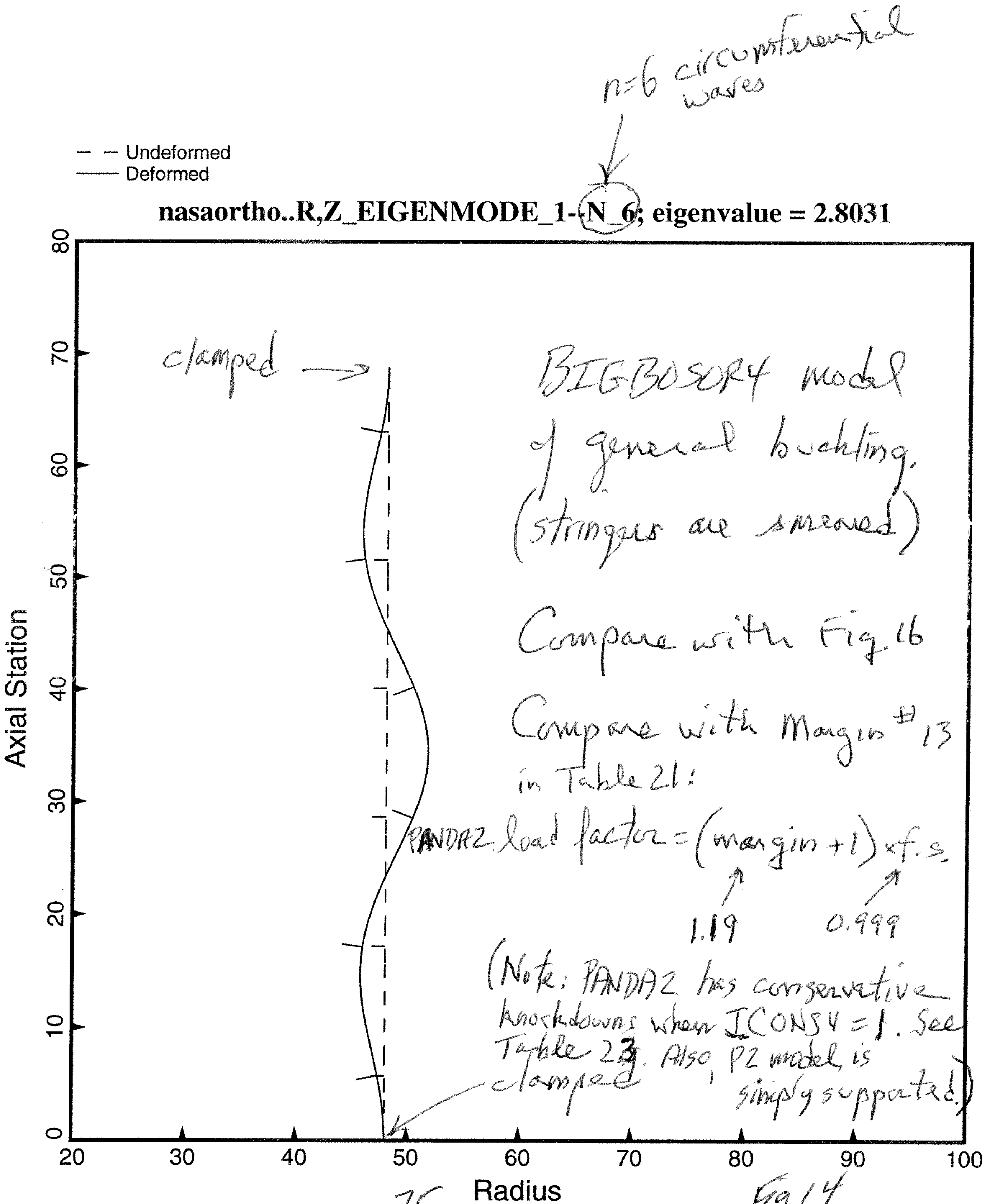

n=6 circumferential waves
Undeformed
Deformed
nasaortho..R,Z_EIGENMODE_1--N_6; eigenvalue = 2.8031
Axial Station
Radius
clamped
BIGBOSOR4 model of general buckling. (stringers are smeared)
Compare with Fig. 16
Compare with Margin #13 in Table 21:
PANDA2 load factor = (margin + 1) x f.s.
1.19
0.999
(Note: PANDA2 has conservative knockdowns when ICONSV = 1. See Table 23. Also, P2 model is simply supported)
clamped

Fig. 14

17 circumferential waves

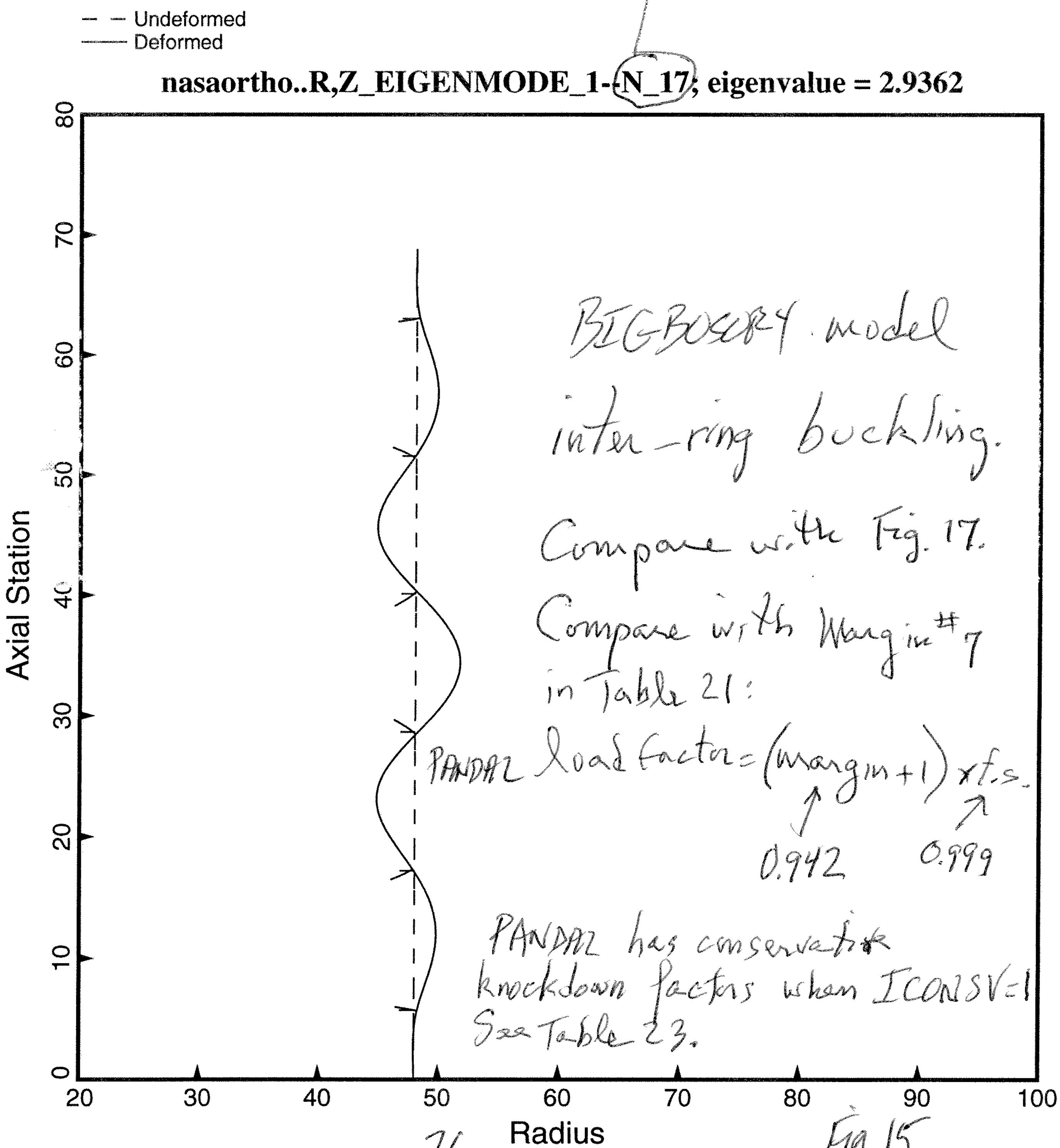


Fig. 15

Table 31 nasaortho.OUT

nasaortho.bigbosor4.wimp0.125.superopt1.simplesupport.OUT

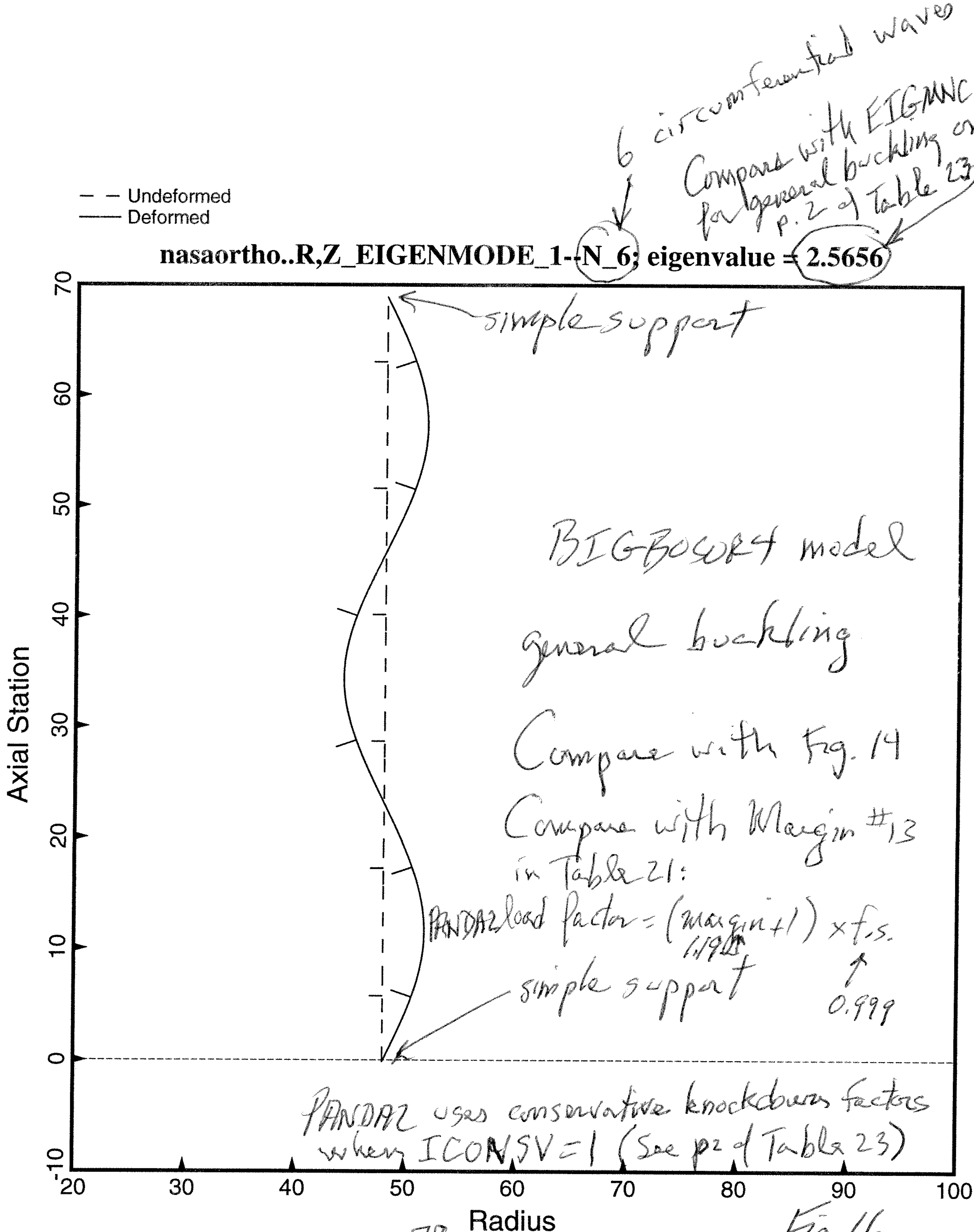
```
nasaortho.OUT (abridged output from BIGBOSOR4
               for simply-supported shell with
               membrane state prebuckling. These
               results correspond to PANDA2's
               with the length modification factor,
               LENMOD = 1.0, which LENMOD is in
               this case.)

 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    4.7203E+00(   2)
    4.2945E+00(   3)
    3.5727E+00(   4)
    2.8543E+00(   5)
    2.5656E+00(   6) <--general buckling
    2.6801E+00(   7)
    2.8466E+00(   8)
    3.0791E+00(   9)
    3.0771E+00(  10)
    3.0516E+00(  11)
    3.0166E+00(  12)
    2.9826E+00(  13)
    2.9548E+00(  14)
    2.9349E+00(  15)
    2.9230E+00(  16)
    2.9185E+00(  17) <--inter-ring buckling
    2.9204E+00(  18)
    2.9276E+00(  19)
    2.9390E+00(  20)
 =======================================
```

(compare with Table 30) [beside general buckling]

(compare with Table 30) [beside inter-ring buckling]

output from BIGBOSOR4 (bigbosorall) for $\boxed{\text{simply-supported}}$ rather than clamped cylindrical shell.



6 circumferential waves
Compare with EIGMNC for general buckling on p.2 of Table 23
— — Undeformed
—— Deformed
nasaortho..R,Z_EIGENMODE_1--N_6; eigenvalue = 2.5656
simple support
BIGBOSOR4 model
general buckling
Compare with Fig. 14
Compare with Margin #13 in Table 21:
PANDA2 load factor = (margin+1) × f.s.
1.192
0.999
simple support
PANDA2 uses conservative knockdown factors when ICONSV=1 (See p2 of Table 23)
Axial Station
Radius

Fig. 16

17 circumferential waves

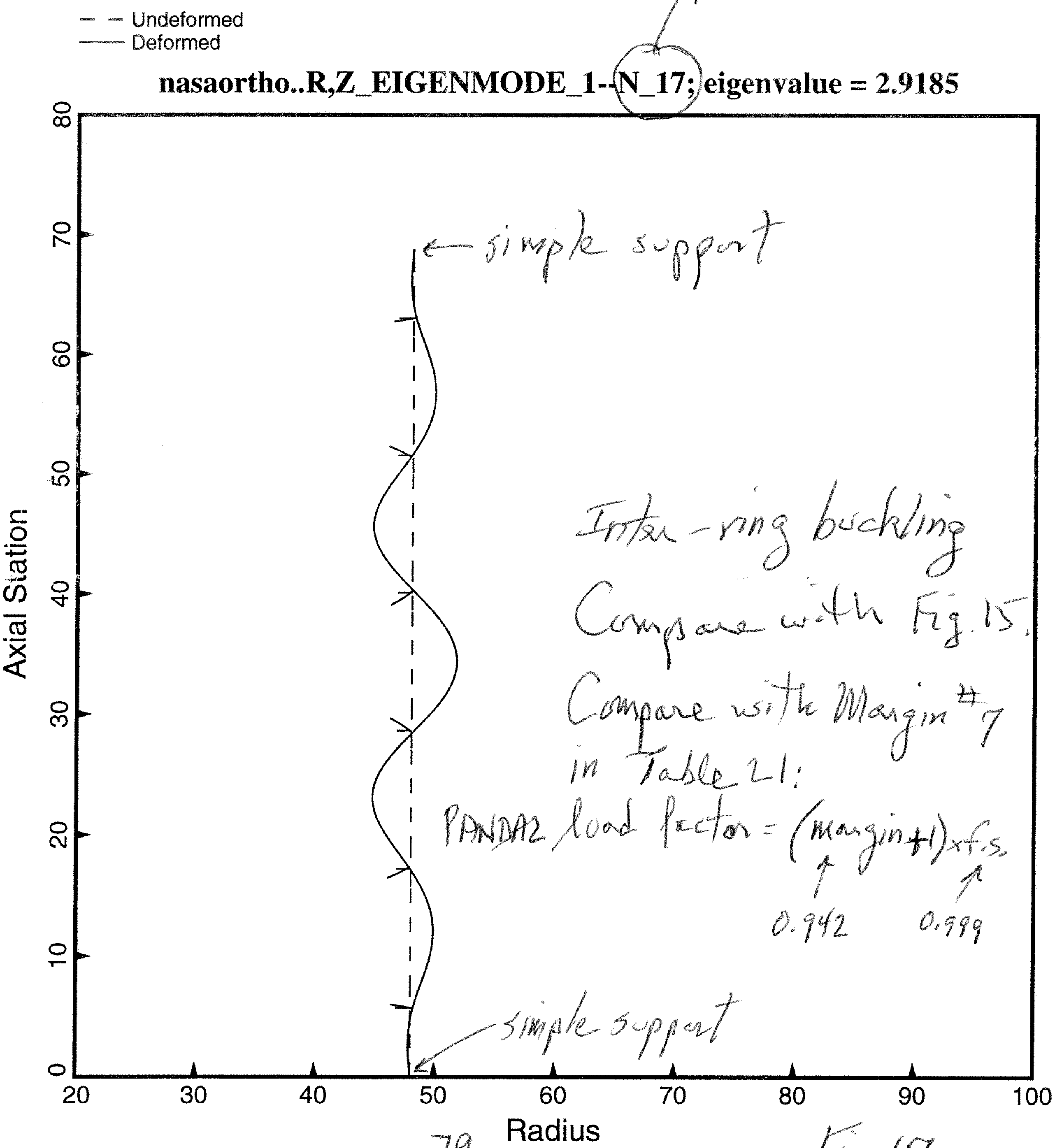


Fig. 17

Table 32 nasaortho.CHG ("stagsworthy" design nearest to the optimum design from PANDA2)

```
      n         $ Do you want a tutorial session and tutorial output?
      y         $ Do you want to change any values in Parameter Set No. 1?
         1      $ Number of parameter to change (1, 2, 3, . .)
   1.861685     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         2      $ Number of parameter to change (1, 2, 3, . .)
  0.6197300     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         3      $ Number of parameter to change (1, 2, 3, . .)
  0.8881100     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         4      $ Number of parameter to change (1, 2, 3, . .)
  0.4956500E-01 $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         5      $ Number of parameter to change (1, 2, 3, . .)
  0.8064100E-01 $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         6      $ Number of parameter to change (1, 2, 3, . .)
   11.45833     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         7      $ Number of parameter to change (1, 2, 3, . .)
   0.000000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
   1.754400     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         9      $ Number of parameter to change (1, 2, 3, . .)
  0.8908100E-01 $ New value of the parameter
      n         $ Want to change any other parameters in this set?
      n         $ Do you want to change values of "fixed" parameters?
      n         $ Do you want to change values of allowables?
```

exactly 6 ring spacings in 68.75".
exactly 162 stringers in 360 degrees.

Input to CHANGE in order to establish the "STAGSworthy" design that is closest to the optimum design determined by PANDA2.

Table 33a (3 pages) nasaortho.OPM (abridged)

Wimp = ± 0.125"

```
nasaortho.OPM (abridged) for "STAGSworthy" configuration,
Wimp = plus and minus 0.0125 inch
=======================================================
 **********************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0376E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0437E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE               DEFINITION
 1  4.98E-02 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  4.47E-02 Bending-torsion buckling; M=4  ;FS=0.999
 3  3.87E-02 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  2.54E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 5  7.69E+06 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  2.73E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 7  1.76E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.63E-01 Ring sidesway buk., discrete model, n=49  circ.halfwaves;FS=0.999
 9  1.14E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-MID.;FS=1.
10  2.87E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  4.40E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  1.45E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
13 -8.20E-03 buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
14  5.21E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
15  1.61E+01 buck.(SAND);rolling with smear rings; M=172;N=1;slope=0.;FS=0.999
16  6.79E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
17  1.53E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
18  6.27E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

see Table 5, middle

Compare Margin 4 & Margin 9 also on the next page

```
 **********************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0612E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0765E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE               DEFINITION
 1  8.27E-02 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  7.65E-02 Bending-torsion buckling; M=4  ;FS=1.
 3  6.23E-02 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  2.50E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; RNGS;FS=1.
 5  3.37E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; RNGS;FS=1.
 6  2.11E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7  2.06E-01 Inter-ring bucklng, discrete model, n=63  circ.halfwaves;FS=0.999
 8  2.05E-01 Lo-n Inter-ring buck.,discrete model,n=60  circ.halfwaves;FS=0.999
 9  1.14E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-RNGS;FS=1.
10  3.65E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11  4.37E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
12  5.55E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .RNGS;FS=1.
13  1.41E+00 buck.(SAND);rolling with smear string;M=1;N=14;slope=0.;FS=0.999
14  1.61E+01 buck.(SAND);rolling with smear rings; M=172;N=1;slope=0.;FS=0.999
15  7.43E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
16  2.32E-02 buck.(SAND);rolling only of   rings;  M=0;N=50;slope=0.;FS=1.4
```

Wimp = ± 0.125"

Table 33a (p. 2 of 3)

```
17  1.53E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
18  6.02E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.

 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 2;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0946E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1197E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1  1.21E-01 Local buckling from discrete model-1.,M=6   axial halfwaves;FS=0.99
 2  1.31E-01 Long-axial-wave bending-torsion buckling; M=1  ;FS=0.999
 3  9.57E-02 Local buckling from Koiter theory,M=6   axial halfwaves;FS=0.999
 4  1.19E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; MID.;FS=1.
 5  2.50E+06 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  1.26E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0403; MID.;FS=1.
 7  9.07E-03 (m=1   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  2.28E-01 Inter-ring bucklng, discrete model, n=63   circ.halfwaves;FS=0.999
 9  2.27E-01 Lo-n Inter-ring buck.,discrete model,n=60  circ.halfwaves;FS=0.999
10  1.15E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0248;-MID.;FS=1.
11  2.87E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  4.40E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
13  7.08E+00 buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
14 -8.22E-03 buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
15  5.21E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
16  5.68E-02 buck.(SAND);rolling with smear string;M=1;N=62;slope=0.;FS=0.999
17  1.03E+01 buck.(SAND);rolling with smear rings; M=176;N=1;slope=0.;FS=0.999
18  6.79E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
19  2.32E-02 buck.(SAND);rolling only of   rings;  M=0;N=50;slope=0.;FS=1.4
20  1.53E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
21  3.44E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

Compare Margin 4 & Margin 10

Wimp = 0.125" ~ 0.125"

```
 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 2;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0786E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1125E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1  1.15E-01 Local buckling from discrete model-1.,M=6   axial halfwaves;FS=0.99
 2  1.05E-01 Long-axial-wave bending-torsion buckling; M=1  ;FS=1.
 3  7.97E-02 Local buckling from Koiter theory,M=6   axial halfwaves;FS=0.999
 4  1.13E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; RNGS;FS=1.
 5  2.01E+06 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6  1.22E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0403; RNGS;FS=1.
 7 -2.08E-05 (m=1   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.64E-01 Ring sidesway buk., discrete model, n=49  circ.halfwaves;FS=0.999
 9  1.13E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0248;-RNGS;FS=1.
10  3.65E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11  4.37E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
12  1.07E+01 buckling margin stringer Iseg.3 . Local halfwaves=5  .RNGS;FS=1.
13  1.03E+01 buck.(SAND);rolling with smear rings; M=176;N=1;slope=0.;FS=0.999
14  7.43E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
```

Table 33a (p.3 of 3)

```
15  1.53E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
16  3.36E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 2 LOAD SETS PROCESSED  ***********
 *************************************************

          SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER    CURRENT     UPPER       DEFINITION
  NO. VAR.  VAR.  VAR.    TO    CONSTANT   BOUND     VALUE      BOUND
   1   Y     N     N      0    0.00E+00  1.00E+00 1.8617E+00  1.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y      1    3.33E-01  0.00E+00 6.1973E-01  0.00E+00       B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N      0    0.00E+00  1.00E-02 8.8811E-01  2.00E+00        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N      0    0.00E+00  1.00E-02 4.9565E-02  1.00E+00    T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N      0    0.00E+00  1.00E-02 8.0641E-02  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   6   Y     N     N      0    0.00E+00  1.00E+00 1.1458E+01  3.00E+01        B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
   7   N     N     N      0    0.00E+00  0.00E+00 0.0000E+00  0.00E+00       B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
   8   Y     N     N      0    0.00E+00  1.00E-02 1.7544E+00  2.00E+00        H(RNG):height of s»
tiffener (type H for sketch), h:
   9   Y     Y     N      0    0.00E+00  1.00E-02 8.9081E-02  1.00E+00    T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER    CURRENT
 NO.  RNG  NO.   NO.      VALUE            DEFINITION
            0     0     1.001E+02   WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                                 =    4.8816E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                        =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                            =    3.7888E+01
  TOTAL WEIGHT OF RINGS                                =    1.3433E+01
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=         9.6590E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF nasaortho.OPM FILE ****************
```

"STAGS worthy" design closest to the optimum design from PANDA2.

Wimp = ± 0.125"

Table 3 3b/ 2 pages nasaortho.OPM (abridged

Wimp = 0.0

nasaortho.OPM (abridged output from pandaopt for "stagsworthy" design closest to the optimum design in nasaortho.wimp0.125.superopt1.opm: the stringer spacing has been changed from its optimum value, 1.8594 inches, to a value that corresponds exactly to 162 stringers in the 360-degree cylindrical shell, that is, 1.861685 inches. The ring spacing has been changed from its optimum value,11.772 inches to a value that corresponds exactly to 6 ring spacings over the length, 68.75 inches, of the cylindrical shell, that is, 11.45833 inches. The amplitude, Wimp, of the general buckling modal imperfection is set equal to zero.)

Buckling load factor = (margin + 1.0) × (factor of safety)

```
 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.3562E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.3403E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE             DEFINITION
 1  3.44E-01 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  3.42E-01 Bending-torsion buckling; M=4  ;FS=0.999
 3  3.58E-01 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  1.84E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 5  1.71E+00 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 6  3.50E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7  1.04E+00 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
 8  1.84E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=-0.0248;-MID.;FS=1.
 9  1.71E+00 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
10  1.09E+01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  1.03E+00 buckling margin stringer Iseg.3 . Local halfwaves=6  .MID.;FS=1.
12  1.03E+00 buckling margin stringer Iseg.3 . Local halfwaves=6  .NOPO:FS=1.
13  1.21E+00 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
14  1.58E+01 buck.(SAND);rolling with smear rings; M=176;N=1;slope=0.;FS=0.999
15  2.00E+00 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
16  4.44E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

Compare with STAGS: Fig. 23

Compare with STAGS: Figs 20, 21 (PANDA2 has ICONSV=1)

Compare with STAGS: Figs 18, 27 (ICONSV=1)

```
 ************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.3765E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.3707E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE             DEFINITION
 1  3.76E-01 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  3.71E-01 Bending-torsion buckling; M=4  ;FS=1.
 3  3.78E-01 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  1.78E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.0248; RNGS;FS=1.
 5  1.76E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=-0.0403; RNGS;FS=1.
 6  3.68E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 7  1.03E+00 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
 8  1.83E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=0.0248;-RNGS;FS=1.
```

Table 33b (p. 2 of 2)

```
 9  1.81E+00 eff.stress:matl=2,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
10  1.07E+01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
11  1.18E+00 buckling margin stringer Iseg.3 . Local halfwaves=6  .RNGS;FS=1.
12  1.56E+01 buck.(SAND);rolling with smear rings; M=176;N=1;slope=0.;FS=0.999
13  2.14E+00 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
14  4.32E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 1 LOAD SETS PROCESSED  ***********
 ****************************************************

          SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER    CURRENT     UPPER        DEFINITION
  NO. VAR.  VAR.  VAR.    TO    CONSTANT   BOUND     VALUE      BOUND
   1   Y     N     N      0    0.00E+00  1.00E+00 1.8617E+00  1.00E+01      B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y      1    3.33E-01  0.00E+00 6.1973E-01  0.00E+00      B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N      0    0.00E+00  1.00E-02 8.8811E-01  2.00E+00      H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N      0    0.00E+00  1.00E-02 4.9565E-02  1.00E+00    T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N      0    0.00E+00  1.00E-02 8.0641E-02  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   6   Y     N     N      0    0.00E+00  1.00E+00 1.1458E+01  3.00E+01      B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
   7   N     N     N      0    0.00E+00  0.00E+00 0.0000E+00  0.00E+00      B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
   8   Y     N     N      0    0.00E+00  1.00E-02 1.7544E+00  2.00E+00      H(RNG):height of s»
tiffener (type H for sketch), h:
   9   Y     Y     N      0    0.00E+00  1.00E-02 8.9081E-02  1.00E+00    T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE           DEFINITION
            0     0    1.001E+02   WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                               =    4.8816E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                      =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                          =    3.7888E+01
  TOTAL WEIGHT OF RINGS                              =    1.3433E+01
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=       9.6590E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF nasaortho.OPM FILE ****************
```

"STAGSworthy" design closest to the optimum design from PANDA2

Wimp = 0.0

Table 34 nasacntho.STG

```
   n         $ Do you want a tutorial session and tutorial output?
      1      $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
      0      $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
 1.000000    $ Local buckling load factor from PANDA2, EIGLOC
   y         $ Are the dimensions in this case in inches?
      0      $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
      0      $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
 68.75000    $ X-direction length of the STAGS model of the panel: XSTAGS
 150.796     $ Panel length in the plane of the screen, L2
   y         $ Is the nodal point spacing uniform along the stringer axis?
   101       $ Number of nodes in the X-direction: NODEX
  -2219      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
      0      $ In-plane shear in load set A,                        Nxy
      0      $ Normal pressure in STAGS model in Load Set A, p
      0      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
      0      $ Normal pressure in STAGS model in Load Set B, p0
 1.000000    $ Starting load factor for Load System A, STLD(1)
 0.000000    $ Load factor increment for Load System A, STEP(1)
 1.000000    $ Maximum load factor for Load System A, FACM(1)
      0      $ Starting load factor for Load System B, STLD(2)
      0      $ Load factor increment for Load System B, STEP(2)
      0      $ Maximum load factor for Load System B, FACM(2)
      1      $ How many eigenvalues do you want? NEIGS
   480       $ Choose element type (410 or 411 or 480) for panel skin
   n         $ Have you obtained buckling modes from STAGS for this case?
   162       $ Number of stringers in STAGS model of 360-deg. cylinder
      7      $ Number of rings in the STAGS model of the panel
   y         $ Are there rings at the ends of the panel?
      1      $ Number of finite elements between adjacent stringers
      6      $ Number of finite elements between adjacent rings
      3      $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
      3      $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
     -1      $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n         $ Do you want to use fasteners (they are like rigid links)?
   y         $ Are the stringers to be "smeared out"?
   y         $ Are the rings to be "smeared out"?
      5      $ Number of nodes over height of stiffener webs, NODWEB
      5      $ Number of nodes over width of stringer flange, NDFLGS
      5      $ Number of nodes over width of ring flange, NDFLGR
   n         $ Do you want stringer(s) with a high nodal point density?
   n         $ Do you want ring(s) with a high nodal point density?
   n         $ Is there plasticity in this STAGS model?
   y         $ Do you want to use the "least-squares" model for torque?
   y         $ Is stiffener sidesway permitted at the panel edges?
   n         $ Do you want symmetry conditions along the straight edges?
      0      $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

note

STAGSUNIT produces the two STAGS input files, nasacntho.bin & nasacntho.inp

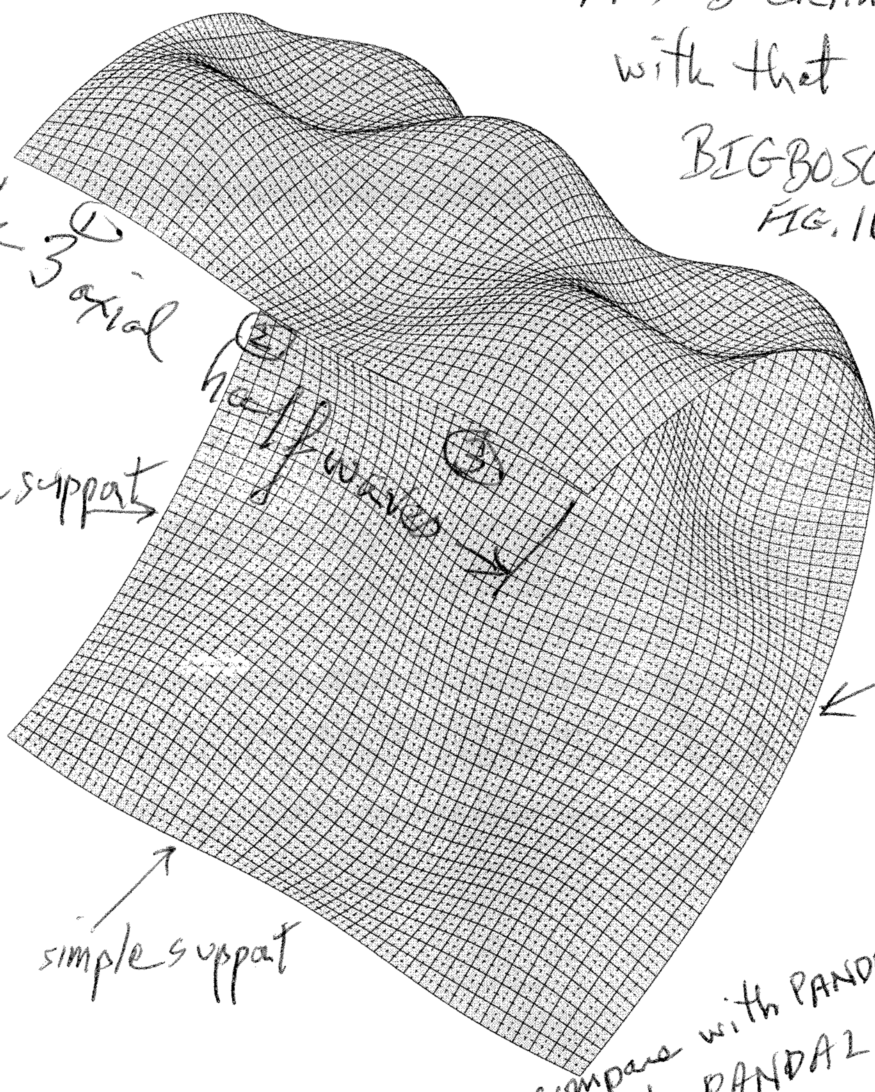
Input to STAGSUNIT

180 degrees is included in the STAGS model. Otherwise, there would be too many degrees of freedom.

Both stringers & rings are smeared out.

STAGS model of general buckling.
Stringers & rings are smeared out.

This buckling mode agrees with that predicted by BIGBOSOR4 & PANDA2
FIG. 16 Table 33b, Margin 13



simple support

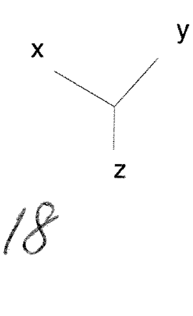
simple support

simple support

Also, compare with PANDA2 on p. 274: "EIGMNC"
Compare with PANDA2: Tables 33b & Margin 13
Compare with BIGBOSOR4 (Fig. 16)

solution scale = 0.5762E+01
mode 1, pcr = 0.25815E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63



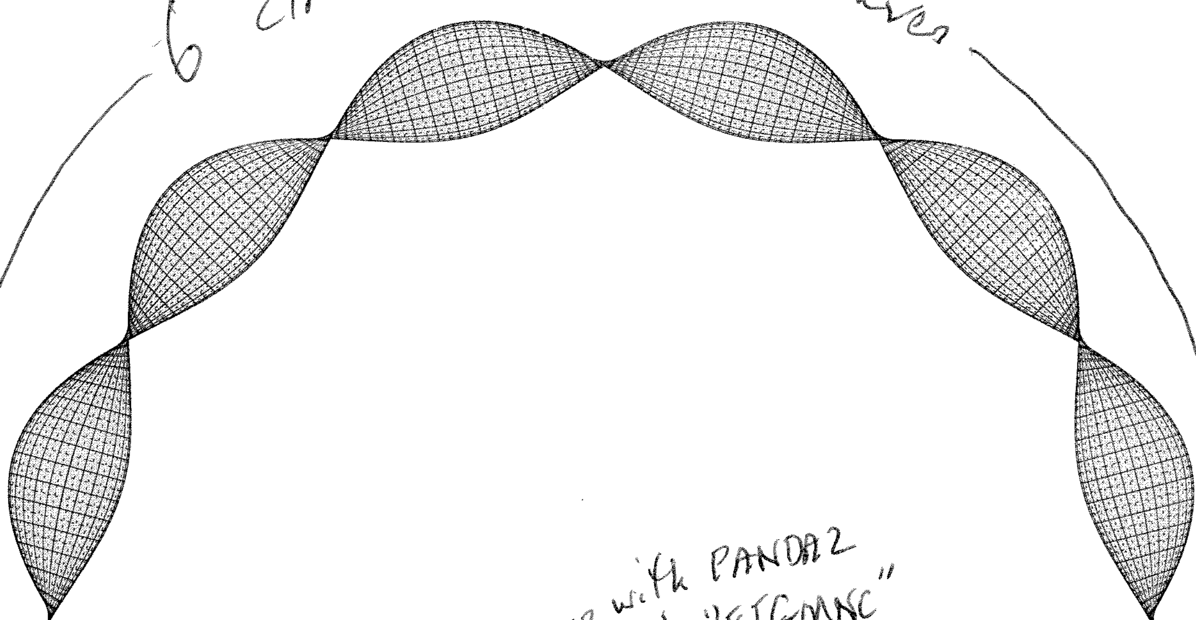
1.790E+01

Fig. 18

The general buckling mode agrees with that from PANDA2 & BIGBOSOR4

Table 33b, Margin #13 — Fig. 6

6 circumferential halfwaves



compare with PANDA2 "EIGMNC" outp. p. 274

solution scale = 0.4966E+01
mode 1, $\boxed{\text{pcr} = 0.25815\text{E}+01}$
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x 0.00
Θ y 90.00
Θ z 0.00

y
x z

1.600E+01

Fig. 19

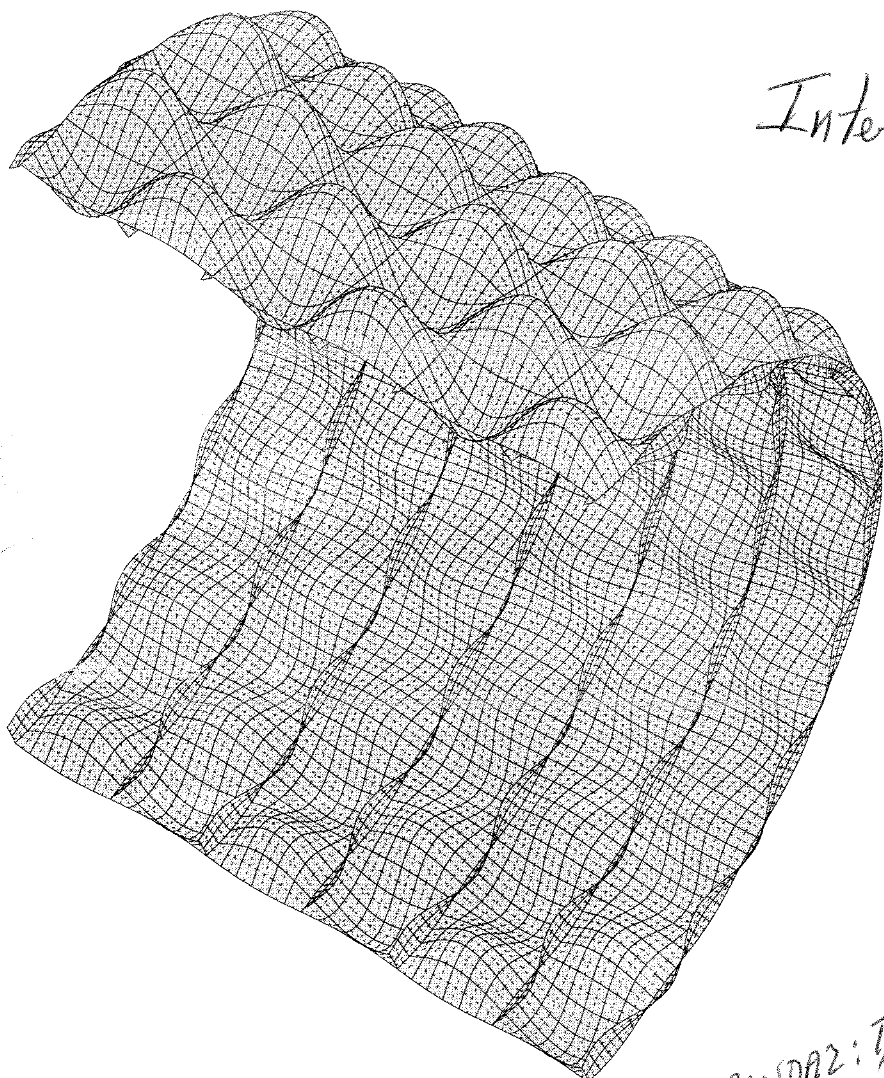
Table 35 nasaortho. STG

```
  n        $ Do you want a tutorial session and tutorial output?
     1     $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
     0     $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.000000   $ Local buckling load factor from PANDA2, EIGLOC
  y        $ Are the dimensions in this case in inches?
     0     $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
     0     $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
68.75000   $ X-direction length of the STAGS model of the panel: XSTAGS
150.796    $ Panel length in the plane of the screen, L2
  y        $ Is the nodal point spacing uniform along the stringer axis?
   101     $ Number of nodes in the X-direction: NODEX
  -2219    $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
     0     $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
     0     $ In-plane shear in load set A,                        Nxy
     0     $ Normal pressure in STAGS model in Load Set A, p
     0     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
     0     $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
     0     $ Normal pressure in STAGS model in Load Set B, p0
1.000000   $ Starting load factor for Load System A, STLD(1)
0.000000   $ Load factor increment for Load System A, STEP(1)
1.000000   $ Maximum load factor for Load System A, FACM(1)
     0     $ Starting load factor for Load System B, STLD(2)
     0     $ Load factor increment for Load System B, STEP(2)
     0     $ Maximum load factor for Load System B, FACM(2)
     1     $ How many eigenvalues do you want? NEIGS
   480     $ Choose element type (410 or 411 or 480) for panel skin
  n        $ Have you obtained buckling modes from STAGS for this case?
   162     $ Number of stringers in STAGS model of 360-deg. cylinder
     7     $ Number of rings in the STAGS model of the panel
  y        $ Are there rings at the ends of the panel?
     1     $ Number of finite elements between adjacent stringers
     6     $ Number of finite elements between adjacent rings
     3     $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
     3     $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
    -1     $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
  n        $ Do you want to use fasteners (they are like rigid links)?
note
  y        $ Are the stringers to be "smeared out"?
  n        $ Are the rings to be "smeared out"?
     5     $ Number of nodes over height of stiffener webs, NODWEB
     5     $ Number of nodes over width of stringer flange, NDFLGS
     5     $ Number of nodes over width of ring flange, NDFLGR
  n        $ Do you want stringer(s) with a high nodal point density?
  n        $ Do you want ring(s) with a high nodal point density?
  n        $ Is there plasticity in this STAGS model?
  y        $ Do you want to use the "least-squares" model for torque?
  y        $ Is stiffener sidesway permitted at the panel edges?
  n        $ Do you want symmetry conditions along the straight edges?
     0     $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

Input for STAGSUNIT

Stringers are smeared; rings are not smeared.

Inter-ring buckling
from STAGS



Inter-ring buckling

Compare with PANDA2: Tables 3, 3b, 3d, 4
Margin 17

solution scale = 0.6717E+01
mode 1, pcr = 0.25156E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63

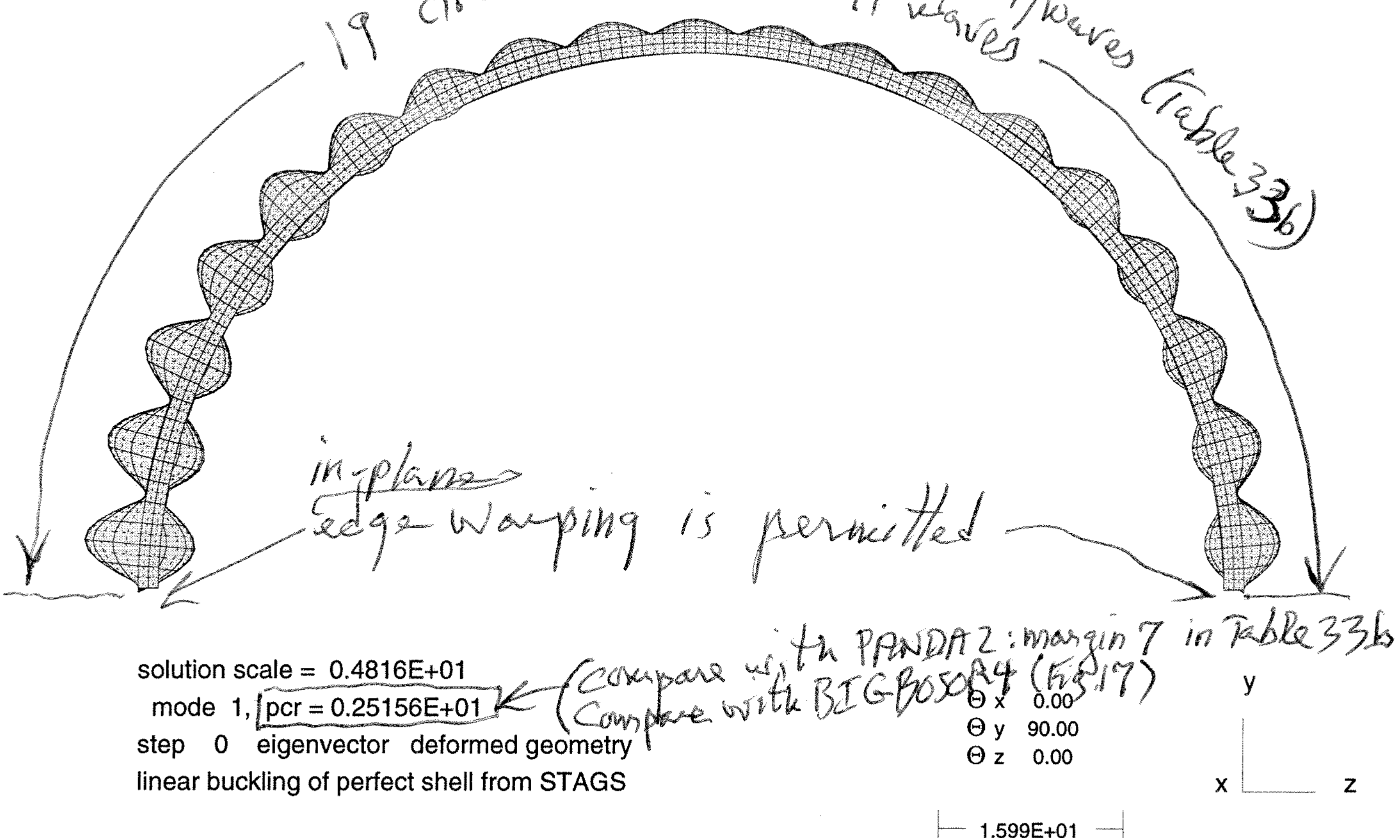
x y z

1.789E+01

Fig. 20

PANDA2 predicts 17 circ. halfwaves (Table 33b)
19 circumferential halfwaves

in-plane
edge warping is permitted



(Compare with PANDA2: margin 7 in Table 33b
(Compare with BIGBOSOR4 (Fig. 17)

Fig. 2~~0~~

Table 36 nasacntho. STG

```
   n          $ Do you want a tutorial session and tutorial output?
      1       $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
      0       $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.000000      $ Local buckling load factor from PANDA2, EIGLOC
   y          $ Are the dimensions in this case in inches?
      0       $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
      0       $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
34.37499      $ X-direction length of the STAGS model of the panel: XSTAGS
  5.585055    $ Panel length in the plane of the screen, L2
   y          $ Is the nodal point spacing uniform along the stringer axis?
    101       $ Number of nodes in the X-direction: NODEX
  -2219       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
      0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
      0       $ In-plane shear in load set A,                        Nxy
      0       $ Normal pressure in STAGS model in Load Set A, p
      0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
      0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
      0       $ Normal pressure in STAGS model in Load Set B, p0
1.000000      $ Starting load factor for Load System A, STLD(1)
0.000000      $ Load factor increment for Load System A, STEP(1)
1.000000      $ Maximum load factor for Load System A, FACM(1)
      0       $ Starting load factor for Load System B, STLD(2)
      0       $ Load factor increment for Load System B, STEP(2)
      0       $ Maximum load factor for Load System B, FACM(2)
      1       $ How many eigenvalues do you want? NEIGS
    480       $ Choose element type (410 or 411 or 480) for panel skin
   n          $ Have you obtained buckling modes from STAGS for this case?
    162       $ Number of stringers in STAGS model of 360-deg. cylinder
      4       $ Number of rings in the STAGS model of the panel
   y          $ Are there rings at the ends of the panel?
      3       $ Number of finite elements between adjacent stringers
     18       $ Number of finite elements between adjacent rings
      3       $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
      3       $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
     -1       $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n          $ Do you want to use fasteners (they are like rigid links)?
   n          $ Are the stringers to be "smeared out"?
   n          $ Are the rings to be "smeared out"?
      5       $ Number of nodes over height of stiffener webs, NODWEB
      5       $ Number of nodes over width of stringer flange, NDFLGS
      5       $ Number of nodes over width of ring flange, NDFLGR
   n          $ Do you want stringer(s) with a high nodal point density?
   n          $ Do you want ring(s) with a high nodal point density?
   n          $ Is there plasticity in this STAGS model?
   y          $ Do you want to use the "least-squares" model for torque?
   y          $ Is stiffener sidesway permitted at the panel edges?
   n          $ Do you want symmetry conditions along the straight edges?
      0       $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

note

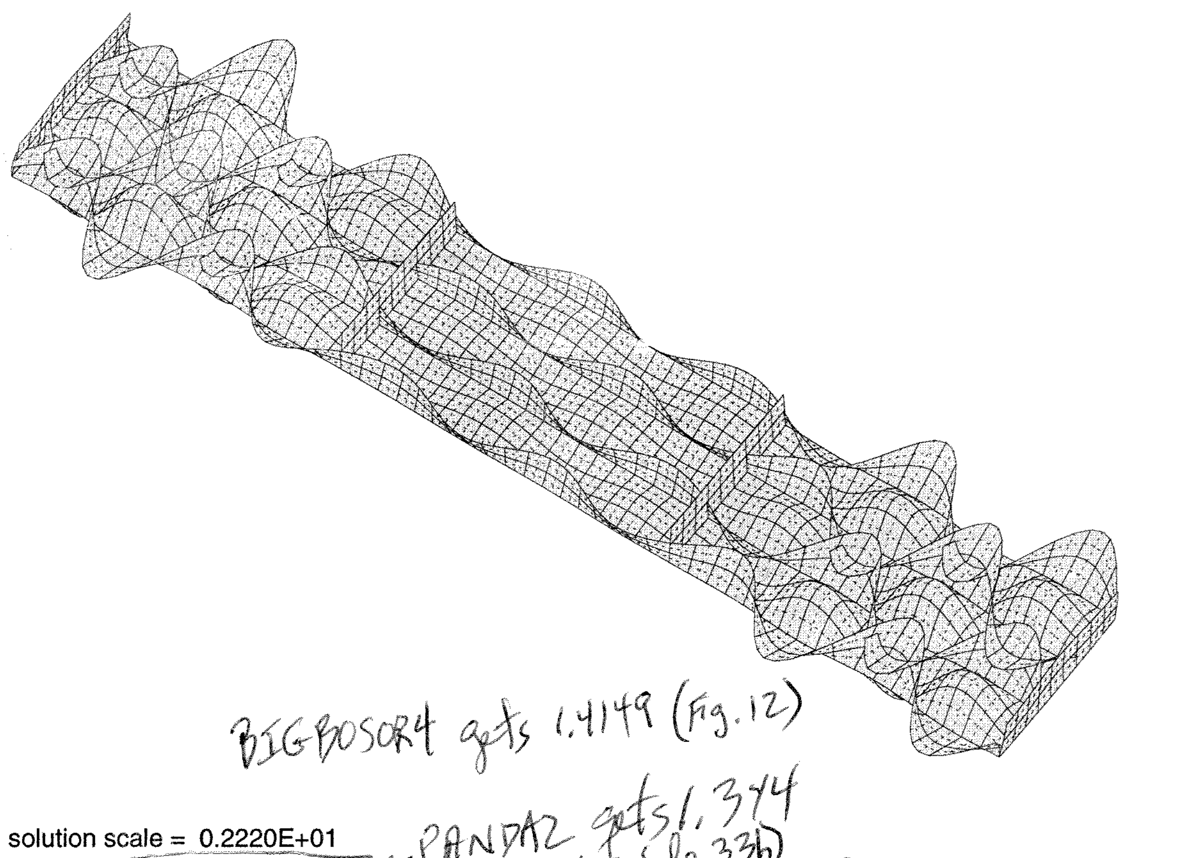
Input to STAGSUNIT

3 stringer bays & 3 ring bays

$3 \times 1.8617 = 5.5851$ (Table 33b)

$3 \times 11.458 = 34.374$ (Table 33b)

STAGS model for local buckling



BIGBOSOR4 gets 1.4149 (Fig. 12)

solution scale = 0.2220E+01
mode 1, pcr = 0.13413E+01 ← PANDA2 gets 1.344 (Table 33b)
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Fig. 22

Table 37 nasaortho. STG

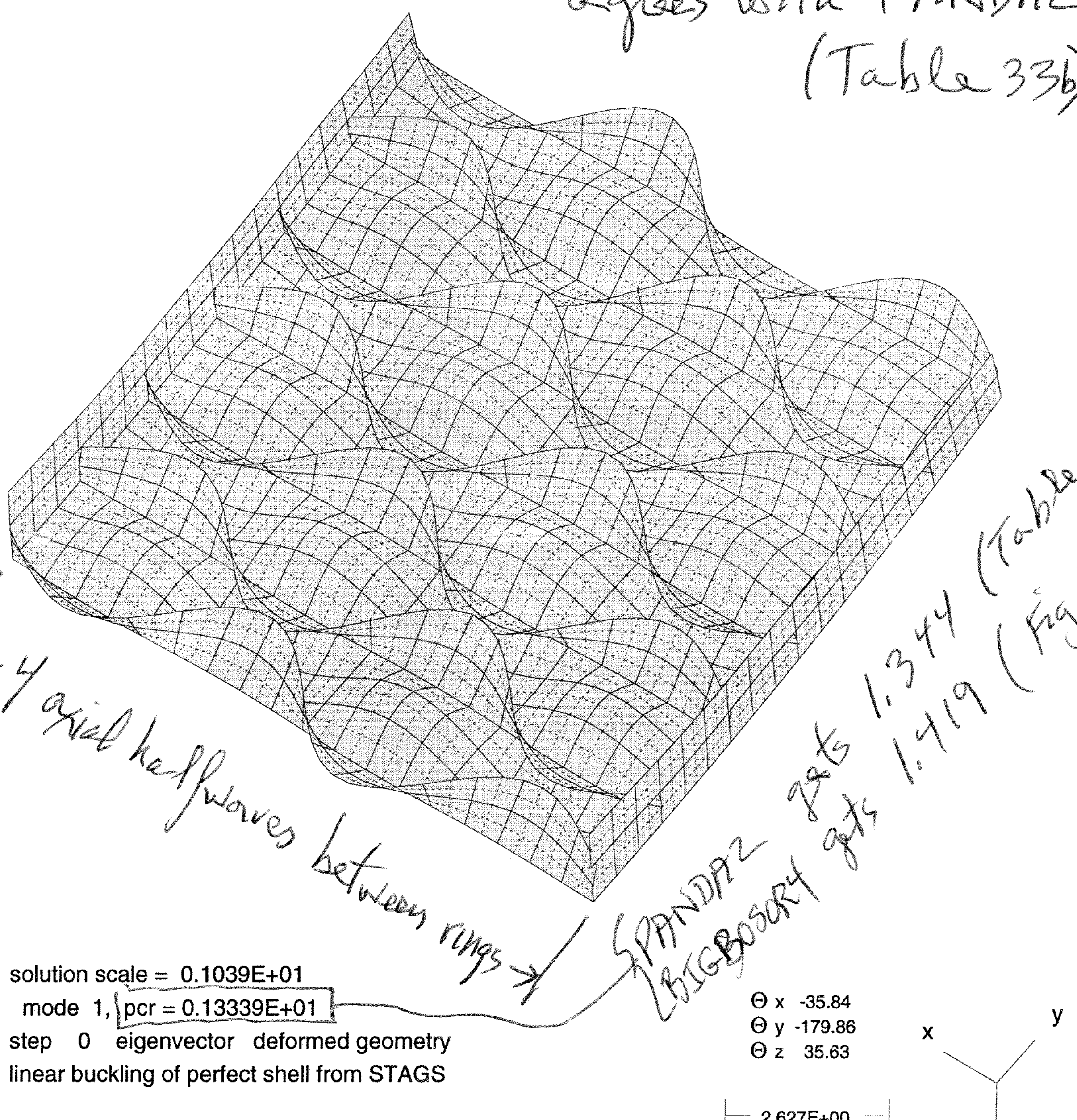
```
   n        $ Do you want a tutorial session and tutorial output?
      1     $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
      0     $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
 1.000000   $ Local buckling load factor from PANDA2, EIGLOC
   y        $ Are the dimensions in this case in inches?
      0     $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
      0     $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
 11.45833   $ X-direction length of the STAGS model of the panel: XSTAGS
 11.17011   $ Panel length in the plane of the screen, L2
   y        $ Is the nodal point spacing uniform along the stringer axis?
    101     $ Number of nodes in the X-direction: NODEX
  -2219     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
      0     $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
      0     $ In-plane shear in load set A,                        Nxy
      0     $ Normal pressure in STAGS model in Load Set A, p
      0     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
      0     $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
      0     $ Normal pressure in STAGS model in Load Set B, p0
 1.000000   $ Starting load factor for Load System A, STLD(1)
 0.000000   $ Load factor increment for Load System A, STEP(1)
 1.000000   $ Maximum load factor for Load System A, FACM(1)
      0     $ Starting load factor for Load System B, STLD(2)
      0     $ Load factor increment for Load System B, STEP(2)
      0     $ Maximum load factor for Load System B, FACM(2)
      1     $ How many eigenvalues do you want? NEIGS
    480     $ Choose element type (410 or 411 or 480) for panel skin
   n        $ Have you obtained buckling modes from STAGS for this case?
    162     $ Number of stringers in STAGS model of 360-deg. cylinder
      2     $ Number of rings in the STAGS model of the panel
   y        $ Are there rings at the ends of the panel?
      3     $ Number of finite elements between adjacent stringers
     18     $ Number of finite elements between adjacent rings
      3     $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
      3     $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
     -1     $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n        $ Do you want to use fasteners (they are like rigid links)?
   n        $ Are the stringers to be "smeared out"?
   n        $ Are the rings to be "smeared out"?
      5     $ Number of nodes over height of stiffener webs, NODWEB
      5     $ Number of nodes over width of stringer flange, NDFLGS
      5     $ Number of nodes over width of ring flange, NDFLGR
   n        $ Do you want stringer(s) with a high nodal point density?
   n        $ Do you want ring(s) with a high nodal point density?
   n        $ Is there plasticity in this STAGS model?
   y        $ Do you want to use the "least-squares" model for torque?
   y        $ Is stiffener sidesway permitted at the panel edges?
   n        $ Do you want symmetry conditions along the straight edges?
      0     $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

Input for STAGSUNIT

6 stringer bays X 1 ring bay

STAGS model for local buckling

Local buckling mode agrees with PANDA2 (Table 33b)



← 4 axial halfwaves between rings →

PANDA2 gets 1.344 (Table 33)

BIGBOSOR4 gets 1.419 (Fig. 12)

Fig. 23

Table 38 nasaortho.STG

Input for STAGSUNIT

```
   n         $ Do you want a tutorial session and tutorial output?
      1      $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
      0      $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.000000     $ Local buckling load factor from PANDA2, EIGLOC
   y         $ Are the dimensions in this case in inches?
      0      $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
      0      $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
68.75        $ X-direction length of the STAGS model of the panel: XSTAGS
50.26548     $ Panel length in the plane of the screen, L2
   y         $ Is the nodal point spacing uniform along the stringer axis?
    101      $ Number of nodes in the X-direction: NODEX
  -2219      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
      0      $ In-plane shear in load set A,                        Nxy
      0      $ Normal pressure in STAGS model in Load Set A, p
      0      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
      0      $ Normal pressure in STAGS model in Load Set B, p0
1.000000     $ Starting load factor for Load System A, STLD(1)
0.000000     $ Load factor increment for Load System A, STEP(1)
1.000000     $ Maximum load factor for Load System A, FACM(1)
      0      $ Starting load factor for Load System B, STLD(2)
      0      $ Load factor increment for Load System B, STEP(2)
      0      $ Maximum load factor for Load System B, FACM(2)
      1      $ How many eigenvalues do you want? NEIGS
    480      $ Choose element type (410 or 411 or 480) for panel skin
   n         $ Have you obtained buckling modes from STAGS for this case?
    162      $ Number of stringers in STAGS model of 360-deg. cylinder
      7      $ Number of rings in the STAGS model of the panel
   y         $ Are there rings at the ends of the panel?
      2      $ Number of finite elements between adjacent stringers
      9      $ Number of finite elements between adjacent rings
      3      $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
      3      $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
     -1      $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n         $ Do you want to use fasteners (they are like rigid links)?
   y         $ Are the stringers to be "smeared out"?
   y         $ Are the rings to be "smeared out"?
      5      $ Number of nodes over height of stiffener webs, NODWEB
      5      $ Number of nodes over width of stringer flange, NDFLGS
      5      $ Number of nodes over width of ring flange, NDFLGR
   n         $ Do you want stringer(s) with a high nodal point density?
   n         $ Do you want ring(s) with a high nodal point density?
   n         $ Is there plasticity in this STAGS model?
   y         $ Do you want to use the "least-squares" model for torque?
   y         $ Is stiffener sidesway permitted at the panel edges?
   y         $ Do you want symmetry conditions along the straight edges?
      0      $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

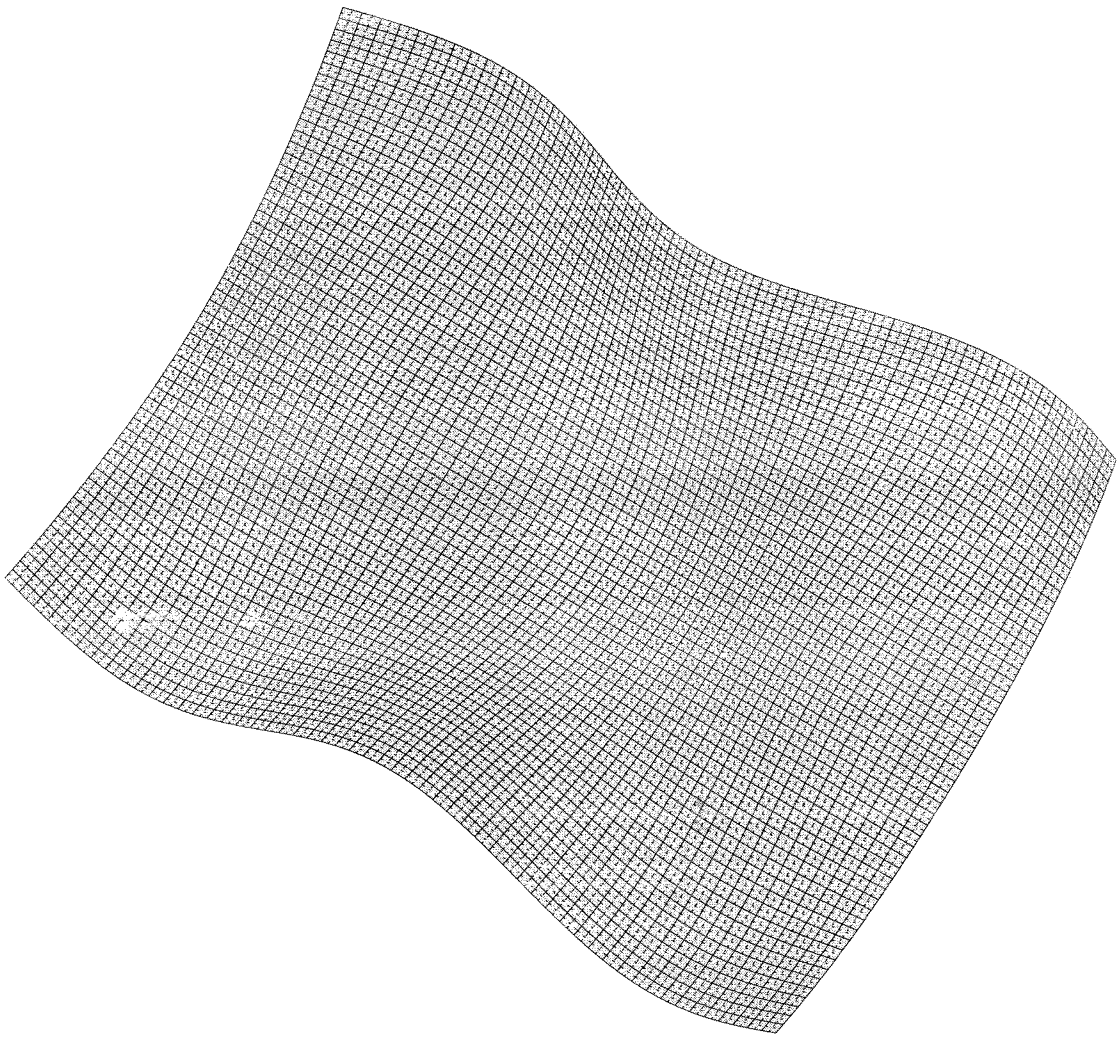
note

note: symmetry along the two straight edges. Allows 60-degree STAGS model: One full circumferential wave of the critical general buckling mode, which has 6 circ. halfwaves over 180 degrees of the circumference (see Margin #13 in Table 33b & see Fig. 19 for STAGS prediction).

There are 27 stringer bays in this model:

$50.26548'' = 27 \times 1.8617'' = 50.2659''$ (Table 33b)

60-degree STAGS model
(all stiffeners smeared)



solution scale = 0.4205E+01 ← compare with Fig. 18
mode 1, $\boxed{\text{pcr = 0.25814E+01}}$
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63

1.336E+01

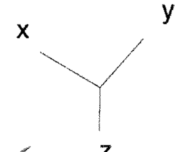


Fig. 24

60-degree STAGS model for general buckling.

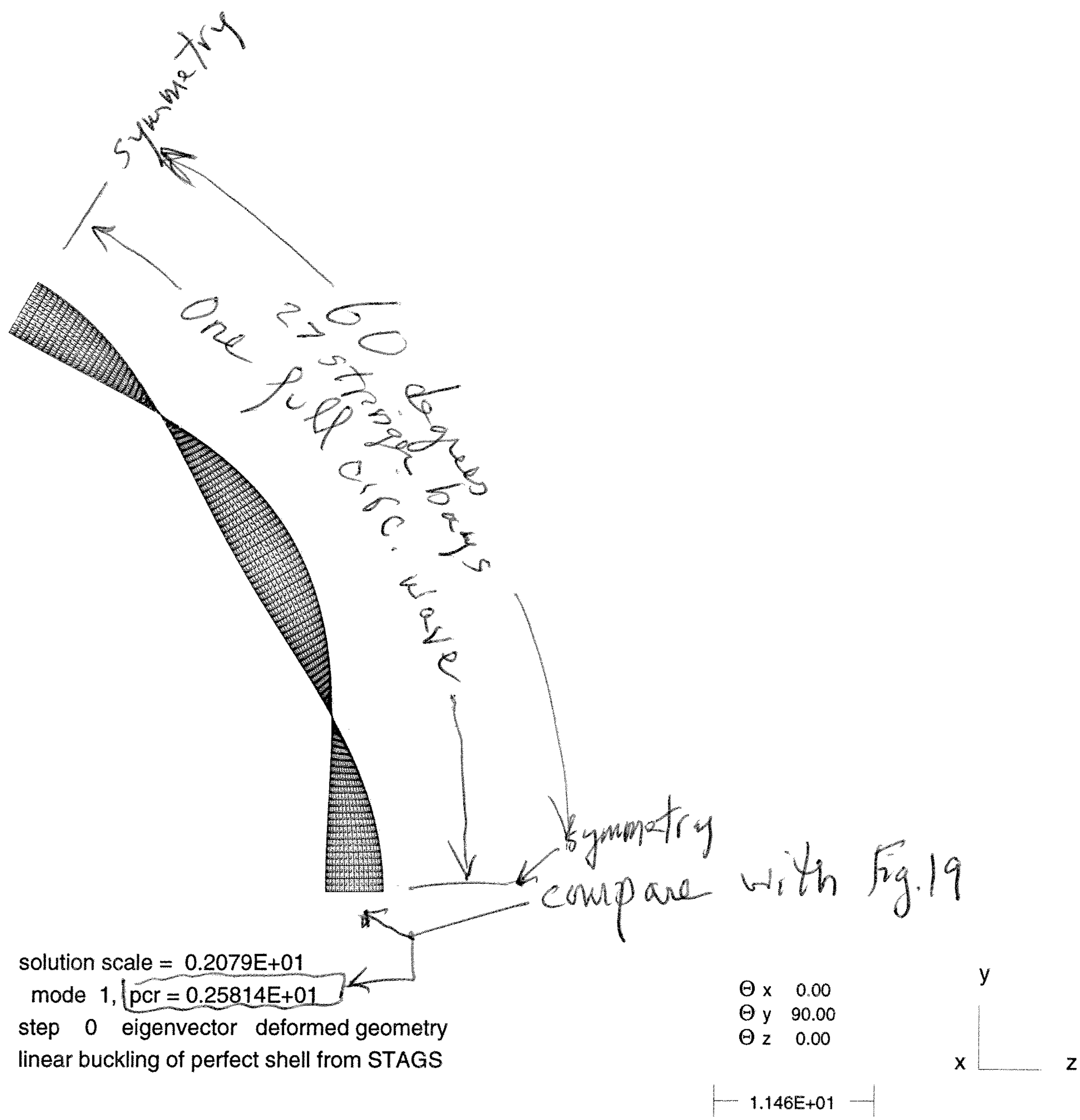


Fig. 25

Table 39 nasaortho, STG

```
n          $ Do you want a tutorial session and tutorial output?
   1       $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
   0       $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.000000   $ Local buckling load factor from PANDA2, EIGLOC
  y        $ Are the dimensions in this case in inches?
   0       $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
   0       $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
68.75      $ X-direction length of the STAGS model of the panel: XSTAGS
50.26548   $ Panel length in the plane of the screen, L2
  y        $ Is the nodal point spacing uniform along the stringer axis?
  101      $ Number of nodes in the X-direction: NODEX
 -2219     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
   0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
   0       $ In-plane shear in load set A,                        Nxy
   0       $ Normal pressure in STAGS model in Load Set A, p
   0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
   0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
   0       $ Normal pressure in STAGS model in Load Set B, p0
1.000000   $ Starting load factor for Load System A, STLD(1)
0.000000   $ Load factor increment for Load System A, STEP(1)
1.000000   $ Maximum load factor for Load System A, FACM(1)
   0       $ Starting load factor for Load System B, STLD(2)
   0       $ Load factor increment for Load System B, STEP(2)
   0       $ Maximum load factor for Load System B, FACM(2)
   1       $ How many eigenvalues do you want? NEIGS
  480      $ Choose element type (410 or 411 or 480) for panel skin
 n         $ Have you obtained buckling modes from STAGS for this case?
  162      $ Number of stringers in STAGS model of 360-deg. cylinder
   7       $ Number of rings in the STAGS model of the panel
 y         $ Are there rings at the ends of the panel?
   2       $ Number of finite elements between adjacent stringers
   9       $ Number of finite elements between adjacent rings
   3       $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
   3       $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
  -1       $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
 n         $ Do you want to use fasteners (they are like rigid links)?
 y         $ Are the stringers to be "smeared out"?
 n         $ Are the rings to be "smeared out"?
   5       $ Number of nodes over height of stiffener webs, NODWEB
   5       $ Number of nodes over width of stringer flange, NDFLGS
   5       $ Number of nodes over width of ring flange, NDFLGR
 n         $ Do you want stringer(s) with a high nodal point density?
 n         $ Do you want ring(s) with a high nodal point density?
 n         $ Is there plasticity in this STAGS model?
 y         $ Do you want to use the "least-squares" model for torque?
 y         $ Is stiffener sidesway permitted at the panel edges?
 y         $ Do you want symmetry conditions along the straight edges?
   0       $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

We changed this to 8

note

Input for STAGSUNIT

Same as Table 38 except the rings are not smeared out.

Before executing STAGS we changed the number of eigenvalues wanted from 1 to 8, & we changed the eigenvalue shift from 0.7 to 2.5.

Table 40

nasaortho.out2 (ABRIDGED) stringers smeared, rings not smeared

shift = 2.5, no negative roots
0 CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

		CRITICAL LOAD FACTOR COMBINATION			
NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF	
1	2.514932E+00	2.514932E+00	0.000000E+00	6213	← inter-ring buckling (Fig 26)
2	2.534885E+00	2.534885E+00	0.000000E+00	5889	
3	2.556169E+00	2.556169E+00	0.000000E+00	5889	
4	2.564626E+00	2.564626E+00	0.000000E+00	86329	← general buckling (Fig. 27)
5	2.582188E+00	2.582188E+00	0.000000E+00	5889	
6	2.638585E+00	2.638585E+00	0.000000E+00	65397	
7	2.695458E+00	2.695458E+00	0.000000E+00	6213	
8	2.707707E+00	2.707707E+00	0.000000E+00	8829	

Output from STAGS