Table 77 nasaortho2.OPM (abridged) (3 pages)

nasaortho2.OPM (abridged, after one execution of SUPEROPT)

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 ***********************************************************
 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 =  1.0174E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0144E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE               DEFINITION
  1  1.55E-02 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
  2  1.54E-02 Bending-torsion buckling; M=5  ;FS=0.999
  3  1.84E-02 Bending-torsion buckling: Koiter theory,M=5 , axial halfwav;FS=0.99
  4  1.73E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.019; MID.;FS=1.
  5  4.48E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0353; MID.;FS=1.
  6  1.09E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
  7  9.25E-02 Ring sidesway buk., discrete model, n=50  circ.halfwaves;FS=0.999
  8  2.34E-01 Lo-n Inter-ring buck.,discrete model,n=19  circ.halfwaves;FS=0.999
  9  1.04E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.019;-MID.;FS=1.
 10  4.62E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 11  9.24E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 12  2.48E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .MID.;FS=1.
 13  2.27E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .NOPO;FS=1.
 14  3.19E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
 15  1.54E+01 buck.(SAND);rolling with smear rings; M=225;N=1;slope=0.;FS=0.999
 16  8.78E-01 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
 17  1.45E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
 18  4.49E+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 =  1.0412E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0482E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE               DEFINITION
  1  4.93E-02 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
  2  4.82E-02 Bending-torsion buckling; M=5  ;FS=1.
  3  4.23E-02 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
  4  1.66E+00 eff.stress:matl=1,STR,Dseg=4,node=6,layer=1,z=-0.019; RNGS;FS=1.
  5  5.53E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0353; RNGS;FS=1.
  6  1.43E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
  7 -4.11E-03 Inter-ring bucklng, discrete model, n=58  circ.halfwaves;FS=0.999
  8  1.02E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.019;-RNGS;FS=1.
  9  5.91E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
 10  9.13E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
 11  3.14E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .RNGS;FS=1.
 12  4.05E-01 buck.(SAND);rolling with smear string;M=1;N=16;slope=0.;FS=0.999
 13  1.53E+01 buck.(SAND);rolling with smear rings; M=225;N=1;slope=0.;FS=0.999
 14  9.71E-01 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
 15 -1.12E-02 buck.(SAND);rolling only of   rings;  M=0;N=50;slope=0.;FS=1.4
 16  1.45E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
 17  4.31E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

Wimp = +0.050"

Table 77 (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 =  1.0198E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0417E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE               DEFINITION
 1  4.28E-02 Local buckling from discrete model-1.,M=9   axial halfwaves;FS=0.99
 2  9.71E-02 Long-axial-wave bending-torsion buckling; M=5  ;FS=0.999
 3  2.08E-02 Local buckling from Koiter theory,M=9   axial halfwaves;FS=0.999
 4  1.04E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.019; MID.;FS=1.
 5  6.70E+05 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  1.06E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0353; MID.;FS=1.
 7  4.15E-02 (m=7   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  5.74E-03 Inter-ring bucklng, discrete model, n=58  circ.halfwaves;FS=0.999
 9  1.03E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.019;-MID.;FS=1.
10  4.63E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  9.23E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  1.79E+00 buckling margin stringer Iseg.3 . Local halfwaves=7  .MID.;FS=1.
13  2.25E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .NOPO;FS=1.
14  3.23E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
15  1.19E+01 buck.(SAND);rolling with smear rings; M=215;N=1;slope=0.;FS=0.999
16  8.75E-01 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
17  1.45E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
18  3.19E+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 =  9.9523E-01 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0293E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE               DEFINITION
 1  3.04E-02 Local buckling from discrete model-1.,M=9   axial halfwaves;FS=0.99
 2  1.21E-01 Long-axial-wave bending-torsion buckling; M=4  ;FS=1.
 3 -3.77E-03 Local buckling from Koiter theory,M=9   axial halfwaves;FS=0.999
 4  7.27E-01 eff.stress:matl=1,SKN,Dseg=1,node=1,layer=1,z=0.019; RNGS;FS=1.
 5  2.78E+04 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6  9.17E-01 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=0.0353; RNGS;FS=1.
 7  4.54E-02 (m=6   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.89E-01 Ring sidesway buk., discrete model, n=50  circ.halfwaves;FS=0.999
 9  1.88E-01 Lo-n Ring sidesway, discrete model, n=48  circ.halfwaves;FS=0.999
10  9.29E-01 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.019;-RNGS;FS=1.
11  6.51E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
12  9.86E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
13  2.15E+00 buckling margin stringer Iseg.3 . Local halfwaves=7  .RNGS;FS=1.
14  1.21E+01 buck.(SAND);rolling with smear rings; M=215;N=1;slope=0.;FS=0.999
15  1.05E+00 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
16  1.57E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
17  3.09E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 2 LOAD SETS PROCESSED  ***********
```

Wimp = -0.050

Table 77 (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  1.4976E+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  4.9915E-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  7.6153E-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  3.7966E-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  7.0532E-02  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   6   N     N     N      0    0.00E+00   0.00E+00  1.1772E+01  0.00E+00       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  1.7724E+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  6.6125E-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    8.252E+01    WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                              =    3.7392E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                     =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                         =    3.5324E+01
  TOTAL WEIGHT OF RINGS                             =    9.8052E+00
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=    7.9598E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho2.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF nasaortho2.OPM FILE *****************
```

Optimum design for

Wimp = ±0.050"

Compare with Table 33a

Table 78 (2 pages) nasaortho2.OPM (Wimp = 0.0)

```
nasaortho2.OPM (abridged output file for 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 =  1.1696E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1584E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE              DEFINITION
  1  1.60E-01 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
  2  1.60E-01 Bending-torsion buckling; M=5  ;FS=0.999
  3  1.71E-01 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
  4  1.39E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.019; MID.;FS=1.
  5  1.27E+00 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0353; MID.;FS=1.
  6  1.64E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
  7  2.79E-01 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
  8  1.39E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=-0.019;-MID.;FS=1.
  9  1.27E+00 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 10  8.90E+00 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 11  7.37E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .MID.;FS=1.
 12  7.36E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .NOPO;FS=1.
 13  6.14E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
 14  1.53E+01 buck.(SAND);rolling with smear rings; M=215;N=1;slope=0.;FS=0.999
 15  1.61E+00 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
 16  3.73E+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 =  1.1875E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.1886E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE              DEFINITION
  1  1.90E-01 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.99
  2  1.89E-01 Bending-torsion buckling; M=5  ;FS=1.
  3  1.89E-01 Bending-torsion buckling: Koiter theory,M=5   axial halfwav;FS=0.99
  4  1.32E+00 eff.stress:matl=1,STR,Dseg=4,node=11,layer=1,z=0.019; RNGS;FS=1.
  5  1.30E+00 eff.stress:matl=2,STR,Dseg=3,node=1,layer=1,z=-0.0353; RNGS;FS=1.
  6  1.81E-01 (m=5   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
  7  2.75E-01 Inter-ring bucklng, discrete model, n=17  circ.halfwaves;FS=0.999
  8  1.37E+00 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=0.019;-RNGS;FS=1.
  9  1.36E+00 eff.stress:matl=2,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
 10  8.66E+00 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-RNGS;FS=1.
 11  8.69E-01 buckling margin stringer Iseg.3 . Local halfwaves=7  .RNGS;FS=1.
 12  1.52E+01 buck.(SAND);rolling with smear rings; M=215;N=1;slope=0.;FS=0.999
 13  1.73E+00 buck.(SAND);rolling only of stringers;M=56;N=0;slope=0.;FS=1.4
 14  3.60E+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
```

Table 78 (p. 2 of 2)

```
 NO. VAR.  VAR.  VAR.    TO    CONSTANT    BOUND       VALUE       BOUND
  1   Y     N     N      0    0.00E+00   1.00E+00  1.4976E+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  4.9915E-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  7.6153E-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  3.7966E-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  7.0532E-02  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
  6   N     N     N      0    0.00E+00   0.00E+00  1.1772E+01  0.00E+00        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  1.7724E+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  6.6125E-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    8.252E+01    WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                                  =    3.7392E+01
  TOTAL WEIGHT OF SUBSTIFFENERS                         =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                             =    3.5323E+01
  TOTAL WEIGHT OF RINGS                                 =    9.8054E+00
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=     7.9598E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 nasaortho2.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF nasaortho2.OPM FILE ****************
```

Optimum design obtained with Wimp = 0.050" (same as in Table 77)

Table 7 nasaortho2.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, . .)
 1.497600      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       2       $ Number of parameter to change (1, 2, 3, . .)
0.4991500      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       3       $ Number of parameter to change (1, 2, 3, . .)
0.7615300      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       4       $ Number of parameter to change (1, 2, 3, . .)
0.3796600E-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, . .)
0.7053200E-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, . .)
 1.772400      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       9       $ Number of parameter to change (1, 2, 3, . .)
0.6612500E-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

Purpose: to save the optimum design.

Table 80 nasaortho2.PAN

```
     n          $ Do you want a tutorial session and tutorial output?
 74.88000       $ 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
        5       $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
        3       $ How many eigenvalues (get at least 3) do you want?
```

Input for PANEL

exactly 50 stringer spacings:

$50 \times \underbrace{1.4976''}_{\text{Table 78}} = 74.88''$

Table 81 (2 pp.) ~~res~~ input for resetup & output from bigrestart

nasaortho2.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?
```

---

nasaortho2.OUT (abridged output from BIGBOSOR4 processor called bigrestart):

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

 EIGENVALUES =
    1.34558E+00    1.35474E+00    1.36569E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      200

 EIGENVALUES =
    1.51311E+00    1.53868E+00    1.55817E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      300

 EIGENVALUES =
    1.29399E+00    1.30823E+00    1.31915E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      400

 EIGENVALUES =
    1.22782E+00    1.23469E+00    1.23990E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      500

 EIGENVALUES =
    1.21715E+00    1.21934E+00    1.22185E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      600

 EIGENVALUES =
    1.22389E+00    1.22575E+00    1.22793E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      700

 EIGENVALUES =
    1.23517E+00    1.23717E+00    1.23916E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      800

 EIGENVALUES =
    1.24536E+00    1.24718E+00    1.24897E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =      900

 EIGENVALUES =
    1.25462E+00    1.25642E+00    1.25857E+00

 BUCKLING LOADS FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =     1000

 EIGENVALUES =
    1.26675E+00    1.26912E+00    1.27149E+00
```

← means "m=1 axial halfwaves between rings" (Appendix 1)

inter-ring buckling, Fig. 94

← means "m=5 axial halfwaves between rings" (Appendix 1)

local buckling, Fig. 95

Table 81 (p. 282)

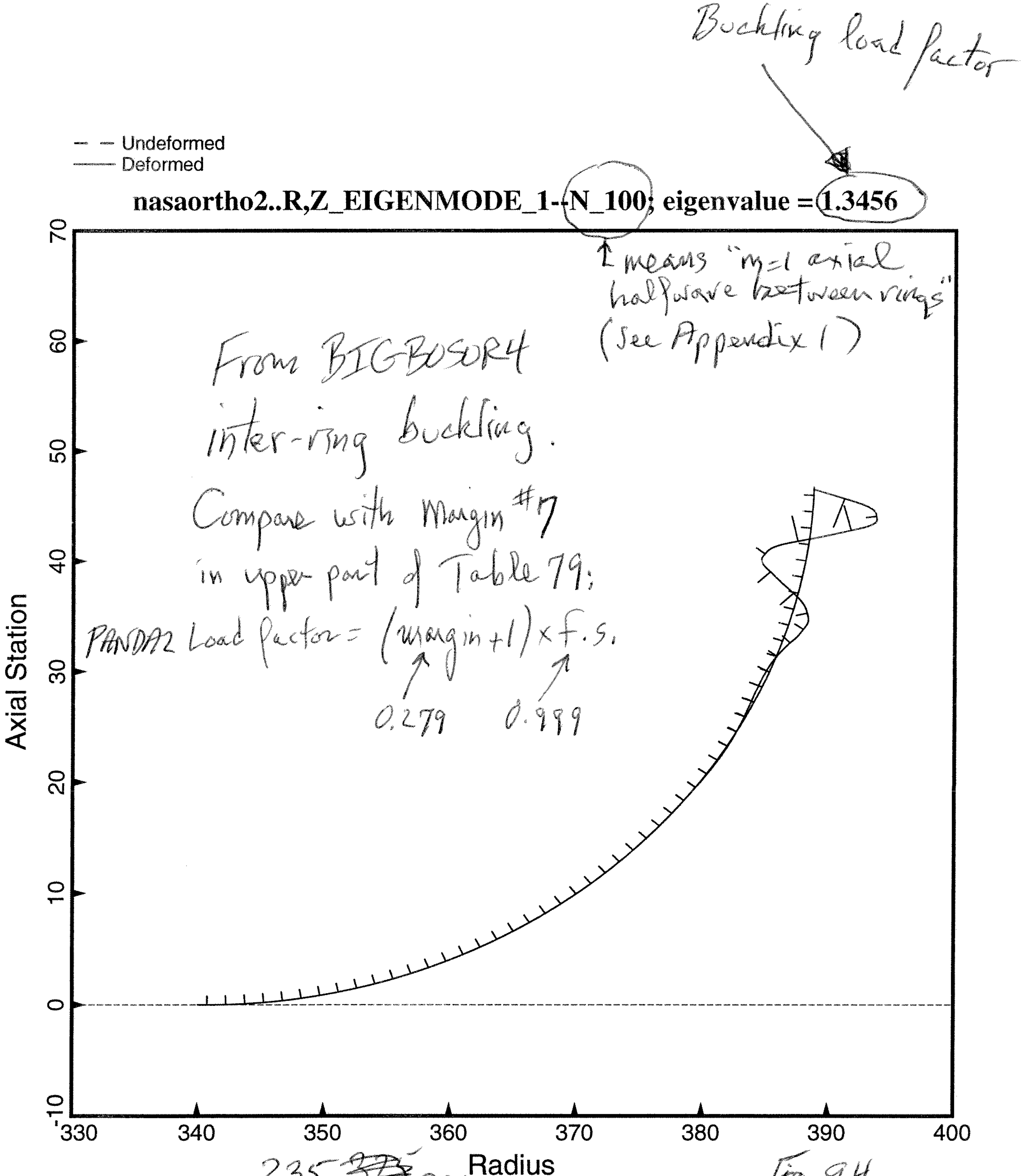
```
**** CRITICAL EIGENVALUE AND WAVENUMBER ****
EIGCRT=  1.2171E+00; NO. OF CIRC. WAVES, NWVCRT=  500
**************************************************

***** EIGENVALUES AND MODE SHAPES *****
 EIGENVALUE(CIRC. WAVES)
=======================================
   1.3456E+00( 100)
   1.5131E+00( 200)
   1.2940E+00( 300)
   1.2278E+00( 400)
   1.2171E+00( 500)
   1.2239E+00( 600)
   1.2352E+00( 700)
   1.2454E+00( 800)
   1.2546E+00( 900)
   1.2668E+00(1000)
=======================================
```

← inter-ring buckling (Fig. 94)

← local buckling (Fig. 95)

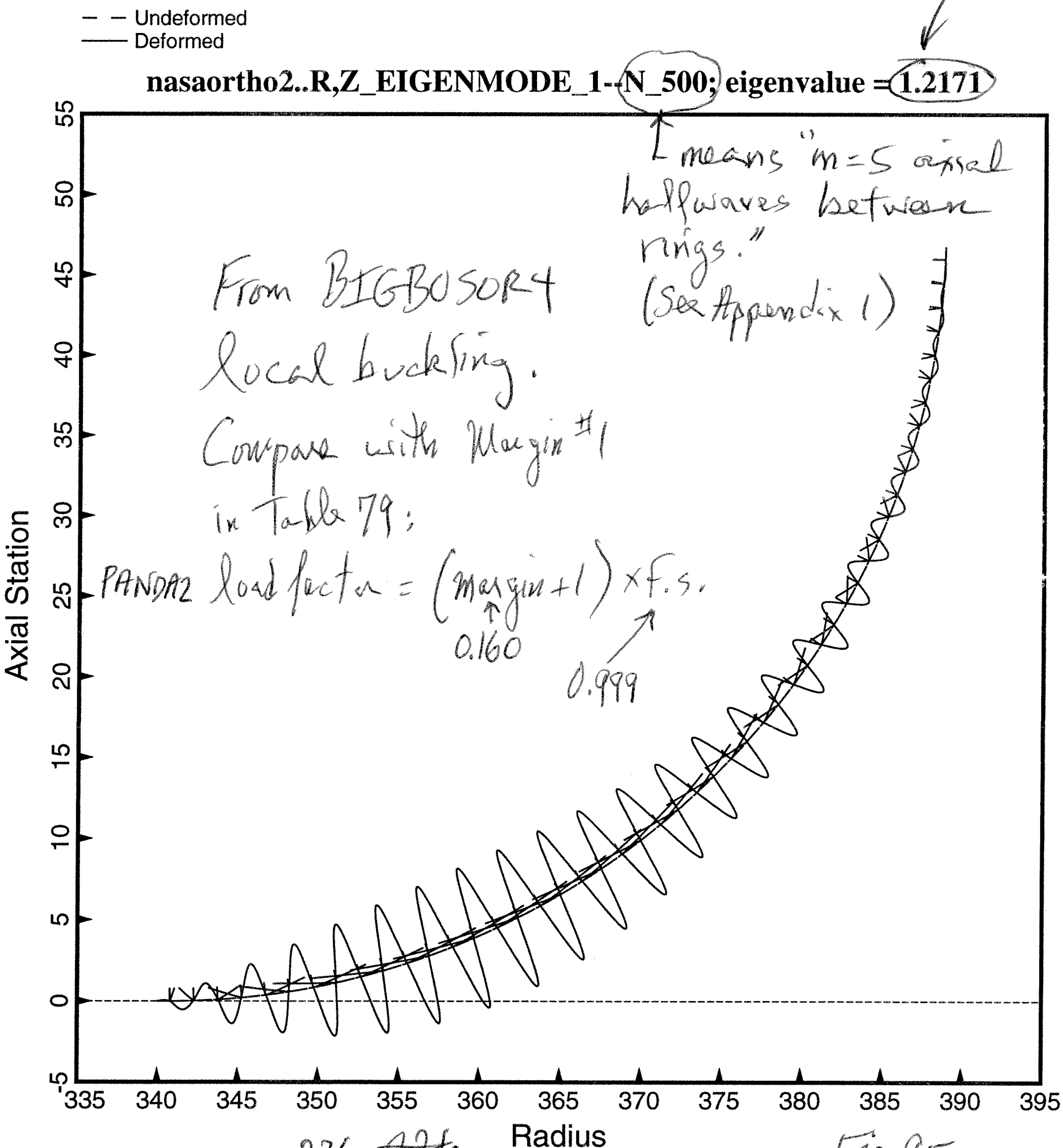
Output from bigrestart: nasaortho2.OUT



235 ~~235~~ ~~236~~

Fig 94

buckling load factor



means "m=5 axial halfwaves between rings."
(See Appendix 1)

From BIGBOSOR4
local buckling.
Compare with Margin #1
in Table 79;
PANDA2 load factor = (margin+1) x f.s.
0.160
0.999

236 ~~326~~

Fig 95

Table 82 nasaortho2.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 to PANEL2

Table 83 nasaortho2.OUT

nasaortho2.OUT (abridged output from bigbosorall)

```
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 ========================================
     3.3831E+00(   2)
     3.1330E+00(   3)
     2.6943E+00(   4)
     2.2258E+00(   5)
     2.0220E+00(   6) <--general buckling (Fig. 96)
     2.0601E+00(   7)
     2.1583E+00(   8)
     2.1286E+00(   9)
     2.0750E+00(  10)
     2.0259E+00(  11)
     1.9849E+00(  12)
     1.9523E+00(  13)
     1.9279E+00(  14)
     1.9112E+00(  15)
     1.9013E+00(  16)
     1.8972E+00(  17) <--interring buckling (Fig. 97)
     1.8981E+00(  18)
     1.9032E+00(  19)
     1.9115E+00(  20)
 ========================================
```

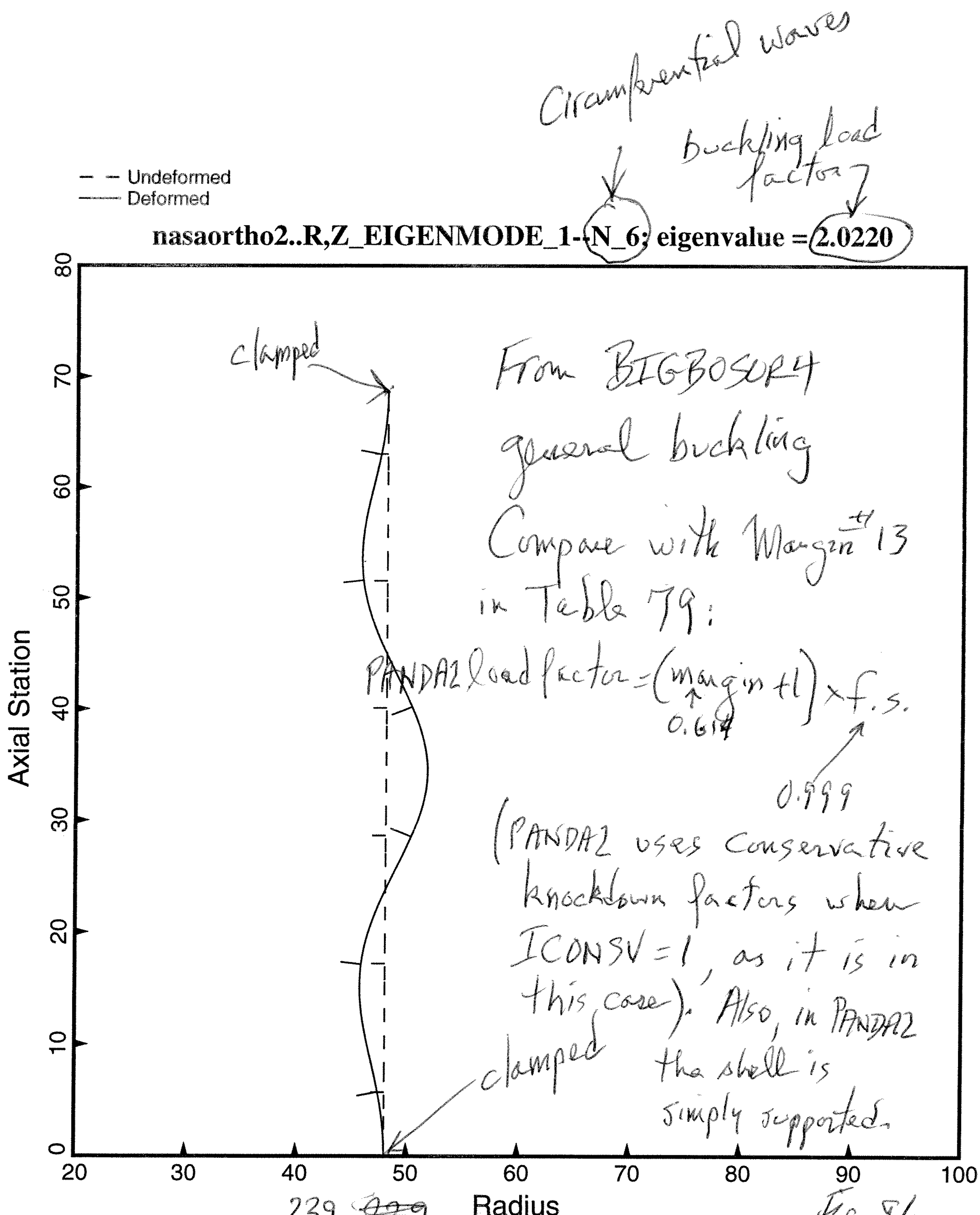
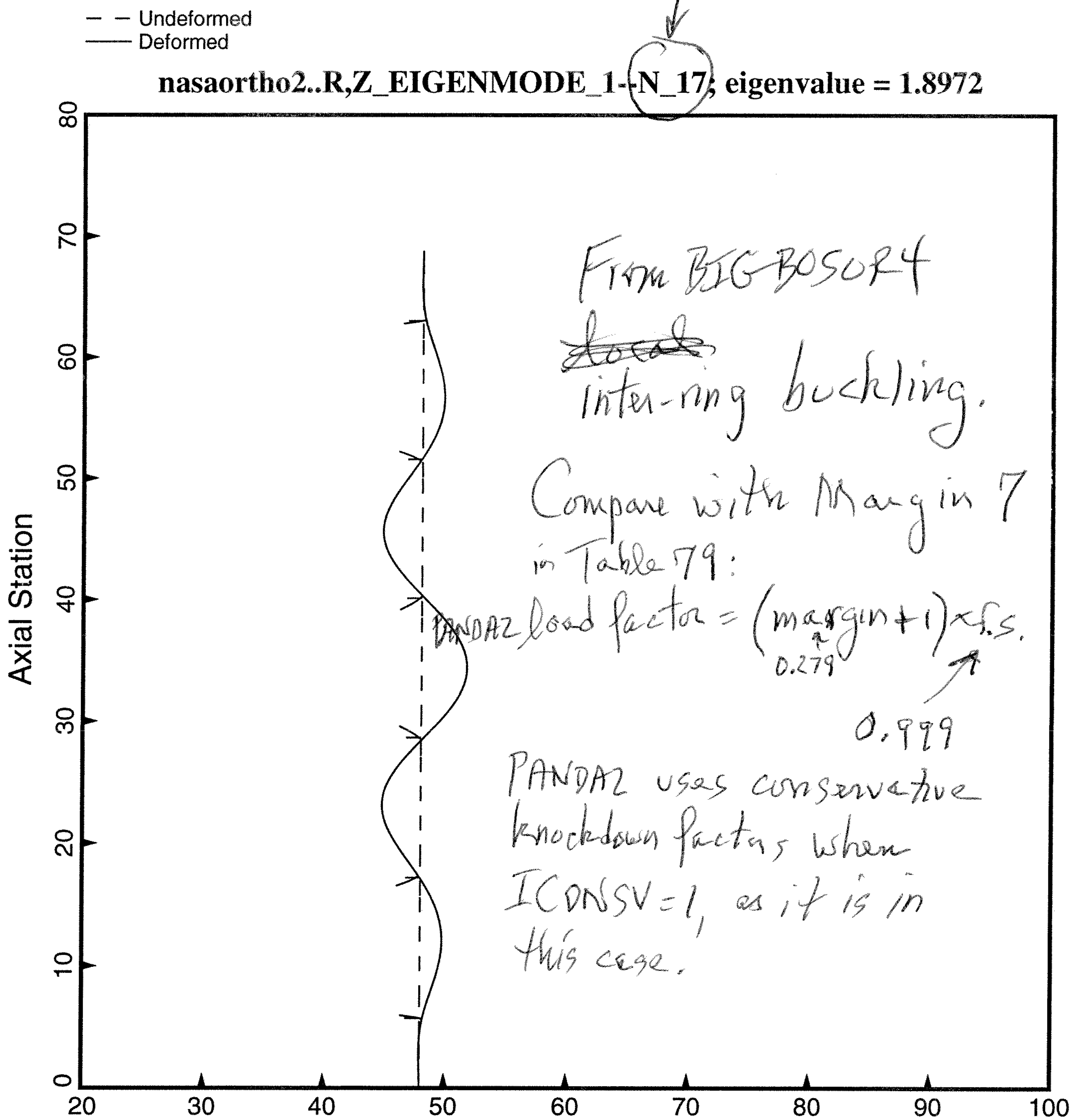

Circumferential waves
buckling load factor
- - Undeformed
—— Deformed
nasaortho2..R,Z_EIGENMODE_1--N_6; eigenvalue = 2.0220
clamped
From BIGBOSOR4 general buckling
Compare with Margin #13 in Table 79:
PANDA2 load factor = (margin +1) × f.s.
0.614
0.999
(PANDA2 uses conservative knockdown factors when ICONSV = 1, as it is in this case). Also, in PANDA2 the shell is simply supported.
clamped
Axial Station
0
10
20
30
40
50
60
70
80
20
30
40
50
60
70
80
90
100
Radius

Fig. 96

Circumferential waves.



From BIGBOSOR4

~~local~~ inter-ring buckling.

Compare with Margin 7 in Table 79:

PANDA2 load factor = (margin+1)×f.s.

0.279

0.999

PANDA2 uses conservative knockdown factors when ICONSV=1, as it is in this case.

240 ~~330~~

Fig. 97

APPENDIX 1

From AIAA Paper 2007-2216, 48th SDM Meeting, 2007

halfwaves, **dm**, in the PANDA2 model, as listed in Part 1 of Table 8 for example, the imperfection amplitude used by PANDA2 is different in this particular case from that to be used in the STAGS nonlinear models. With the "yes, change imperfection" option, the amplitude of the general buckling modal imperfection in the PANDA2 models is plus or minus **0.25/(m+dm)**, in which **dm** can be either positive, zero, or negative. From part 1 of Table 8 we see that in this particular case the amplitude of the general buckling modal imperfection in the PANDA2 model is **0.25/(m+dm) = 0.25/(5 – 0.41628) = 0.054541 inches.** The STAGS model of the imperfect shell is somewhat conservative relative to the PANDA2 model in this case because it has a general buckling modal imperfection with a somewhat higher amplitude, Wimp = 0.0625 inch, compared to the PANDA2 amplitude, Wimp = 0.054541 inch.

12.2.2 Results from linear buckling analyses with BIGBOSOR4 [14F]

There are PANDA2 processors, PANEL (Fig. 36, p. 539 of [1A]) and PANEL2 (Fig. 33 of [1G]), by means of which input files for BOSOR4 (or BIGBOSOR4) [14] are generated automatically. Figures 20b, 21b, and 23b pertain to this sub-section.

The **PANEL** processor generates an input file, *.ALL, for the BIGBOSOR4 [14F] **buckling analysis of the portion of the optimized stiffened cylindrical shell between rings** (multiple skin-stringer modules each module of which is similar to the one module shown in Fig. 4). The sector of the stringer-stiffened portion of the cylindrical shell shown in Figs. 20b and 23b is modeled as a segment of a toroidal shell ([26], also see Fig. 192, p. 221 of [8]) with a large radius R to the center of meridional curvature. (R is close to 286 inches in this case). Figures 23b and 20b display **local** and **bending-torsion** buckling modes, respectively, predicted by BIGBOSOR4. BIGBOSOR4 computes buckling load factors (eigenvalues) over a user-specified range of circumferential wave numbers, N, as listed in the table inserted on the right-hand side of Fig. 23b. In the BIGBOSOR4 model generated by PANEL there are no rings. The rings are replaced by anti-symmetry (simple support) boundary conditions, that is, two adjacent rings are replaced by two nodal lines in the trigonometric circumferential variation of buckling modal displacements. These two nodal lines lie parallel to the plane of the paper. The spacing between them is equal to the ring spacing, of course. In Figs. 23b and 20b **m**, the number of axial halfwaves between rings, is listed in the title: **m** = 11 in Fig. 23b and **m** = 2 in Fig. 20b. N = 100 x **m** is the number of **full** waves around the entire circumference of the huge toroidal shell. N = 100 corresponds a circumferential **halfwavelength** equal to the ring spacing, which is 9.375 inches in Case 2 (Table 4). (NOTE: the ring spacing and the circumferential halfwavelength of a buckling mode in this "huge torus" model are measured **normal** to the plane of the paper. The average horizontal radius, R(ave), from the axis of revolution of the huge torus to the halfway point along the meridional arc of the multi-module model displayed in Figs. 23b and 20b can be computed as follows: 2 x pi x R(ave) = 2 x 100 x 9.375 inches. Therefore, R(ave) = 298.4 inches.) The critical **local** buckling mode (Fig. 23b) has N = 1100 circumferential full waves around the circumference of the huge toroidal shell. Hence, there are **m** = 11 halfwaves between rings. The critical **bending-torsion** buckling mode (Fig. 20b) has 200 circumferential full waves around the circumference of the huge toroidal shell. Therefore **m** = 2 halfwaves between rings. The buckling load factors (eigenvalues), Eig(local) = 1.0862 (Fig. 23b) and Eig(bending-torsion) = 1.289 (Fig. 20b), agree well with the PANDA2 margins listed in Table 7: Margin No. 1 (Sub-case 1) = 0.0636 (corresponding load factor = 1.0636) and Margin No. 2 (Sub-case 2) = 0.291 (corresponding load factor= 1.291), respectively. The small inserts in Figs. 20b and 23b show buckling modes that correspond to **edge buckling**. These modes have eigenvalues that are lower than that corresponding to buckling over the entire toroidal sector. However, they are not of interest in the comparison of predictions from BIGBOSOR4 with those from PANDA2 and STAGS because edge buckling of the types displayed in the small inserts in Figs. 20b and 23b is not permitted in the PANDA2 and STAGS models.

The **PANEL2** processor generates a BIGBOSOR4 input file, *.ALL, for the **buckling analysis of the entire optimized stiffened shell.** In this model the stringers are smeared out in the manner of Baruch and Singer [12] and the rings are modeled as branched shell structures. The shell is simply supported along the two curved ends. Figure 21b shows the critical **general** buckling mode predicted by BIGBOSOR4. The mode shape, **(m,n)** = (M,N) = (4,6), agrees with that predicted by PANDA2, as seen from Margin No. 11 in the top part of Table 7. Margin No. 11 = 0.890, which corresponds to a load factor 1.890. This load factor agrees very well with the load factor from BIGBOSOR4: Eig(general) = 1.8767, listed in both the title and in the small table inserted in Fig. 21b.

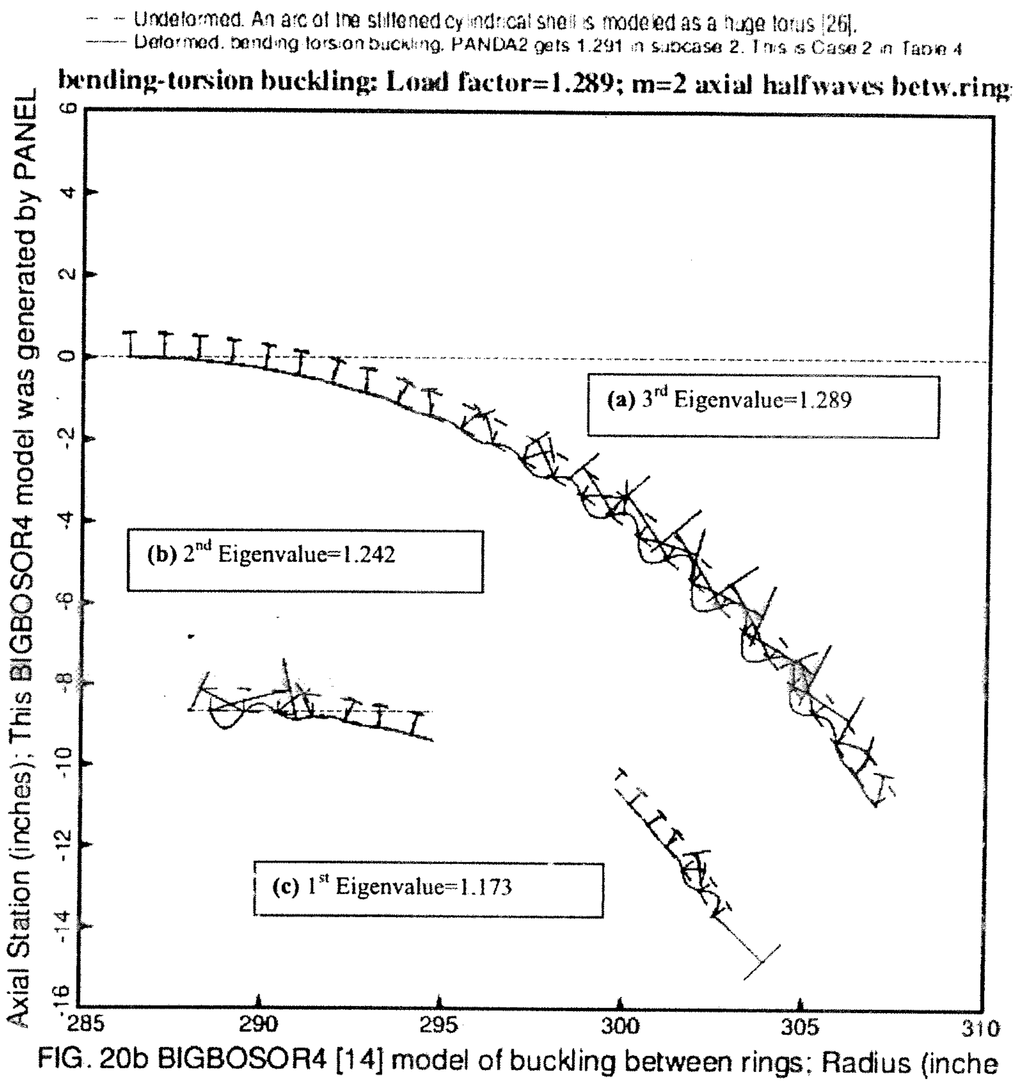


FIG. 20b BIGBOSOR4 model of Case 2 in Table 4: Results from a BIGBOSOR4 model generated by the PANDA2 processor called PANEL. This figure shows bending-torsion buckling between rings (same buckling mode as that corresponding to PANDA2's Margin 2 in both the upper and lower parts of Table 7). This BIGBOSOR4 model is a huge toroidal segment [26] with radius to the center of meridional curvature of about 286 inches. The axial variation of the critical buckling modal displacement is trigonometric with **m** = 2 axial halfwaves between rings (N=200 circumferential waves around the huge torus). The axial coordinate direction for the cylindrical shell is normal to the plane of the paper in this figure. The "critical" buckling mode of interest **(a)** happens to correspond, in this particular case, to the 3rd eigenvalue computed for N = 200. The 1st and 2nd eigenvalues for N = 200, inserts **(c)** and **(b)**, correspond to edge buckling, not permitted in the PANDA2 or STAGS models and therefore not of interest in the comparison of predictions from BIGBOSOR4 with those from PANDA2 and STAGS.

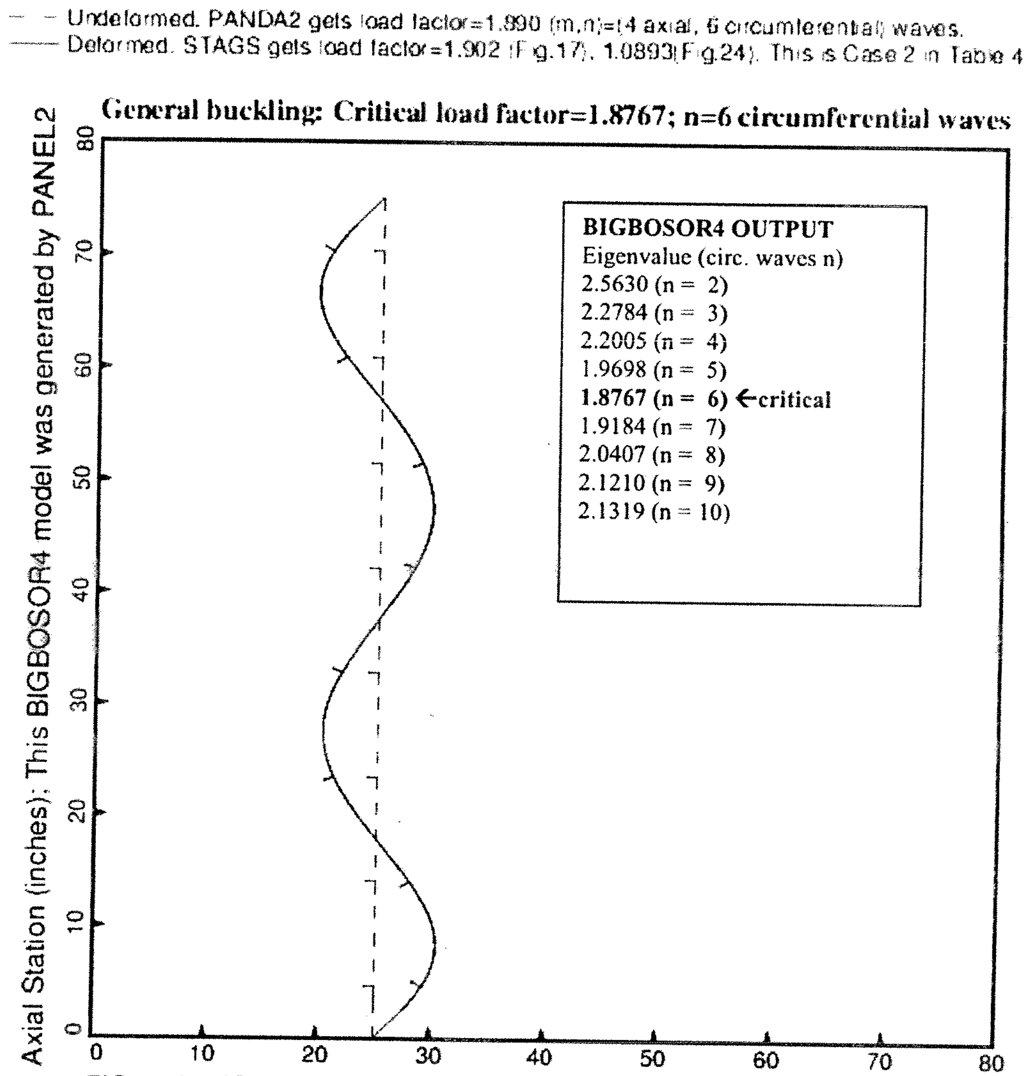


FIG. 21b BIGBOSOR4 [14] model of general instability; Radius (inches)

Fig. 21b BIGBOSOR4 model of Case 2 in Table 4: Results from a BIGBOSOR4 model generated by the PANDA2 processor called PANEL2. This figure shows the critical general buckling mode for Case 2 (same as that corresponding to PANDA2's Margin 11 in the upper part of Table 7). The outstanding flanges of the internal rings are very narrow and therefore are hardly visible in this figure. Circumferential variation of the buckling modal displacement, trigonometric with **n** = 6 full circumferential waves, is in the coordinate direction normal to the plane of the paper in this figure.

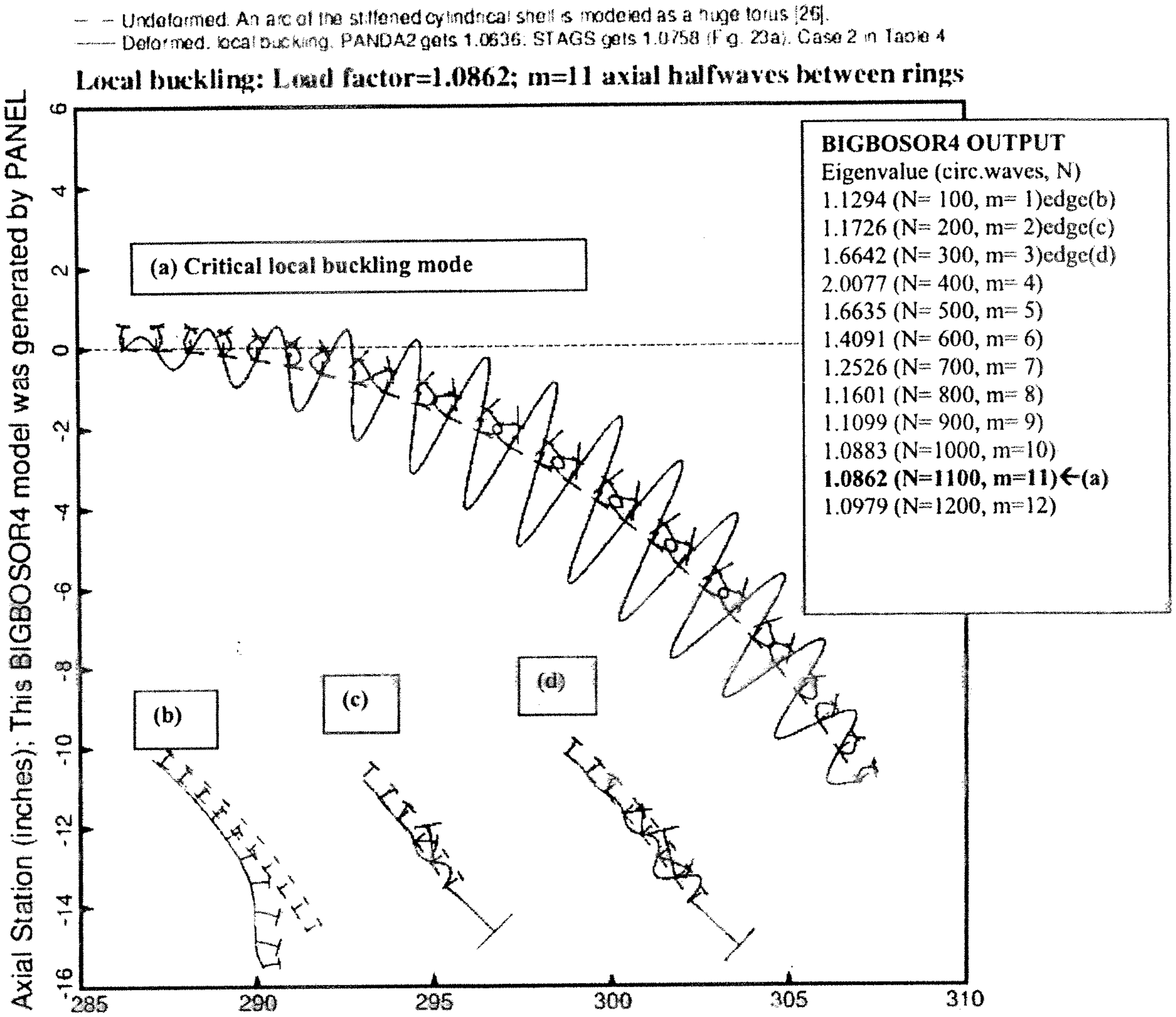


FIG. 23b BIGBOSOR4 [14] model of buckling between rings; Radius (inche

FIG. 23b BIGBOSOR4 model of Case 2 in Table 4: Results from a BIGBOSOR4 model generated by the PANDA2 processor called PANEL. This figure shows local buckling between rings (same critical buckling mode as that listed as PANDA2's Margin 1 in both the upper and lower parts of Table 7). The BIGBOSOR4 "torus" model is the same as that displayed in Fig. 20b. Only the critical number of axial halfwaves between rings, **m**=11, is different from that given in Fig. 20b. The three inserts, **(b)**, **(c)**, **(d)**, near the bottom of the figure show "edge" buckling modes corresponding to **m** = 1, 2, and 3 axial halfwaves between rings. The buckling modes for all other **m** resemble that displayed in **(a)**. Since edge buckling is not permitted in the PANDA2 and STAGS models, the edge buckling modes, **(b)**, **(c)**, **(d)**, are not of interest and are therefore disregarded in the comparison of BIGBOSOR4 predictions with those from PANDA2 and STAGS.

 pp. 81-83

DETAILS FROM A PANDA2 EXECUTION OF PANDAOPT WITH THE OPTIMIZED DESIGN LISTED IN TABLE 33a. This appendix shows what calculations PANDA2 performs for a "fixed" design (not optimization). Additional discussion complements the output produced in the nasaortho.OPM file.

Some comments have been added to the output from PANDA2

```
=====================================================================

*********************************************************************
*********************************************************************
*********************************************************************
```

Begin a rather long discussion of PANDA2 results that lead to Table 33a.

For extensive detail about what PANDA2 does during all the computations associated with Load Case 1, Subcase 1 in connection with the optimum design of the imperfect shell, please inspect the following file:

...panda2/doc/panda2chapters.pdf

Most of the file, ...panda2/doc/panda2chapters.pdf, is repeated here for the convenience of the reader. Discussion is added to various sections in this long list.

Only a very short summary of the nasaortho.OPM file is presented in Table 33a.

In PANDA2 the "reporting" (listing results in the nasaortho.OPM file) from the computations is divided into 28 chapters (called "CHAPTER"s in the *.OPM output file generated by execution of PANDAOPT). These CHAPTERs are as follows:

```
****** BEGIN INTRODUCTORY OUTPUT IN nasaortho.OPM WHEN NPRINT = 2 *********
 **********************************************************
 ENTERING SUBROUTINE STRUCT
 ****************    TABLE OF CONTENTS    *********************
 CHAPTER 1   Compute the 6 x 6 constitutive matrices [C] for
             individual model segments and various combinations
             thereof (skin with smeared stiffener sets [1A]).
 CHAPTER 2   Do PANDA-type [1B] general buckling analysis to
             get Donnell factors for later use, if appropriate.
 CHAPTER 3   Do various PANDA-type [1B] general buckling
             analyses needed for later computation of effective
             length of the panel. Compute the effective length.

 CHAPTER NEW Compute wide-column buckling from discretized
             skin-stringer module model (Figs. 20b,c & 22b,c in
             [1A]) with only Nx (Ny=0, Nxy=0). The purpose is to
             obtain a knockdown factor, WIDKNK, for smearing
             the stringers in an inter-ring buckling mode
 CHAPTER 4   Compute axisymmetric prebuckling "hungry-horse"
             state of the curved panel or cylindrical shell.
             (See Ref.[1E]).
 CHAPTER 5   Get static response of panel to normal pressure
             [1A].
 CHAPTER 6   Do PANDA-type [1B] general and inter-ring buckling
             analyses to permit later computation of
             amplification of panel bowing.
 CHAPTER 7   Compute distribution of loads in panel module
             skin-stringer segments, neglecting redistribution
             due to initial buckling modal imperfections
             (See Section 10 of [1A]).
 CHAPTER 8   Do PANDA-type local, inter-ring, general buckling
             analyses and PANDA-type stringer web and ring web
             buckling analyses to get knockdown factors to
             compensate for lack of in-plane shear Nxy loading
             and anisotropy in discretized BOSOR4-type models.
             (See Section 11 of [1A] and Item No. 81 in [1L]).
 CHAPTER 9   Do BOSOR4-type "skin"-ring buckling analyses to
             compute knockdown factor to compensate for
             inherent unconservativeness of models with
             smeared rings. (See Items 509, 511, 522, and
             605 in [1L]; "skin"=skin+smeared stringers).
 CHAPTER 10  Compute knockdown factors and prebuckling bending
             associated with initial general, inter-ring, local
```

buckling modal imperfections. (See Ref.[1E]).

CHAPTER 10.1 Compute knockdown factor and prebuckling bending associated with general buckling modal initial imperfection. (See Sectons 13 and 14 and Tables 9 and 10 of [1K] for a detailed example)

CHAPTER 10.2 Compute knockdown factor and prebuckling bending associated with inter-ring buckling modal initial imperfection.

CHAPTER 10.3 Compute knockdown factor and prebuckling bending associated with local buckling modal initial imperfection.

CHAPTER 10.4 Present a summary of imperfection sensitivity results. (See Section 13 and Table 9 of [1K])

CHAPTER 11 Get change in stress resultants, Nx, Ny, Nxy in various segments of the skin-stringer module during prebuckling bending of the imperfect shell. Also, do PANDA-type [1B] local, inter-ring, general buckling analyses and PANDA-type stringer web and ring web buckling analyses to get knockdown factors to compensate for the lack of in-plane shear Nxy loading and anisotropy in discretized BOSOR4-type models. (See Section 11 in [1A])

CHAPTER 12 List prebuckled state of the initially imperfect and loaded and bent panel or shell. This section includes the redistribution of Nx, Ny, Nxy in the various segments of the stiffened shell structure.

CHAPTER 13 List prebuckling stress resultants, Nx, Ny, needed for the discretized single-module skin-stringer model used for local buckling and bending-torsion buckling (BOSOR4-type model: see Figs. 18, 20, 22, 97, and 98 of [1A], for examples).

CHAPTER 14 Compute local buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 in [1A].

CHAPTER 15 Compute bending-torsion (low-m) buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 in [1A].

CHAPTER 16 Compute post-local buckling from the Koiter theory given in Ref.[1C]. (Figs. 23, 24 in [1A] and Fig. 6 in [1C]).

CHAPTER 17 Compute stresses in layers and at various locations in skin-stringer module model, including local post-buckling, if any. Compute stringer popoff constraints [1A].SUBROUTINE STRTHK is used.

CHAPTER 18 Present summary of state of loaded imperfect panel and give effective stiffnesses of possibly locally postbuckled skin-stringer module. These effective stiffnesses (Table 12 of Ref. [18]) are used later for overall buckling and inter-ring buckling.

CHAPTER 19 Do wide-column inter-ring buckling analysis with possibly locally postbuckled skin-stringer module model. (See Fig. 20c of [1A]).

CHAPTER 20 Compute width-wise wide column buckling and lateral-torsional buckling load factors from the possibly locally postbuckled skin-stringer module model (inter-ring buckling modes). See panda2.news Item Numbers 379 and 381 in [1L].

CHAPTER 20b Compute high-m buckling of single discretized skin-stringer module (same model as used in CHAPTER 14 except explored in the range of high numbers of axial halfwaves). See panda2.news Item Numbers 682 and 754.

CHAPTER 20c Compute buckling of a single discretized skin-substringer module. See panda2.news Item 764. The axial length of the module is equal to the spacing of the subrings, and the width of the module is equal to the spacing of the substringers.

CHAPTER 21 Compute "skin"-ring buckling load factor for computing knockdown to compensate for inherent unconservativeness of smeared ring models. (See bottom row in Fig. 30 of Ref.[1G]. Also see panda2.news Items 509, 511, 522, 532, 605, 617 619, 632, 633, 676.

CHAPTER 22 Compute "skin"-ring buckling load factors for:
1. medium-n inter-ring buckling mode (See rightmost three mode shapes in top row of Fig. 30 of Ref.[1G]),
2. high-n inter-ring buckling mode (See rightmost

A2

```
            mode shape in middle row of Fig. 30, Ref.[1G]),
         3. low-n inter-ring buckling mode (See leftmost
            mode shape in top row of Fig. 30, Ref.[1G]).
 CHAPTER 23 Compute stresses in layers and at various
            locations in modules for both positive and
            negative imperfection amplitudes from SUBROUTINE
            STRCON (local postbuckling neglected).
 CHAPTER 24 Present short summary of redistribution of stress
            resultants, Nx, Ny, Nxy, caused by prebuckling
            bending of an initially imperfect shell.
            See Section 6.0 in [1K].
 CHAPTER 25 Compute buckling load factors from PANDA-type
            theory for the various segments of a stringer and
            a ring. Typical buckling modes are displayed in
            Figs. 5 and 6 of Ref.[1B].
 CHAPTER 26 Compute local, inter-ring, general buckling load
            factors from PANDA-type models [1B] and from
            "alternative" (double-trigonometric series
            expansion) models, Ref.[1G]. Also compute
            sandwich wall behavior [1F], if applicable.
            Also, compute buckling load factors appropriate
            when substiffeners are present.
 CHAPTER 27 Compute the objective function (e.g. WEIGHT).
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. (See Table 6 in [18])
****** END OF INTRODUCTORY OUTPUT IN nasaortho.OPM WHEN NPRINT = 2 *********
```

The numbers of the references [ ] given in the CHAPTER headings above correspond to those listed at the end of the paper:

[18] 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

********* ALSO LISTED IN nasaortho.OPM WHEN NPRINT = 2 *******

The overall structure of PANDA2 and its use are described in the first PANDA2 paper, Ref.[1A], cited in the April 2007 paper just identified. Ref.[1A] is the following paper:
Bushnell, D.,
"PANDA2 - Program for minimum weight design of stiffened, composite, locally buckled panels", COMPUTERS AND STRUCTURES, Vol. 25, No. 4, pp 469-605, 1987

Concepts such as "wide-column" buckling, "discretized module model", "stringer pop-off", "constitutive matrices" "reduction factor for transverse shear deformtion (t.s.d.)" "smeared stiffeners", "neutral surface", "overall and local static response to uniform pressure", "knockdown factors for anisotropy and in-plane shear loading", "crippling of stiffener parts", and "local postbuckling" are described there, with many early PANDA2 examples provided.

The string, "PANDA-type theory" often occurs. This refers to the theory presented in Ref. [1B] of the April 2007 citation listed first. Ref.[1B] contains the theory given in the paper:
Bushnell, D.,
"Theoretical basis of the PANDA computer program for preliminary design of stiffened panels under combined in-plane loads", COMPUTERS & STRUCTURES, v. 27, No. 4, pp 541-563 (1987).

The theory used for local postbuckling behavior appears in Ref. [1C] of the April 2007 paper cited first (above).
Ref. [1C] is the following paper:
Bushnell, D.,
"Optimization of composite, stiffened, imperfect panels under combined loads for service in the postbuckling regime", Computer Methods in Applied Mechanics and Engineering, Vol. 103 (1993) 43-114

The theory used for imperfection sensitivity appears in Refs. [1E] and [1D] of the first-cited paper above.
Refs. [1E] and [1D] are the following two papers:

Bushnell, D. and Bushnell, W. D.,
"Approximate method for the optimum design of ring and stringer stiffened cylindrical panels and shells with

local, inter-ring, and general buckling modal imperfections"
Computers and Structures, Vol. 59, No. 3, pp 489-527 (1996)

Bushnell, D.,
"Recent enhancements to PANDA2" AIAA Paper 96-1337-CP,
Proc. of the AIAA 37th Structures, Structural Dynamics and
Materials Conference, pp 126-182, April, 1996.

The last paper cited also describes the "global" optimizer,
"SUPEROPT", implementation of Sanders shell equations into
PANDA2, implementation of the Arbocz theory for imperfection
sensitivity, implementation of isogrid geometry, and
implementation of various truss-core geometries, with examples.

The theories used in PANDA2 for the analysis of sandwich
walls are given in Ref.[1F] of the first-cited paper above.
Ref. [1K] is the following paper:
Bushnell, D.,
"Optimum design via PANDA2 of composite sandwich panels with
honeycomb or foam cores", AIAA Paper 97-1142, Proc. 38th AIAA
Structures, Structural Dynamics and Materials Conference,
pp 2163-2202, April, 1997

The "alternate" (double-trigonometric series expansion
buckling theory) and the discretized "skin"-ring module
model are described in Ref. [1G] of the first-cited paper.
Ref. [1G] is the following paper:
Bushnell, D., Jiang, H., and Knight, N.F.,
"Additional buckling solutions in PANDA2", Proceedings of the
40th AIAA SDM Conference, AIAA Paper 99-1233, pp 302-345
April 1999

Details of the strategy used in PANDA2 for accounting for
initial buckling modal imperfections are described and listed
in a table in Ref. [1K]. Ref. [1K] is the following paper:
Bushnell, D. and Rankin, C.C.,
"Difficulties in optimization of imperfect stiffened
cylindrical shells",
AIAA Paper 1943, 47th AIAA Structures, Structural Dynamics and
Materials Meeting, Newport RI, April 2006
********* END OF "ALSO LISTED IN nasaortho.OPM WHEN NPRINT = 2" *******

The following long discussion covers most of these computations.
Most of the following PANDA2 output corresponds to Load Set 1, Subcase 1,
Wimp = +0.125 inch. There is a section concerning CHAPTERs 13 and 14 for
which output from CHAPTERs 13 and 14 is listed first for Load Set 1,
then for Load Set 2. These two sections are listed one right after the
other, which is not the order in which the computations are performed
in PANDA2. In PANDA2 ALL Load set 1 computations are performed first,
followed by ALL Load Set 2 computations.

Some of the output in the following list is obtained with the print
index, NPRINT, set equal to 0 in the nasaortho.OPM file. Other output
is obtained with NPRINT = 2.

****** OUTPUT FROM CHAPTERs 1 - 3 & CHAPTER NEW with NPRINT = 0 *******
****
CHAPTER 1 Compute the 6 x 6 constitutive matrices [C] for
individual model segments and various combinations
thereof (skin with smeared stiffener sets [1A]).
See Section 8 in [1A], Eq.(8.1) on p.495 of [1A].

*** BEGIN SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***
See Section 8, pp 494-503 of Reference [1A]. First the 6 x 6
integrated constitutive coefficients Cij (Eq.8.1) and thermal
loading are found for each segment in the skin-stringer module
then for the skin-ring module, then for the skin with smeared
stringers only, then for the skin with smeared rings only,
and finally for the skin with both stringers and rings smeared.
**** END SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***
********* DESIGN PERTURBATION INDEX, IMOD= 0 *********

****
CHAPTER 2 Do PANDA-type [1B] general buckling analysis to
get Donnell factors for later use, if appropriate.

```
** BEGIN SUBROUTINE BUCPAN (GENERAL PANDA-TYPE BUCKL.) ***
PURPOSE IS TO GET DONNELL FACTORS FOR LATER USE IN SUB.DONELL.
*** END  SUBROUTINE BUCPAN (EIGENVALUES. PANDA-TYPE BUCKL.) ***
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

********************************************************************
CHAPTER 3  Do various PANDA-type [1B] general buckling
           analyses needed for later computation of effective
           length of the panel. Compute the effective length.

User-specified axial length of the panel, AXIAL=  6.8750E+01
Computed factor to modify the length, AXIAL: LENMOD=  1.0000E+00
Axial length of "equivalent" simply-supported panel, LENMOD*AXIAL=  6.8750E+01

********************************************************************
CHAPTER NEW Compute wide-column buckling from discretized
            skin-stringer module model (Figs. 20b,c & 22b,c in
            [1A]) with only Nx (Ny=0, Nxy=0). The purpose is to
            obtain a knockdown factor, WIDKNK, for smearing
            the stringers in an inter-ring buckling mode
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

******* Begin the section where WIDKNK is computed *********
******* See ..panda2/doc/panda2.news Items 724 & 725.*******

 WIDE COLUMN PANEL BUCKLING LOAD FACTOR =   2.5571E+00
ISKINX = 0. MODE OF BUCKLING IS THE PANEL SKIN IF ISKINX = 1.
ITIPWX = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIPWX=1
ICWBWX = 0. MODE OF BUCKLING IS THE STRINGER WEB IF ICWBWX=1
IFLGWX = 0. MODE OF BUCKLING IS STRINGER OUTSTANDING FLANGE IF IFLGWX=1
ICRWNX = 0. MODE OF BUCKLING IS THE CROWN OF THE HAT IF ICRWNX=1

Mode number  1 IS a wide column mode and is therefore acceptable.

SMEARED STRINGER KNOCKDOWN FROM SKIN-STRINGER DISCRETE MODEL
(See ..panda2/doc/panda2.news Items 724 and 725):
Buckling axial resultant Nx from simple Euler model,     EULER =  7.0914E+03
Buckling axial resultant Nx from discretized  model,     EIGWID=  5.6742E+03
Knockdown factor for cross section rigidity & t.s.d.,    WIDKNK=  8.0015E-01
Effective axial length of the wide column model,         AXLEFF=  1.1458E+01

Axial resultant, Nx, in each of the segments of the
discretized skin-stringer cross-section before any deformation
-1.2600E+03 -1.2600E+03 -2.0102E+03 -1.2600E+03
******* End of the section where WIDKNK is computed *******
******* See ..panda2/doc/panda2.news Items 724 & 725.*******
****** END OUTPUT FROM CHAPTERs 1 - 3 & CHAPTER NEW with NPRINT = 0 *******
```

From CHAPTER 4: PANDA2 determines the axisymmetric "hungry horse" deformation between adjacent rings. The theory used to do this is described in the paper:

[4] Bushnell, D. and Bushnell, W. D., "Approximate method for the optimum design of ring and stringer stiffened cylindrical panels and shells with local, inter-ring, and general buckling modal imperfections" Computers and Structures, Vol. 59, No. 3, pp 489-527 (1996)

In particular, see the section in that paper entitled, "Introduction of prebuckling axisymmetric bending into PANDA2" on 495 - 498. This theory is implemented in CHAPTER 4. Results from CHAPTER 4 for the optimized shell of Table 33a are as follows:

```
----- BEGIN CHAPTER 4 PART OF THE nasaortho.OPM FILE, NPRINT=2 --------
CHAPTER 4  Compute axisymmetric prebuckling "hungry-horse"
           state of the curved panel or cylindrical shell.
           (See Ref.[1E], especially Fig. 1 and pp.495-498).

 ***** BEGIN COMPUTATIONS FOR AXISYMMETRIC PREBUCKLING
 ***** STATE OF THE PANEL. (See pp 495-498 of journal
 ***** article, COMPUTERS & STRUCTURES vol 59, no.3, 1996
 ***** Computations carried out in SUBROUTINE SKIN.
 ***** Axisymmetric response of the curved panel to the loads in Load Set A *****
 Entering SUB. SKIN (get prebuckling behavior), IMOD= 0
  Normal pressure,                      P= -4.6229E-05
  Axial resultant,                     Nx= -2.2190E+03
  Hoop  resultant,                     Ny= -2.2190E-03
```

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```
 Average hoop strain,                    E0Y=  5.4370E-04
 Average hoop thermal strain, ETHERM(2)=  0.0000E+00
 Value of computation control,   WCALCS=  0.0000E+00
 Prebuckling b.c. indicator,     IBPRE =  0
 Ring stiffener indicator,      ISTIF(2)=  3
 Average Nyo, membrane theory,  FNYAVE = -8.1575E+01
 Average normal displacement,   WDPAVE =  2.6098E-02

PREBUCKLING STATE IN CYLINDRICAL PANEL. X=0 CORRESPONDS TO MIDBAY
      AXIAL        NORMAL     MERIDIONAL    AXIAL        HOOP
   COORDINATE  DISPLACEMENT CURVATURE   RESULTANT   RESULTANT
I       X          WDISP       WXXDSP       FNXX        FNYY
 1  0.0000E+00  2.6623E-02 -1.1065E-04 -2.2190E+03 -7.1498E+01 <--midbay
 2  2.2917E-01  2.6621E-02 -1.1012E-04 -2.2190E+03 -7.1551E+01
 3  4.5833E-01  2.6612E-02 -1.0854E-04 -2.2190E+03 -7.1709E+01
 4  6.8750E-01  2.6598E-02 -1.0591E-04 -2.2190E+03 -7.1971E+01
 5  9.1667E-01  2.6578E-02 -1.0221E-04 -2.2190E+03 -7.2335E+01
 6  1.1458E+00  2.6552E-02 -9.7466E-05 -2.2190E+03 -7.2800E+01
 7  1.3750E+00  2.6522E-02 -9.1658E-05 -2.2190E+03 -7.3362E+01
 8  1.6042E+00  2.6487E-02 -8.4790E-05 -2.2190E+03 -7.4018E+01
 9  1.8333E+00  2.6447E-02 -7.6860E-05 -2.2190E+03 -7.4764E+01
10  2.0625E+00  2.6403E-02 -6.7864E-05 -2.2190E+03 -7.5594E+01
11  2.2917E+00  2.6356E-02 -5.7800E-05 -2.2190E+03 -7.6504E+01
12  2.5208E+00  2.6306E-02 -4.6666E-05 -2.2190E+03 -7.7487E+01
13  2.7500E+00  2.6253E-02 -3.4460E-05 -2.2190E+03 -7.8536E+01
14  2.9792E+00  2.6198E-02 -2.1179E-05 -2.2190E+03 -7.9645E+01
15  3.2083E+00  2.6143E-02 -6.8208E-06 -2.2190E+03 -8.0803E+01
16  3.4375E+00  2.6087E-02  8.6160E-06 -2.2190E+03 -8.2004E+01
17  3.6667E+00  2.6031E-02  2.5133E-05 -2.2190E+03 -8.3237E+01
18  3.8958E+00  2.5977E-02  4.2730E-05 -2.2190E+03 -8.4492E+01
19  4.1250E+00  2.5925E-02  6.1408E-05 -2.2190E+03 -8.5758E+01
20  4.3542E+00  2.5876E-02  8.1165E-05 -2.2190E+03 -8.7023E+01
21  4.5833E+00  2.5832E-02  1.0200E-04 -2.2190E+03 -8.8276E+01
22  4.8125E+00  2.5793E-02  1.2391E-04 -2.2190E+03 -8.9503E+01
23  5.0417E+00  2.5760E-02  1.4689E-04 -2.2190E+03 -9.0690E+01
24  5.2708E+00  2.5735E-02  1.7093E-04 -2.2190E+03 -9.1823E+01
25  5.5000E+00  2.5719E-02  1.9603E-04 -2.2190E+03 -9.2886E+01
26  5.7292E+00  2.5714E-02  2.2217E-04 -2.2190E+03 -9.3864E+01 <--at rings

Average Ny over x-integration interval (XL=  5.7292E+00): Ny(ave)= -8.0467E+01
Average normal displacement over x-integration interval=  2.6198E-02
Average axial curvature change over x-integration int. =  2.2301E-06
 Value of computation control,   WCALCS=  0.0000E+00
 Hoop resultant in web of ring,             FCEWEB =  5.3470E+02
 Hoop resultant in flange of ring,          FCEFLG =  0.0000E+00
 Hoop strain in web and flange of ring,     EPSRNG =  5.3570E-04
 Hoop resultant at each node in ring web, (FCXWEB(i),i=1,11)=
 5.2493E+02  5.2686E+02  5.2880E+02  5.3075E+02  5.3272E+02  5.3470E+02
 5.3670E+02  5.3871E+02  5.4074E+02  5.4279E+02  5.4484E+02
 Meridional resultant at each node in ring web, (FCYWEB(i),i=1,11)=
 1.9543E+01  1.7589E+01  1.5635E+01  1.3680E+01  1.1726E+01  9.7717E+00
 7.8173E+00  5.8630E+00  3.9087E+00  1.9543E+00  0.0000E+00

PREBUCKLING DEFORMATION OF CYLINDRICAL SHELL BETWEEN RINGS:
 Subcase number                               ICASE =    1
 Radius of cylindrical shell                      R = -4.8000E+01
 Ring spacing,                                 B(2) =  1.1458E+01
 Axial resultant,                      Nx(Loadset A) = -2.2190E+03
 Hoop  resultant,                      Ny(Loadset A) = -2.2190E-03
 Normal displacement at midbay,                WMID =  2.6623E-02
 Normal displacement at rings,                WRING =  2.5714E-02
 Average normal displacement, Wave =-EPSILON(y)*R =  2.6098E-02
 Meridional curvature change at midbay,      WXXMID = -1.1065E-04
 Meridional curvature change at rings,       WXXRNG =  2.2217E-04
 Axial boundary layer length,                   BLL =  2.1441E+01
 Hoop stiffness EA of ring,                EA(ring) =  1.7191E+06
 Applied normal pressure,               P(Loadset A) =  4.6229E-05
 Shear in web of stringer,                   SHEARX =  0.0000E+00
 Correction to hoop resultant,               DFNYP0 =  5.0458E+00
 Transverse resultant in isogrid web,        POPISO =  0.0000E+00
------- END CHAPTER 4 PART OF THE nasaortho.OPM FILE, NPRINT=2 --------


****** OUTPUT FROM CHAPTERs 5 - 9 with NPRINT = 0 **********
************************************************************
CHAPTER 5  Get static response of panel to normal pressure
           [1A], especially Section 9 and Section 20.5 and
           Figs. 55 - 60 in [1A].
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~~240~~250