Table 14 test. BEG (p.4 of 4)

```
        9       $ high end of the M-range for local buckling: MHIGHL
        1       $ Number NCASES  of load cases (environments): NCASES
 -1507964.      $ total axial load (2 x pi x r x resultant): PX( 1)
        0       $ pressure (negative for external pressure): PRESS( 1)
        0       $ total "Load Set B" load: PX0( 1)
        0       $ "Load Set B" pressure (external=negative): PRESS0( 1)
  1.000000      $ allowable for local buckling load factor: LOCBUKA( 1)
  1.000000      $ factor of safety for local buckling: LOCBUKF( 1)
  1.000000      $ allowable for general buckling load factor: GENBUKA( 1)
  1.000000      $ general buckling factor of safety: GENBUKF( 1)
        5       $ Number JSTRM1  of columns in the array, STRM1: JSTRM1
  200798.0      $ allowable stress in material 1: STRM1A( 1, 1)
   185925       $ allowable stress in material 1: STRM1A( 1, 2)
  8350.000      $ allowable stress in material 1: STRM1A( 1, 3)
  16400.00      $ allowable stress in material 1: STRM1A( 1, 4)
  17357.00      $ allowable stress in material 1: STRM1A( 1, 5)
  1.000000      $ factor of safety for stress in material 1: STRM1F( 1, 1)
  1.000000      $ factor of safety for stress in material 1: STRM1F( 1, 2)
  1.000000      $ factor of safety for stress in material 1: STRM1F( 1, 3)
  1.000000      $ factor of safety for stress in material 1: STRM1F( 1, 4)
  1.000000      $ factor of safety for stress in material 1: STRM1F( 1, 5)
  200798.0      $ allowable for stress in material 2: STRM2A( 1, 1)
   185925       $ allowable for stress in material 2: STRM2A( 1, 2)
  8350.000      $ allowable for stress in material 2: STRM2A( 1, 3)
  16400.00      $ allowable for stress in material 2: STRM2A( 1, 4)
  17357.00      $ allowable for stress in material 2: STRM2A( 1, 5)
        1       $ factor of safety for stress in material 2: STRM2F( 1, 1)
        1       $ factor of safety for stress in material 2: STRM2F( 1, 2)
        1       $ factor of safety for stress in material 2: STRM2F( 1, 3)
        1       $ factor of safety for stress in material 2: STRM2F( 1, 4)
        1       $ factor of safety for stress in material 2: STRM2F( 1, 5)
```

Note: All factors of safety = 1.0.
These f.s. are increased later to compensate for possible initial imperfections. (Table 27)
Input for "BEGIN"

Table 15 input for "DECIDE" test.DEC (2 pages)

```
    n          $ Do you want a tutorial session and tutorial output?
      1        $ Choose a decision variable (1,2,3,...)
 2.000000      $ Lower bound of variable no.( 1)                       PITCH (b in Fig.1)
 10.00000      $ Upper bound of variable no.( 1)
    y          $ Any more decision variables (Y or N) ?
      2        $ Choose a decision variable (1,2,3,...)
 1.000000      $ Lower bound of variable no.( 2)                       BCROWN (b2 in Fig.1)
 5.000000      $ Upper bound of variable no.( 2)
    y          $ Any more decision variables (Y or N) ?
      3        $ Choose a decision variable (1,2,3,...)
0.3000000      $ Lower bound of variable no.( 3)                       HEIGHT (h in Fig.1)
 2.000000      $ Upper bound of variable no.( 3)
    y          $ Any more decision variables (Y or N) ?
      4        $ Choose a decision variable (1,2,3,...)
0.3000000E-01  $ Lower bound of variable no.( 4)                       RACUTE (R1 - wall thickness
0.3000000      $ Upper bound of variable no.( 4)                          of Seg. 9 in Fig.1)
    y          $ Any more decision variables (Y or N) ?
      5        $ Choose a decision variable (1,2,3,...)
0.3000000E-01  $ Lower bound of variable no.( 5)                       ROBTUS (R2 - wall thickness
0.3000000      $ Upper bound of variable no.( 5)                          of Seg. 2 in Fig.1)
    y          $ Any more decision variables (Y or N) ?
      6        $ Choose a decision variable (1,2,3,...)
0.5200000E-02  $ Lower bound of variable no.( 6)                       THICK(1) (t1 in Fig 8)
0.1560000E-01  $ Upper bound of variable no.( 6)
    y          $ Any more decision variables (Y or N) ?
      8        $ Choose a decision variable (1,2,3,...)
0.5200000E-02  $ Lower bound of variable no.( 8)                       THICK(3) (t3 in Fig.8)
0.1560000E-01  $ Upper bound of variable no.( 8)
    y          $ Any more decision variables (Y or N) ?
      9        $ Choose a decision variable (1,2,3,...)
0.5200000E-02  $ Lower bound of variable no.( 9)                       THICK(4) (t4 in Fig.8)
0.1560000E-01  $ Upper bound of variable no.( 9)
    y          $ Any more decision variables (Y or N) ?
     11        $ Choose a decision variable (1,2,3,...)
0.5200000E-02  $ Lower bound of variable no.(11)                       THICK(6) (t6 in Fig.8)
0.1560000E-01  $ Upper bound of variable no.(11)
    y          $ Any more decision variables (Y or N) ?
     12        $ Choose a decision variable (1,2,3,...)
0.5200000E-02  $ Lower bound of variable no.(12)                       THICK(7) (t7 in Fig.8)
0.1560000E-01  $ Upper bound of variable no.(12)
    n          $ Any more decision variables (Y or N) ?
    y          $ Any linked variables (Y or N) ?
      7        $ Choose a linked variable (1,2,3,...)  <- THICK(2) (t2 in Fig.8)
      1        $ Choose type of linking (1=polynomial; 2=user-defined)
      6        $ To which variable is this variable linked? <- THICK(1) (t1 in Fig.8)
 1.000000      $ Assign a value to the linking coefficient, C(j)
      1        $ To what power is the decision variable raised?
    n          $ Any other decision variables in the linking expression?
    n          $ Any constant C0 in the linking expression?
    y          $ Any more linked variables (Y or N) ?
     10        $ Choose a linked variable (1,2,3,...) <- THICK(5) (t5 in Fig.8)
      1        $ Choose type of linking (1=polynomial; 2=user-defined)
      9        $ To which variable is this variable linked? <- THICK(4) (t4 in Fig.8)
 1.000000      $ Assign a value to the linking coefficient, C(j)
      1        $ To what power is the decision variable raised?
    n          $ Any other decision variables in the linking expression?
    n          $ Any constant C0 in the linking expression?
    n          $ Any more linked variables (Y or N) ?
    y          $ Any inequality relations among variables? (type H)
    n          $ Want to see an example of how to calculate C0, C1, D1,..?
      2        $ Identify the type of inequality expression (1 or 2)
 1.000000      $ Give a value to the constant, C0                          1 < 1 - BCROWN
      2        $ Choose a variable from the list above (1, 2, 3,...)         +0.45 PITCH
-1.000000      $ Choose a value for the coefficient, C1
      1        $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...   or
      1        $ Choose a variable from the list above (1, 2, 3,...)
0.4500000      $ Choose a value for the coefficient, Cn                    b2 < 0.45 b in
      1        $ Choose a value for the power, Dn                            Fig. 1
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
    y          $ Are there any more inequality expressions?
      2        $ Identify the type of inequality expression (1 or 2)   1 < 1+.45(b-b2)
 1.000000      $ Give a value to the constant, C0
      1        $ Choose a variable from the list above (1, 2, 3,...)        - RACUTE
0.4500000      $ Choose a value for the coefficient, C1
      1        $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
      2        $ Choose a variable from the list above (1, 2, 3,...)
                                                                            or
                                                                   RACUTE < 0.45(b-b2)
```

Table 15 test. DEC (p. 2 of 2)

```
-0.4500000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
        4      $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
    y          $ Are there any more inequality expressions?
        2      $ Identify the type of inequality expression (1 or 2)
  1.000000     $ Give a value to the constant, C0
        2      $ Choose a variable from the list above (1, 2, 3,...)
 0.4500000     $ Choose a value for the coefficient, C1
        1      $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
        5      $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
```

$1 < 1 + 0.45 b_2$ − ROBTUS or ROBTUS $< 0.45 b_2$

```
    y          $ Are there any more inequality expressions?
        2      $ Identify the type of inequality expression (1 or 2)
  1.000000     $ Give a value to the constant, C0
        3      $ Choose a variable from the list above (1, 2, 3,...)
 0.2500000     $ Choose a value for the coefficient, C1
        1      $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
        4      $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
```

$1 < 1 + 0.25$ HEIGHT − RACUTE or RACUTE $< 0.25 h$ in Fig. 1

```
    y          $ Are there any more inequality expressions?
        2      $ Identify the type of inequality expression (1 or 2)
  1.000000     $ Give a value to the constant, C0
        3      $ Choose a variable from the list above (1, 2, 3,...)
 0.2500000     $ Choose a value for the coefficient, C1
        1      $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
        5      $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
```

$1 < 1 + 0.25$ HEIGHT − ROBTUS or ROBTUS $< 0.25 h$ in Fig. 1

```
    y          $ Are there any more inequality expressions?
        2      $ Identify the type of inequality expression (1 or 2)
  1.000000     $ Give a value to the constant, C0
        5      $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000     $ Choose a value for the coefficient, C1
        1      $ Choose a value for the power, D1
    y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
        4      $ Choose a variable from the list above (1, 2, 3,...)
 0.9000000     $ Choose a value for the coefficient, Cn
        1      $ Choose a value for the power, Dn
    n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
```

$1 < 1 -$ ROBTUS $+ 0.9$ RACUTE or ROBTUS < 0.9 RACUTE

```
    n          $ Are there any more inequality expressions?
    y          $ Any escape variables (Y or N) ?
    y          $ Want to have escape variables chosen by default?
```

Input for "DECIDE"

Table 16

test.OPT

```
n         $ Do you want a tutorial session and tutorial output?
   0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
   2      $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
Note → 2  $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
```

input for "MAINSETUP"

for analysis of a fixed design

test.OPM

Table 17 (4 pages)

Table 17 Output from "OPTIMIZE" for the starting design

```
test.OPM file corresponding to the "nasatruss" optimum design
identified in Table 27 of [9].
=================================================================
      n         $ Do you want a tutorial session and tutorial output?
         0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
         2      $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
         2      $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
         5      $ How many design iterations in this run (3 to 25)?
      n         $ Take "shortcuts" for perturbed designs (Y or N)?
         2      $ Choose 1 or 2 or 3 or 4 or 5 for IDESIGN
         1      $ Choose 1 or 2 or 3 or 4 or 5 for move limits, IMOVE
      y         $ Do you want default (RATIO=10) for initial move limit jump?
      y         $ Do you want the default perturbation (dx/x = 0.05)?
      n         $ Do you want to have dx/x modified by GENOPT?
      n         $ Do you want to reset total iterations to zero (Type H)?

 ************ END OF THE  test.OPT  FILE ***********
 ************ JUNE, 2009 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  test.OPM  FILE *********


 ********************** MAIN PROCESSOR *********************
 The purpose of the mainprocessor, OPTIMIZE, is to perform,
 in a batch mode, the work specified by MAINSETUP for the case
 called test.  Results are stored in the file  test.OPM.
 Please inspect test.OPM before doing more design iterations.
 ***********************************************************
```

optimum design from the "nasatruss" project [9]

```
 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 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  2.00E+00  5.1924E+00  1.00E+01  circumferential width of»
 a single module: PITCH
   2   Y     N     N      0     0.00E+00  1.00E+00  2.3399E+00  5.00E+00  circumferential width of»
 the trapezoid crown: BCROWN
   3   Y     N     N      0     0.00E+00  3.00E-01  1.4172E+00  2.00E+00  height of the truss-core»
 sandwich: HEIGHT
   4   Y     N     N      0     0.00E+00  3.00E-02  1.0000E-01  3.00E-01  local radius from base t»
o side of trapezoidal tool: RACUT
   5   Y     N     N      0     0.00E+00  3.00E-02  1.0000E-01  3.00E-01  local radius from side t»
o crown of trapezoidal tool: ROBT
   6   Y     Y     N      0     0.00E+00  5.20E-03  5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(1 )
   7   N     N     Y      6     1.00E+00  0.00E+00  5.2000E-03  0.00E+00  layer type thickness: TH»
ICK(2 )
   8   Y     Y     N      0     0.00E+00  5.20E-03  5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(3 )
   9   Y     Y     N      0     0.00E+00  5.20E-03  5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(4 )
  10   N     N     Y      9     1.00E+00  0.00E+00  5.2000E-03  0.00E+00  layer type thickness: TH»
ICK(5 )
  11   Y     Y     N      0     0.00E+00  5.20E-03  1.5600E-02  1.56E-02  layer type thickness: TH»
ICK(6 )
  12   Y     Y     N      0     0.00E+00  5.20E-03  1.5600E-02  1.56E-02  layer type thickness: TH»
ICK(7 )
  BEHAVIOR FOR  1 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1


 BIGBOSOR4 input file for: local buckling load
test.BEHX1
```

Table 17, p. 2 of 4

```
 LOCAL BUCKLING LOAD FACTORS AND MODES (BEHX1)
        6.0133E+00( 100)
        2.5222E+00( 200)
        1.8161E+00( 300)
        1.6694E+00( 400) <--critical local buckling. "400" in the "huge torus"
        1.7336E+00( 500)    GENOPT/BIGBOSOR4 model means "4 axial half-waves
        1.9141E+00( 600)    over the axial length, FACLEN x LENGTH = 0.1 x 96 inches".
        2.1764E+00( 700)    Hence the predicted axial half-wavelength of the critical
        2.5054E+00( 800)    local buckles is 2.4 inches in this "huge torus" model.
        2.8934E+00( 900)
 Critical buckling load factor, LOCBUK=  1.6694E+00
 Critical number of circumferential waves, NWVCRT=  400
    1        1.669418      local buckling load factor: LOCBUK(1 )


 BIGBOSOR4 input file for: general buckling load
test.BEHX2

 GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX2)
        2.3655E+00( 100)
        2.8234E+00( 200)
        3.5544E+00( 300)
        4.4168E+00( 400)
        5.2736E+00( 500)
 Critical buckling load factor, GENBUK=  2.3655E+00
 Critical number of circumferential waves, NWVCRT=  100
    2        2.365467      general buckling load factor: GENBUK(1 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX3 (Material type 1):
 0 deg. tension  3.713389E+04
 0 deg. comp.    4.789538E+04
90 deg. tension  6.191263E+03
90 deg. comp.    0.000000E+00
 in-plane shear  4.040571E+03
    3        37133.89      stress component in material 1: STRM1(1 ,1 )
    4        47895.38      stress component in material 1: STRM1(1 ,2 )
    5        6191.263      stress component in material 1: STRM1(1 ,3 )
    6      0.1000000E-09   stress component in material 1: STRM1(1 ,4 )
    7        4040.571      stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX4 (Material type 2):
 0 deg. tension  0.000000E+00
 0 deg. comp.    0.000000E+00      There is no material type 2
90 deg. tension  0.000000E+00      in the SPECIFIC case, "test"
90 deg. comp.    0.000000E+00
 in-plane shear  0.000000E+00
    8      0.1000000E-09   stress component in material 2: STRM2(1 ,1 )
    9      0.1000000E-09   stress component in material 2: STRM2(1 ,2 )
   10      0.1000000E-09   stress component in material 2: STRM2(1 ,3 )
   11      0.1000000E-09   stress component in material 2: STRM2(1 ,4 )
   12      0.1000000E-09   stress component in material 2: STRM2(1 ,5 )

 Objective =weight per surface area from OBJECT =  1.251372E-02
 PHI,ALPHA,AREA1,AREA2,RADACU,RADOBT=
  6.9594E-01  8.7486E-01  5.1155E-03  2.2136E-03  1.2600E-01  1.2600E-01

 ***** RESULTS FOR LOAD SET NO.  1  ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)

 BEH.   CURRENT
 NO.     VALUE           DEFINITION
  1    1.669E+00    local buckling load factor: LOCBUK(1 )
  2    2.365E+00    general buckling load factor: GENBUK(1 )
  3    3.713E+04    stress component in material 1: STRM1(1 ,1 )
  4    4.790E+04    stress component in material 1: STRM1(1 ,2 )
  5    6.191E+03    stress component in material 1: STRM1(1 ,3 )
  6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
  7    4.041E+03    stress component in material 1: STRM1(1 ,5 )
  8    1.000E-10    stress component in material 2: STRM2(1 ,1 )
  9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10    1.000E-10    stress component in material 2: STRM2(1 ,3 )
 11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
 12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
```

Table 17, p.3 of 4

```
******* NOTE ******* NOTE ******* NOTE ****** NOTE ******
The phrase, "NOT APPLY", for MARGIN VALUE means that that
particular margin value is exactly zero.
*** END NOTE *** END NOTE *** END NOTE *** END NOTE *****


***** RESULTS FOR LOAD SET NO.  1  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)

MARGIN CURRENT
NO.     VALUE           DEFINITION
 1   -3.320E-03  1-1.00*V(2)+0.45*V(1) -1.
 2    1.184E+00  1+0.45*V(1)-0.45*V(2)-1.00*V(4) -1.
 3    9.530E-01  1+0.45*V(2)-1.00*V(5) -1.
 4    2.543E-01  1+0.25*V(3)-1.00*V(4) -1.
 5    2.543E-01  1+0.25*V(3)-1.00*V(5) -1.
 6   -1.000E-02  1-1.00*V(5)+0.90*V(4) -1.
 7    1.129E-01  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.50
 8    1.827E-01  (GENBUK(1 )/GENBUKA(1 )) / GENBUKF(1 )-1; F.S.=  2.00
 9    2.605E+00  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.50
10    1.588E+00  (STRM1A(1 ,2 )/STRM1(1 ,2 )) / STRM1F(1 ,2 )-1; F.S.=  1.50
11    2.261E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.10
12    1.864E+00  (STRM1A(1 ,5 )/STRM1(1 ,5 )) / STRM1F(1 ,5 )-1; F.S.=  1.50

***************************************************
******************** DESIGN OBJECTIVE ******************
*************                         ***********
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:

VAR.   CURRENT
NO.     VALUE             DEFINITION
 1    1.251E-02  weight/area of the truss-core sandwich wall: WEIGHT

*************                       ************
******************** DESIGN OBJECTIVE ******************
*****************************************************
***********  ALL 1 LOAD CASES PROCESSED ***********
*****************************************************


PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.

VAR.   CURRENT
NO.     VALUE             DEFINITION
 1     9.600E+01  length of the cylindrical shell: LENGTH
 2     1.000E-01  fraction of LENGTH for local buckling: FACLEN
 3     4.800E+01  radius of the cylindrical shell: RADIUS
 4     1.851E+07  axial modulus of a corner "noodle": ENOODL
 5     5.700E-02  weight density of the "noodle" material: DNOODL
 6     0.000E+00  elastic foam "Winkler" foundation stiffness: EFOUND
 7     0.000E+00  elastic "noodle" Winkler foundation modulus: EFNOOD
 8     1.851E+07  elastic modulus in the fiber direction: EMOD1(1 )
 9     1.640E+06  elastic modulus transverse to fibers: EMOD2(1 )
10     8.706E+05  in-plane shear modulus: G12(1 )
11     8.706E+05  out-of-plane x-z shear modulus: G13(1 )
12     8.706E+05  out-of-plain y-z shear modulus: G23(1 )
13     2.660E-02  minor (small) Poisson ratio: NU(1 )
14     2.500E-07  coef. of thermal expansion along the fibers: ALPHA1(1 )
15     1.620E-05  coef. of thermal expansion transverse to fibers: ALPHA2(1 )
16     2.400E+02  curing temperature difference: TEMCUR(1 )
17     5.700E-02  weight density of material: DENSTY(1 )
18     4.500E+01  layer type layup angle: ANGLE(1 )
19    -4.500E+01  layer type layup angle: ANGLE(2 )
20     9.000E+01  layer type layup angle: ANGLE(3 )
21     4.500E+01  layer type layup angle: ANGLE(4 )
22    -4.500E+01  layer type layup angle: ANGLE(5 )
23     0.000E+00  layer type layup angle: ANGLE(6 )
24     9.000E+01  layer type layup angle: ANGLE(7 )
PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR.   CURRENT
NO.     VALUE             DEFINITION
 1    -1.508E+06  total axial load (2 x pi x r x resultant): PX(1 )
 2     0.000E+00  pressure (negative for external pressure): PRESS(1 )
 3     0.000E+00  total "Load Set B" load: PX0(1 )
 4     0.000E+00  "Load Set B" pressure (external=negative): PRESS0(1 )
PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)
```

Compare with Table 4

Agrees with "nasatruss" value, 0.012315 (after correction for error in material density in the "nasatruss" case.)

Note: zero values are used here.

Table 17, p. 4 of 4

```
VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    1.000E+00  allowable for local buckling load factor: LOCBUKA(1 )
 2    1.000E+00  allowable for general buckling load factor: GENBUKA(1 )
 3    2.008E+05  allowable stress in material 1: STRM1A(1 ,1 )
 4    1.859E+05  allowable stress in material 1: STRM1A(1 ,2 )
 5    8.350E+03  allowable stress in material 1: STRM1A(1 ,3 )
 6    1.640E+04  allowable stress in material 1: STRM1A(1 ,4 )
 7    1.736E+04  allowable stress in material 1: STRM1A(1 ,5 )
 8    2.008E+05  allowable for stress in material 2: STRM2A(1 ,1 )
 9    1.859E+05  allowable for stress in material 2: STRM2A(1 ,2 )
10    8.350E+03  allowable for stress in material 2: STRM2A(1 ,3 )
11    1.640E+04  allowable for stress in material 2: STRM2A(1 ,4 )
12    1.736E+04  allowable for stress in material 2: STRM2A(1 ,5 )
PARAMETERS WHICH ARE FACTORS OF SAFETY

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    1.500E+00  factor of safety for local buckling: LOCBUKF(1 )
 2    2.000E+00  general buckling factor of safety: GENBUKF(1 )
 3    1.500E+00  factor of safety for stress in material 1: STRM1F(1 ,1 )
 4    1.500E+00  factor of safety for stress in material 1: STRM1F(1 ,2 )
 5    1.100E+00  factor of safety for stress in material 1: STRM1F(1 ,3 )
 6    1.500E+00  factor of safety for stress in material 1: STRM1F(1 ,4 )
 7    1.500E+00  factor of safety for stress in material 1: STRM1F(1 ,5 )
 8    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,1 )
 9    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,2 )
10    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,3 )
11    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,4 )
12    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,5 )

   6 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED

 1 <1-1.00*V(2)+0.45*V(1)
 1 <1+0.45*V(1)-0.45*V(2)-1.00*V(4)
 1 <1+0.45*V(2)-1.00*V(5)
 1 <1+0.25*V(3)-1.00*V(4)
 1 <1+0.25*V(3)-1.00*V(5)
 1 <1-1.00*V(5)+0.90*V(4)
```

see input data for "DECIDE"

```
DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

test.NAM = This file contains only the name of the case.
test.OPM = Output data. Please list this file and inspect
           carefully before proceeding.
test.OPP = Output file containing evolution of design and
           margins since the beginning of optimization cycles.
test.CBL = Labelled common blocks for analysis.
           (This is an unformatted sequential file.)
test.OPT = This file contains the input data for MAINSETUP
            as well as OPTIMIZE. The batch command OPTIMIZE
            can be given over and over again without having
            to return to MAINSETUP because test.OPT exists.
URPROMPT.DAT= Prompt file for interactive input.

For further information about files used and generated
during operation of GENOPT, give the command HELPG FILES.

Menu of commands: CHOOSEPLOT, OPTIMIZE, MAINSETUP, CHANGE,
                  DECIDE, SUPEROPT

IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
RUN  "OPTIMIZE"  MANY TIMES DURING AN OPTIMIZATION AND/OR USE
THE "GLOBAL" OPTIMIZING SCRIPT, "SUPEROPT".
******************** END OF test.OPM FILE *****************
```

Table 18 test.ALL for general buckling (6 pages)

First part of the simpler 6-segment module model used for general buckling. This is the properly annotated input file for BIGBOSOR4

```
 general buckling from multiple module model (INDIC=4)
        4        $ INDIC = analysis type indicator
        1        $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
        0        $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
        0        $ IPRE  = indicator for prebuckling stress calculation (0 or 1)
       90        $ NSEG  = number of shell segments (less than 295)
     H           $
     H           $ SEGMENT NUMBER    1    1    1    1    1    1    1    1
     H           $ NODAL POINT DISTRIBUTION FOLLOWS...
       11        $ NMESH = number of node points (5 = min.; 98 = max.)( 1)
        3        $ NTYPEH= control integer (1 or 3) for nodal point spacing
     H           $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        2        $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  3022.095       $ R1      = radius at beginning of segment (see p. 66)
 -0.6837845E-03  $ Z1      = global axial coordinate at beginning of segment
  3024.434       $ R2      = radius at end of segment
 -0.7019520E-01  $ Z2      = global axial coordinate at end of segment
  3021.839       $ RC      = radius from axis of rev. to center of curvature
 -48.00000       $ ZC      = axial coordinate of center of curvature
  1.000000       $ SROT=indicator for direction of increasing arc (-1. or +1.)
     H           $ IMPERFECTION SHAPE FOLLOWS...
        0        $ IMP   = indicator for imperfection (0=none, 1=some)
     H           $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3        $ NTYPEZ= control (1 or 3) for reference surface location
  0.2600000E-01  $ ZVAL  = distance from leftmost surf. to reference surf.
     N           $ Do you want to print out r(s), r'(s), etc. for this segment?
     H           $ DISCRETE RING INPUT FOLLOWS...
        1        $ NRINGS= number (max=20) of discrete rings in this segment
        1        $ NTYPE = control for identification of ring location (2=z, 3=r)
       11        $ IPOINT(I)=segment nodal point of the Ith callout( 1)
        2        $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.( 1)
  0.1851110E+08  $ E       = Young's modulus of ring no.( 1)
  0.8324589E-02  $ A       = cross section area of ring no.( 1)
  0.8662347E-05  $ Is      = moment of inertia about s-axis (see fig. on p.70)( 1)
  0.8662347E-05  $ In      = moment of inertia aboun n-axis, ring no.( 1)
  0.000000       $ Isn     = product of inertia in the (s,n) axis system( 1)
  0.000000       $ ZC      = normal component of ring eccentricity (see p. 70)( 1)
  0.000000       $ SC      = meridional component of ring eccentricity, ring( 1)
  61.67292       $ GJ      = torsional rigidity, ring no.( 1)
  0.4745015E-03  $ RM      = ring material density (alum=.0002535),ring no.( 1)
  0.000000       $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H           $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
        2        $ NSTRES = number of meridional stations for Nx, Ny callouts
       60        $ NRLOAD = number of preloaded discrete rings in entire shell
        1        $ NTYPE = control for meaning of loading callout (2=z, 3=r)
        1        $ IPOINT(I)=segment nodal point of the Ith callout( 1)
       11        $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -2193.258       $ FN20  = circumferential prestress at Ith callout, FN20( 1)
 -2193.258       $ FN20  = circumferential prestress at Ith callout, FN20( 2)
        1        $ IRING=index number of discrete ring with preload,IRING( 1)
        2        $ IRING=index number of discrete ring with preload,IRING( 2)
        3        $ IRING=index number of discrete ring with preload,IRING( 3)
        4        $ IRING=index number of discrete ring with preload,IRING( 4)
        5        $ IRING=index number of discrete ring with preload,IRING( 5)
        6        $ IRING=index number of discrete ring with preload,IRING( 6)
        7        $ IRING=index number of discrete ring with preload,IRING( 7)
        8        $ IRING=index number of discrete ring with preload,IRING( 8)
        9        $ IRING=index number of discrete ring with preload,IRING( 9)
       10        $ IRING=index number of discrete ring with preload,IRING(10)
       11        $ IRING=index number of discrete ring with preload,IRING(11)
       12        $ IRING=index number of discrete ring with preload,IRING(12)
       13        $ IRING=index number of discrete ring with preload,IRING(13)
       14        $ IRING=index number of discrete ring with preload,IRING(14)
       15        $ IRING=index number of discrete ring with preload,IRING(15)
       16        $ IRING=index number of discrete ring with preload,IRING(16)
       17        $ IRING=index number of discrete ring with preload,IRING(17)
       18        $ IRING=index number of discrete ring with preload,IRING(18)
       19        $ IRING=index number of discrete ring with preload,IRING(19)
       20        $ IRING=index number of discrete ring with preload,IRING(20)
```

Compare with -2373.9 in the "nasatross" model in Seg. 1 on p. 1 of Table 7

```
        21        $ IRING=index number of discrete ring with preload,IRING(21)
        22        $ IRING=index number of discrete ring with preload,IRING(22)
        23        $ IRING=index number of discrete ring with preload,IRING(23)
        24        $ IRING=index number of discrete ring with preload,IRING(24)
        25        $ IRING=index number of discrete ring with preload,IRING(25)
        26        $ IRING=index number of discrete ring with preload,IRING(26)
        27        $ IRING=index number of discrete ring with preload,IRING(27)
        28        $ IRING=index number of discrete ring with preload,IRING(28)
        29        $ IRING=index number of discrete ring with preload,IRING(29)
        30        $ IRING=index number of discrete ring with preload,IRING(30)
        31        $ IRING=index number of discrete ring with preload,IRING(31)
        32        $ IRING=index number of discrete ring with preload,IRING(32)
        33        $ IRING=index number of discrete ring with preload,IRING(33)
        34        $ IRING=index number of discrete ring with preload,IRING(34)
        35        $ IRING=index number of discrete ring with preload,IRING(35)
        36        $ IRING=index number of discrete ring with preload,IRING(36)
        37        $ IRING=index number of discrete ring with preload,IRING(37)
        38        $ IRING=index number of discrete ring with preload,IRING(38)
        39        $ IRING=index number of discrete ring with preload,IRING(39)
        40        $ IRING=index number of discrete ring with preload,IRING(40)
        41        $ IRING=index number of discrete ring with preload,IRING(41)
        42        $ IRING=index number of discrete ring with preload,IRING(42)
        43        $ IRING=index number of discrete ring with preload,IRING(43)
        44        $ IRING=index number of discrete ring with preload,IRING(44)
        45        $ IRING=index number of discrete ring with preload,IRING(45)
        46        $ IRING=index number of discrete ring with preload,IRING(46)
        47        $ IRING=index number of discrete ring with preload,IRING(47)
        48        $ IRING=index number of discrete ring with preload,IRING(48)
        49        $ IRING=index number of discrete ring with preload,IRING(49)
        50        $ IRING=index number of discrete ring with preload,IRING(50)
        51        $ IRING=index number of discrete ring with preload,IRING(51)
        52        $ IRING=index number of discrete ring with preload,IRING(52)
        53        $ IRING=index number of discrete ring with preload,IRING(53)
        54        $ IRING=index number of discrete ring with preload,IRING(54)
        55        $ IRING=index number of discrete ring with preload,IRING(55)
        56        $ IRING=index number of discrete ring with preload,IRING(56)
        57        $ IRING=index number of discrete ring with preload,IRING(57)
        58        $ IRING=index number of discrete ring with preload,IRING(58)
        59        $ IRING=index number of discrete ring with preload,IRING(59)
        60        $ IRING=index number of discrete ring with preload,IRING(60)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 1)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 2)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 3)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 4)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 5)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 6)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 7)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 8)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD( 9)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(10)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(11)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(12)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(13)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(14)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(15)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(16)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(17)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(18)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(19)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(20)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(21)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(22)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(23)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(24)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(25)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(26)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(27)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(28)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(29)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(30)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(31)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(32)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(33)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(34)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(35)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(36)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(37)
 -417.0230        $ RLOAD = preload in Ith discrete ring, RLOAD(38)
```

compare with (-112.34)+(-259.61) (AREA2)+(AREA1) in the next table.

Table 18, p. 3-16

```
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(39)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(40)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(41)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(42)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(43)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(44)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(45)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(46)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(47)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(48)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(49)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(50)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(51)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(52)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(53)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(54)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(55)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(56)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(57)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(58)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(59)
-417.0230      $ RLOAD = preload in Ith discrete ring, RLOAD(60)
    N          $ Do you want to print out prestresses at meridional stations?
    H          $ SHELL WALL CONSTRUCTION FOLLOWS...
        4      $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
       12      $ number of layers in the wall
        1      $ layer index (1,2,...), for layer no.( 1)
    Y          $ Is this a new layer type?
0.5200000E-02  $ thickness for layer index no.( 1)
-45.00000      $ winding angle (deg.) for layer index no.( 1)
        1      $ material index (1,2,...) for layer index no.( 1)
        2      $ layer index (1,2,...), for layer no.( 2)
    Y          $ Is this a new layer type?
0.5200000E-02  $ thickness for layer index no.( 2)
 45.00000      $ winding angle (deg.) for layer index no.( 2)
        1      $ material index (1,2,...) for layer index no.( 2)
        3      $ layer index (1,2,...), for layer no.( 3)
    Y          $ Is this a new layer type?
0.5200000E-02  $ thickness for layer index no.( 3)
 0.000000      $ winding angle (deg.) for layer index no.( 3)
        1      $ material index (1,2,...) for layer index no.( 3)
        2      $ layer index (1,2,...), for layer no.( 4)
    N          $ Is this a new layer type?
        1      $ layer index (1,2,...), for layer no.( 5)
    N          $ Is this a new layer type?
        4      $ layer index (1,2,...), for layer no.( 6)
    Y          $ Is this a new layer type?
0.5200000E-02  $ thickness for layer index no.( 4)
-45.00000      $ winding angle (deg.) for layer index no.( 4)
        1      $ material index (1,2,...) for layer index no.( 4)
        5      $ layer index (1,2,...), for layer no.( 7)
    Y          $ Is this a new layer type?
0.5200000E-02  $ thickness for layer index no.( 5)
 45.00000      $ winding angle (deg.) for layer index no.( 5)
        1      $ material index (1,2,...) for layer index no.( 5)
        6      $ layer index (1,2,...), for layer no.( 8)
    Y          $ Is this a new layer type?
0.1560000E-01  $ thickness for layer index no.( 6)
 90.00000      $ winding angle (deg.) for layer index no.( 6)
        1      $ material index (1,2,...) for layer index no.( 6)
        7      $ layer index (1,2,...), for layer no.( 9)
    Y          $ Is this a new layer type?
0.1560000E-01  $ thickness for layer index no.( 7)
 0.000000      $ winding angle (deg.) for layer index no.( 7)
        1      $ material index (1,2,...) for layer index no.( 7)
        6      $ layer index (1,2,...), for layer no.(10)
    N          $ Is this a new layer type?
        5      $ layer index (1,2,...), for layer no.(11)
    N          $ Is this a new layer type?
        4      $ layer index (1,2,...), for layer no.(12)
    N          $ Is this a new layer type?
    Y          $ Next material type... Is material new for material type( 1)
0.1851110E+08  $ modulus in the fiber direction, E1( 1)
 1640000.      $ modulus transverse to fibers,   E2( 1)
 870600.1      $ in-plane shear modulus,          G( 1)
0.2660000E-01  $ small Poisson's ratio,          NU( 1)
0.2500000E-06  $ thermal expansion along fibers, A1( 1)
0.1620000E-04  $ transverse thermal expansion,   A2( 1)
```

Table 18, p. 4 of 6

```
 240.0000       $ residual stress temperature (positive),TEMPTUR( 1)
 0.5700000E-01  $ mass density (e.g. lb-sec**2/in. Aluminum=.00025), DENS( 1)
 200798.0       $ maximum tensile stress along fibers, matl( 1)
 185925.0       $ max compressive stress along fibers, matl( 1)
 8350.000       $ max tensile stress normal to fibers, matl( 1)
 16400.00       $ max compress stress normal to fibers,matl( 1)
 17357.00       $ maximum  shear  stress  in  material type( 1)
        0       $ NRS  = control (0 or 1) for addition of smeared stiffeners
   Y            $ Do you want output for all the nodal points in Segment( 1)
   N            $ Do you want to print out the C(i,j) at meridional stations?
   N            $ Do you want to print out distributed loads along meridian?
   H            $
   H            $ SEGMENT NUMBER    2    2    2    2    2    2    2    2
   H            $ NODAL POINT DISTRIBUTION FOLLOWS...
       11       $ NMESH = number of node points (5 = min.; 98 = max.)( 2)
        3       $ NTYPEH= control integer (1 or 3) for nodal point spacing
   H            $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        2       $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
 3024.434       $ R1     = radius at beginning of segment (see p. 66)
-0.7019234E-01  $ Z1     = global axial coordinate at beginning of segment
 3027.276       $ R2     = radius at end of segment
-0.3089218      $ Z2     = global axial coordinate at end of segment
 3021.839       $ RC     = radius from axis of rev. to center of curvature
-48.00000       $ ZC     = axial coordinate of center of curvature
 1.000000       $ SROT=indicator for direction of increasing arc (-1. or +1.)
   H            $ IMPERFECTION SHAPE FOLLOWS...
        0       $ IMP   = indicator for imperfection (0=none, 1=some)
   H            $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3       $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01  $ ZVAL  = distance from leftmost surf. to reference surf.
   N            $ Do you want to print out r(s), r'(s), etc. for this segment?
   H            $ DISCRETE RING INPUT FOLLOWS...
        1       $ NRINGS= number (max=20) of discrete rings in this segment
        1       $ NTYPE = control for identification of ring location (2=z, 3=r)
       11       $ IPOINT(I)=segment nodal point of the Ith callout( 1)
        2       $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.( 1)
 0.1851110E+08  $ E      = Young's modulus of ring no.( 1)
 0.8324589E-02  $ A      = cross section area of ring no.( 1)
 0.8662347E-05  $ Is     = moment of inertia about s-axis (see fig. on p.70)( 1)
 0.8662347E-05  $ In     = moment of inertia aboun n-axis, ring no.( 1)
 0.000000       $ Isn    = product of inertia in the (s,n) axis system( 1)
 0.000000       $ ZC     = normal component of ring eccentricity (see p. 70)( 1)
 0.000000       $ SC     = meridional component of ring eccentricity, ring( 1)
 61.67292       $ GJ     = torsional rigidity, ring no.( 1)
 0.4745015E-03  $ RM     = ring material density (alum=.0002535),ring no.( 1)
 0.000000       $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
   H            $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
        2       $ NSTRES = number of meridional stations for Nx, Ny callouts
       60       $ NRLOAD = number of preloaded discrete rings in entire shell
        1       $ NTYPE = control for meaning of loading callout (2=z, 3=r)
        1       $ IPOINT(I)=segment nodal point of the Ith callout( 1)
       11       $ IPOINT(I)=segment nodal point of the Ith callout( 2)
 0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 1)
 0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 2)
-2193.258       $ FN20  = circumferential prestress at Ith callout, FN20( 1)
-2193.258       $ FN20  = circumferential prestress at Ith callout, FN20( 2)
   N            $ Do you want to print out prestresses at meridional stations?
   H            $ SHELL WALL CONSTRUCTION FOLLOWS...
        4       $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
       12       $ number of layers in the wall
        1       $ layer index (1,2,...), for layer no.( 1)
   N            $ Is this a new layer type?
        2       $ layer index (1,2,...), for layer no.( 2)
   N            $ Is this a new layer type?
        3       $ layer index (1,2,...), for layer no.( 3)
   N            $ Is this a new layer type?
        2       $ layer index (1,2,...), for layer no.( 4)
   N            $ Is this a new layer type?
        1       $ layer index (1,2,...), for layer no.( 5)
   N            $ Is this a new layer type?
        4       $ layer index (1,2,...), for layer no.( 6)
   N            $ Is this a new layer type?
        5       $ layer index (1,2,...), for layer no.( 7)
   N            $ Is this a new layer type?
        6       $ layer index (1,2,...), for layer no.( 8)
   N            $ Is this a new layer type?
        7       $ layer index (1,2,...), for layer no.( 9)
   N            $ Is this a new layer type?
```

Compare with Seg. 1 in Table 7

Table 18, p. 5 of 6

```
      6         $ layer index (1,2,...), for layer no.(10)
   N            $ Is this a new layer type?
      5         $ layer index (1,2,...), for layer no.(11)
   N            $ Is this a new layer type?
      4         $ layer index (1,2,...), for layer no.(12)
   N            $ Is this a new layer type?
      0         $ NRS  = control (0 or 1) for addition of smeared stiffeners
   Y            $ Do you want output for all the nodal points in Segment( 2)
   N            $ Do you want to print out the C(i,j) at meridional stations?
   N            $ Do you want to print out distributed loads along meridian?
   H            $
   H            $ SEGMENT NUMBER    3    3    3    3    3    3    3    3
   H            $ NODAL POINT DISTRIBUTION FOLLOWS...
     11         $ NMESH = number of node points (5 = min.; 98 = max.)( 3)
      3         $ NTYPEH= control integer (1 or 3) for nodal point spacing
   H            $ REFERENCE SURFACE GEOMETRY FOLLOWS...
      1         $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  3024.434      $ R1     = radius at beginning of segment (see p. 66)
-0.7019234E-01  $ Z1     = global axial coordinate at beginning of segment
  3024.690      $ R2     = radius at end of segment
  1.334894      $ Z2     = global axial coordinate at end of segment
   H            $ IMPERFECTION SHAPE FOLLOWS...
      0         $ IMP   = indicator for imperfection (0=none, 1=some)
   H            $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
      3         $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01  $ ZVAL  = distance from leftmost surf. to reference surf.
   N            $ Do you want to print out r(s), r'(s), etc. for this segment?
   H            $ DISCRETE RING INPUT FOLLOWS...
      1         $ NRINGS= number (max=20) of discrete rings in this segment
      1         $ NTYPE = control for identification of ring location (2=z, 3=r)
     11         $ IPOINT(I)=segment nodal point of the Ith callout( 1)
      2         $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.( 1)
 0.1851110E+08  $ E      = Young's modulus of ring no.( 1)
 0.8324589E-02  $ A      = cross section area of ring no.( 1)
 0.8662347E-05  $ Is     = moment of inertia about s-axis (see fig. on p.70)( 1)
 0.8662347E-05  $ In     = moment of inertia aboun n-axis, ring no.( 1)
  0.000000      $ Isn    = product of inertia in the (s,n) axis system( 1)
  0.000000      $ ZC     = normal component of ring eccentricity (see p. 70)( 1)
  0.000000      $ SC     = meridional component of ring eccentricity, ring( 1)
  61.67292      $ GJ     = torsional rigidity, ring no.( 1)
 0.4745015E-03  $ RM     = ring material density (alum=.0002535),ring no.( 1)
  0.000000      $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
   H            $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
      2         $ NSTRES = number of meridional stations for Nx, Ny callouts
     60         $ NRLOAD = number of preloaded discrete rings in entire shell
      1         $ NTYPE = control for meaning of loading callout (2=z, 3=r)
      1         $ IPOINT(I)=segment nodal point of the Ith callout( 1)
     11         $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000      $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000      $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -526.7880      $ FN20  = circumferential prestress at Ith callout, FN20( 1)   ] Compare with
 -526.7880      $ FN20  = circumferential prestress at Ith callout, FN20( 2)   ] Segments 2 & 4
   N            $ Do you want to print out prestresses at meridional stations?   on p. 2 of
   H            $ SHELL WALL CONSTRUCTION FOLLOWS...                              Table 7:
      4         $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction  Nx(2&4)=
     10         $ number of layers in the wall                                    -454.47
      1         $ layer index (1,2,...), for layer no.( 1)
   N            $ Is this a new layer type?
      2         $ layer index (1,2,...), for layer no.( 2)
   N            $ Is this a new layer type?
      3         $ layer index (1,2,...), for layer no.( 3)
   N            $ Is this a new layer type?
      2         $ layer index (1,2,...), for layer no.( 4)
   N            $ Is this a new layer type?
      1         $ layer index (1,2,...), for layer no.( 5)
   N            $ Is this a new layer type?
      2         $ layer index (1,2,...), for layer no.( 6)
   N            $ Is this a new layer type?
      1         $ layer index (1,2,...), for layer no.( 7)
   N            $ Is this a new layer type?
      3         $ layer index (1,2,...), for layer no.( 8)
   N            $ Is this a new layer type?
      1         $ layer index (1,2,...), for layer no.( 9)
   N            $ Is this a new layer type?
      2         $ layer index (1,2,...), for layer no.(10)
   N            $ Is this a new layer type?
      0         $ NRS  = control (0 or 1) for addition of smeared stiffeners
   Y            $ Do you want output for all the nodal points in Segment( 3)
```

```
N         $ Do you want to print out the C(i,j) at meridional stations?
N         $ Do you want to print out distributed loads along meridian?
H         $
```

etc.

much more not listed here to save space.

(There are 90 segments in this multi-module general buckling model. See Figs. 4 & 5)

Table 19 test.ALL for local buckling (7 pages)

First part of the BIGBOSOR4 input file, test.ALL, for the elaborate 22-segment model used for local buckling. This input file corresponds to the starting design.

```
local buckling from single module model (INDIC=4)
       4        $ INDIC = analysis type indicator
       1        $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
       0        $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
       0        $ IPRE  = indicator for prebuckling stress calculation (0 or 1)
      22        $ NSEG  = number of shell segments (less than 295)
    H           $
    H           $ SEGMENT NUMBER    1    1    1    1    1    1    1    1
    H           $ NODAL POINT DISTRIBUTION FOLLOWS...
      11        $ NMESH = number of node points (5 = min.; 98 = max.)( 1)
       3        $ NTYPEH= control integer (1 or 3) for nodal point spacing
    H           $ REFERENCE SURFACE GEOMETRY FOLLOWS...
       2        $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  303.3428      $ R1      = radius at beginning of segment (see p. 66)
-0.1361847E-02  $ Z1      = global axial coordinate at beginning of segment
  305.4711      $ R2      = radius at end of segment
-0.6461906E-01  $ Z2      = global axial coordinate at end of segment
  302.9813      $ RC      = radius from axis of rev. to center of curvature
 -48.00000      $ ZC      = axial coordinate of center of curvature
  1.000000      $ SROT=indicator for direction of increasing arc (-1. or +1.)
    H           $ IMPERFECTION SHAPE FOLLOWS...
       0        $ IMP   = indicator for imperfection (0=none, 1=some)
    H           $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
       3        $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01  $ ZVAL  = distance from leftmost surf. to reference surf.
    N           $ Do you want to print out r(s), r'(s), etc. for this segment?
    H           $ DISCRETE RING INPUT FOLLOWS...
       0        $ NRINGS= number (max=20) of discrete rings in this segment
  0.000000      $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
    H           $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
       2        $ NSTRES = number of meridional stations for Nx, Ny callouts
       8        $ NRLOAD = number of preloaded discrete rings in entire shell
       1        $ NTYPE = control for meaning of loading callout (2=z, 3=r)
       1        $ IPOINT(I)=segment nodal point of the Ith callout( 1)
      11        $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000      $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000      $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -2221.934      $ FN20  = circumferential prestress at Ith callout, FN20( 1)
 -2221.934      $ FN20  = circumferential prestress at Ith callout, FN20( 2)
       1        $ IRING=index number of discrete ring with preload,IRING( 1)
       2        $ IRING=index number of discrete ring with preload,IRING( 2)
       3        $ IRING=index number of discrete ring with preload,IRING( 3)
       4        $ IRING=index number of discrete ring with preload,IRING( 4)
       5        $ IRING=index number of discrete ring with preload,IRING( 5)
       6        $ IRING=index number of discrete ring with preload,IRING( 6)
       7        $ IRING=index number of discrete ring with preload,IRING( 7)
       8        $ IRING=index number of discrete ring with preload,IRING( 8)
-112.3419       $ RLOAD = preload in Ith discrete ring, RLOAD( 1)
-259.6127       $ RLOAD = preload in Ith discrete ring, RLOAD( 2)
-259.6127       $ RLOAD = preload in Ith discrete ring, RLOAD( 3)
-112.3419       $ RLOAD = preload in Ith discrete ring, RLOAD( 4)
-259.6127       $ RLOAD = preload in Ith discrete ring, RLOAD( 5)
-112.3419       $ RLOAD = preload in Ith discrete ring, RLOAD( 6)
-112.3419       $ RLOAD = preload in Ith discrete ring, RLOAD( 7)
-259.6127       $ RLOAD = preload in Ith discrete ring, RLOAD( 8)
    N           $ Do you want to print out prestresses at meridional stations?
    H           $ SHELL WALL CONSTRUCTION FOLLOWS...
       4        $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
      12        $ number of layers in the wall
       1        $ layer index (1,2,...), for layer no.( 1)
    Y           $ Is this a new layer type?
 0.5200000E-02  $ thickness for layer index no.( 1)
 -45.00000      $ winding angle (deg.) for layer index no.( 1)
       1        $ material index (1,2,...) for layer index no.( 1)
       2        $ layer index (1,2,...), for layer no.( 2)
    Y           $ Is this a new layer type?
 0.5200000E-02  $ thickness for layer index no.( 2)
  45.00000      $ winding angle (deg.) for layer index no.( 2)
       1        $ material index (1,2,...) for layer index no.( 2)
       3        $ layer index (1,2,...), for layer no.( 3)
    Y           $ Is this a new layer type?
```

(-112.34)+(-259.61) compare with (-417) in the previous table

Table 19 (p. 2 of 7)

```
 0.5200000E-02 $ thickness for layer index no.( 3)
  0.000000     $ winding angle (deg.) for layer index no.( 3)
        1      $ material index (1,2,...) for layer index no.( 3)
        2      $ layer index (1,2,...), for layer no.( 4)
    N          $ Is this a new layer type?
        1      $ layer index (1,2,...), for layer no.( 5)
    N          $ Is this a new layer type?
        4      $ layer index (1,2,...), for layer no.( 6)
    Y          $ Is this a new layer type?
 0.5200000E-02 $ thickness for layer index no.( 4)
 -45.00000     $ winding angle (deg.) for layer index no.( 4)
        1      $ material index (1,2,...) for layer index no.( 4)
        5      $ layer index (1,2,...), for layer no.( 7)
    Y          $ Is this a new layer type?
 0.5200000E-02 $ thickness for layer index no.( 5)
  45.00000     $ winding angle (deg.) for layer index no.( 5)
        1      $ material index (1,2,...) for layer index no.( 5)
        6      $ layer index (1,2,...), for layer no.( 8)
    Y          $ Is this a new layer type?
 0.1560000E-01 $ thickness for layer index no.( 6)
  90.00000     $ winding angle (deg.) for layer index no.( 6)
        1      $ material index (1,2,...) for layer index no.( 6)
        7      $ layer index (1,2,...), for layer no.( 9)
    Y          $ Is this a new layer type?
 0.1560000E-01 $ thickness for layer index no.( 7)
  0.000000     $ winding angle (deg.) for layer index no.( 7)
        1      $ material index (1,2,...) for layer index no.( 7)
        6      $ layer index (1,2,...), for layer no.(10)
    N          $ Is this a new layer type?
        5      $ layer index (1,2,...), for layer no.(11)
    N          $ Is this a new layer type?
        4      $ layer index (1,2,...), for layer no.(12)
    N          $ Is this a new layer type?
    Y          $ Next material type... Is material new for material type( 1)
 0.1851110E+08 $ modulus in the fiber direction, E1( 1)
  1640000.     $ modulus transverse to fibers,   E2( 1)
  870600.1     $ in-plane shear modulus,          G( 1)
 0.2660000E-01 $ small Poisson's ratio,          NU( 1)
 0.2500000E-06 $ thermal expansion along fibers, A1( 1)
 0.1620000E-04 $ transverse thermal expansion,   A2( 1)
  240.0000     $ residual stress temperature (positive),TEMPTUR( 1)
 0.5700000E-01 $ mass density (e.g. lb-sec**2/in. Aluminum=.00025), DENS( 1)
  200798.0     $ maximum tensile stress along fibers, matl( 1)
  185925.0     $ max compressive stress along fibers, matl( 1)
  8350.000     $ max tensile stress normal to fibers, matl( 1)
  16400.00     $ max compress stress normal to fibers,matl( 1)
  17357.00     $ maximum  shear  stress  in  material type( 1)
       0       $ NRS  = control (0 or 1) for addition of smeared stiffeners
    Y          $ Do you want output for all the nodal points in Segment( 1)
    N          $ Do you want to print out the C(i,j) at meridional stations?
    N          $ Do you want to print out distributed loads along meridian?
    H          $
    H          $ SEGMENT NUMBER    2    2    2    2    2    2    2    2
    H          $ NODAL POINT DISTRIBUTION FOLLOWS...
      11       $ NMESH = number of node points (5 = min.; 98 = max.)( 2)
       3       $ NTYPEH= control integer (1 or 3) for nodal point spacing
    H          $ REFERENCE SURFACE GEOMETRY FOLLOWS...
       2       $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  305.4711     $ R1     = radius at beginning of segment (see p. 66)
-0.6461906E-01 $ Z1     = global axial coordinate at beginning of segment
  305.5949     $ R2     = radius at end of segment
 0.3251896E-01 $ Z2     = global axial coordinate at end of segment
  305.4711     $ RC     = radius from axis of rev. to center of curvature
 0.6154980E-01 $ ZC     = axial coordinate of center of curvature
 -1.000000     $ SROT=indicator for direction of increasing arc (-1. or +1.)
    H          $ IMPERFECTION SHAPE FOLLOWS...
       0       $ IMP   = indicator for imperfection (0=none, 1=some)
    H          $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
       3       $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01 $ ZVAL  = distance from leftmost surf. to reference surf.
    N          $ Do you want to print out r(s), r'(s), etc. for this segment?
    H          $ DISCRETE RING INPUT FOLLOWS...
       1       $ NRINGS= number (max=20) of discrete rings in this segment
       1       $ NTYPE = control for identification of ring location (2=z, 3=r)
       6       $ IPOINT(I)=segment nodal point of the Ith callout( 1)
       2       $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.( 1)
 0.1851110E+08 $ E     = Young's modulus of ring no.( 1)
 0.2213619E-02 $ A     = cross section area of ring no.( 1)
```

Table 19 (p. 3 of 7)

```
 0.6125136E-06 $ Is     = moment of inertia about s-axis (see fig. on p.70)( 1)
 0.6125136E-06 $ In     = moment of inertia aboun n-axis, ring no.( 1)
  0.000000     $ Isn    = product of inertia in the (s,n) axis system( 1)
 0.1272660E-01 $ ZC     = normal component of ring eccentricity (see p. 70)( 1)
  0.000000     $ SC     = meridional component of ring eccentricity, ring( 1)
  4.360885     $ GJ     = torsional rigidity, ring no.( 1)
 0.1261763E-03 $ RM     = ring material density (alum=.0002535),ring no.( 1)
  0.000000     $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H         $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
        2      $ NSTRES = number of meridional stations for Nx, Ny callouts
        8      $ NRLOAD = number of preloaded discrete rings in entire shell
        1      $ NTYPE = control for meaning of loading callout (2=z, 3=r)
        1      $ IPOINT(I)=segment nodal point of the Ith callout( 1)
       11      $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -266.8378     $ FN20  = circumferential prestress at Ith callout, FN20( 1)
 -266.8378     $ FN20  = circumferential prestress at Ith callout, FN20( 2)
     N         $ Do you want to print out prestresses at meridional stations?
     H         $ SHELL WALL CONSTRUCTION FOLLOWS...
        4      $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
        5      $ number of layers in the wall
        1      $ layer index (1,2,...), for layer no.( 1)
     N         $ Is this a new layer type?
        2      $ layer index (1,2,...), for layer no.( 2)
     N         $ Is this a new layer type?
        3      $ layer index (1,2,...), for layer no.( 3)
     N         $ Is this a new layer type?
        2      $ layer index (1,2,...), for layer no.( 4)
     N         $ Is this a new layer type?
        1      $ layer index (1,2,...), for layer no.( 5)
     N         $ Is this a new layer type?
        0      $ NRS   = control (0 or 1) for addition of smeared stiffeners
     Y         $ Do you want output for all the nodal points in Segment( 2)
     N         $ Do you want to print out the C(i,j) at meridional stations?
     N         $ Do you want to print out distributed loads along meridian?
     H         $
     H         $ SEGMENT NUMBER    3    3    3    3    3    3    3    3
     H         $ NODAL POINT DISTRIBUTION FOLLOWS...
       11      $ NMESH = number of node points (5 = min.; 98 = max.)( 3)
        3      $ NTYPEH= control integer (1 or 3) for nodal point spacing
     H         $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        2      $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  305.4711     $ R1     = radius at beginning of segment (see p. 66)
-0.6461906E-01 $ Z1     = global axial coordinate at beginning of segment
  305.7268     $ R2     = radius at end of segment
-0.7858372E-01 $ Z2     = global axial coordinate at end of segment
  302.9813     $ RC     = radius from axis of rev. to center of curvature
 -48.00000     $ ZC     = axial coordinate of center of curvature
  1.000000     $ SROT=indicator for direction of increasing arc (-1. or +1.)
     H         $ IMPERFECTION SHAPE FOLLOWS...
        0      $ IMP   = indicator for imperfection (0=none, 1=some)
     H         $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3      $ NTYPEZ= control (1 or 3) for reference surface location
  0.000000     $ ZVAL  = distance from leftmost surf. to reference surf.
     N         $ Do you want to print out r(s), r'(s), etc. for this segment?
     H         $ DISCRETE RING INPUT FOLLOWS...
        0      $ NRINGS= number (max=20) of discrete rings in this segment
  0.000000     $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H         $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
        2      $ NSTRES = number of meridional stations for Nx, Ny callouts
        8      $ NRLOAD = number of preloaded discrete rings in entire shell
        1      $ NTYPE = control for meaning of loading callout (2=z, 3=r)
        1      $ IPOINT(I)=segment nodal point of the Ith callout( 1)
       11      $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -1942.146     $ FN20  = circumferential prestress at Ith callout, FN20( 1)
 -1942.146     $ FN20  = circumferential prestress at Ith callout, FN20( 2)
     N         $ Do you want to print out prestresses at meridional stations?
     H         $ SHELL WALL CONSTRUCTION FOLLOWS...
        4      $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
        7      $ number of layers in the wall
        4      $ layer index (1,2,...), for layer no.( 1)
     N         $ Is this a new layer type?
        5      $ layer index (1,2,...), for layer no.( 2)
     N         $ Is this a new layer type?
        6      $ layer index (1,2,...), for layer no.( 3)
```

Table 19, p. 4 of 7

```
    N         $ Is this a new layer type?
      7       $ layer index (1,2,...), for layer no.( 4)
    N         $ Is this a new layer type?
      6       $ layer index (1,2,...), for layer no.( 5)
    N         $ Is this a new layer type?
      5       $ layer index (1,2,...), for layer no.( 6)
    N         $ Is this a new layer type?
      4       $ layer index (1,2,...), for layer no.( 7)
    N         $ Is this a new layer type?
      0       $ NRS  = control (0 or 1) for addition of smeared stiffeners
    Y         $ Do you want output for all the nodal points in Segment( 3)
    N         $ Do you want to print out the C(i,j) at meridional stations?
    N         $ Do you want to print out distributed loads along meridian?
    H         $
    H         $ SEGMENT NUMBER    4    4    4    4    4    4    4    4
    H         $ NODAL POINT DISTRIBUTION FOLLOWS...
     11       $ NMESH = number of node points (5 = min.; 98 = max.)( 4)
      3       $ NTYPEH= control integer (1 or 3) for nodal point spacing
    H         $ REFERENCE SURFACE GEOMETRY FOLLOWS...
      1       $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  305.5949    $ R1     = radius at beginning of segment (see p. 66)
 0.3251896E-01 $ Z1    = global axial coordinate at beginning of segment
  305.6030    $ R2     = radius at end of segment
 0.7699224E-01 $ Z2    = global axial coordinate at end of segment
    H         $ IMPERFECTION SHAPE FOLLOWS...
      0       $ IMP    = indicator for imperfection (0=none, 1=some)
    H         $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
      3       $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01 $ ZVAL  = distance from leftmost surf. to reference surf.
    N         $ Do you want to print out r(s), r'(s), etc. for this segment?
    H         $ DISCRETE RING INPUT FOLLOWS...
      0       $ NRINGS= number (max=20) of discrete rings in this segment
  0.000000    $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
    H         $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
      2       $ NSTRES = number of meridional stations for Nx, Ny callouts
      8       $ NRLOAD = number of preloaded discrete rings in entire shell
      1       $ NTYPE = control for meaning of loading callout (2=z, 3=r)
      1       $ IPOINT(I)=segment nodal point of the Ith callout( 1)
     11       $ IPOINT(I)=segment nodal point of the Ith callout( 2)
  0.000000    $ FN10  = meridional prestress at Ith callout, FN10( 1)
  0.000000    $ FN10  = meridional prestress at Ith callout, FN10( 2)
 -266.8378    $ FN20  = circumferential prestress at Ith callout, FN20( 1)
 -266.8378    $ FN20  = circumferential prestress at Ith callout, FN20( 2)
    N         $ Do you want to print out prestresses at meridional stations?
    H         $ SHELL WALL CONSTRUCTION FOLLOWS...
      4       $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
      5       $ number of layers in the wall
      1       $ layer index (1,2,...), for layer no.( 1)
    N         $ Is this a new layer type?
      2       $ layer index (1,2,...), for layer no.( 2)
    N         $ Is this a new layer type?
      3       $ layer index (1,2,...), for layer no.( 3)
    N         $ Is this a new layer type?
      2       $ layer index (1,2,...), for layer no.( 4)
    N         $ Is this a new layer type?
      1       $ layer index (1,2,...), for layer no.( 5)
    N         $ Is this a new layer type?
      0       $ NRS  = control (0 or 1) for addition of smeared stiffeners
    Y         $ Do you want output for all the nodal points in Segment( 4)
    N         $ Do you want to print out the C(i,j) at meridional stations?
    N         $ Do you want to print out distributed loads along meridian?
    H         $
    H         $ SEGMENT NUMBER    5    5    5    5    5    5    5    5
    H         $ NODAL POINT DISTRIBUTION FOLLOWS...
     21       $ NMESH = number of node points (5 = min.; 98 = max.)( 5)
      3       $ NTYPEH= control integer (1 or 3) for nodal point spacing
    H         $ REFERENCE SURFACE GEOMETRY FOLLOWS...
      2       $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
  305.7268    $ R1     = radius at beginning of segment (see p. 66)
-0.7858372E-01 $ Z1    = global axial coordinate at beginning of segment
  305.6030    $ R2     = radius at end of segment
 0.7699224E-01 $ Z2    = global axial coordinate at end of segment
  305.7268    $ RC     = radius from axis of rev. to center of curvature
 0.4762307E-01 $ ZC    = axial coordinate of center of curvature
  1.000000    $ SROT=indicator for direction of increasing arc (-1. or +1.)
    H         $ IMPERFECTION SHAPE FOLLOWS...
      0       $ IMP    = indicator for imperfection (0=none, 1=some)
    H         $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
```

```
    3         $ NTYPEZ= control (1 or 3) for reference surface location
 0.000000     $ ZVAL  = distance from leftmost surf. to reference surf.
    N         $ Do you want to print out r(s), r'(s), etc. for this segment?
    H         $ DISCRETE RING INPUT FOLLOWS...
    1         $ NRINGS= number (max=20) of discrete rings in this segment
    1         $ NTYPE = control for identification of ring location (2=z, 3=r)
   11         $ IPOINT(I)=segment nodal point of the Ith callout( 1)
    2         $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.( 1)
 0.1851110E+08 $ E     = Young's modulus of ring no.( 1)
 0.5115489E-02 $ A     = cross section area of ring no.( 1)
 0.3271028E-05 $ Is    = moment of inertia about s-axis (see fig. on p.70)( 1)
 0.3271028E-05 $ In    = moment of inertia aboun n-axis, ring no.( 1)
 0.000000     $ Isn   = product of inertia in the (s,n) axis system( 1)
-0.2351165E-01 $ ZC    = normal component of ring eccentricity (see p. 70)( 1)
 0.000000     $ SC    = meridional component of ring eccentricity, ring( 1)
 23.28859     $ GJ    = torsional rigidity, ring no.( 1)
 0.2915829E-03 $ RM    = ring material density (alum=.0002535),ring no.( 1)
 0.000000     $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
    H         $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
    2         $ NSTRES = number of meridional stations for Nx, Ny callouts
    8         $ NRLOAD = number of preloaded discrete rings in entire shell
    1         $ NTYPE = control for meaning of loading callout (2=z, 3=r)
    1         $ IPOINT(I)=segment nodal point of the Ith callout( 1)
   21         $ IPOINT(I)=segment nodal point of the Ith callout( 2)
 0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 1)
 0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 2)
-266.8378     $ FN20  = circumferential prestress at Ith callout, FN20( 1)
-266.8378     $ FN20  = circumferential prestress at Ith callout, FN20( 2)
    N         $ Do you want to print out prestresses at meridional stations?
    H         $ SHELL WALL CONSTRUCTION FOLLOWS...
    4         $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
    5         $ number of layers in the wall
    2         $ layer index (1,2,...), for layer no.( 1)
    N         $ Is this a new layer type?
    1         $ layer index (1,2,...), for layer no.( 2)
    N         $ Is this a new layer type?
    3         $ layer index (1,2,...), for layer no.( 3)
    N         $ Is this a new layer type?
    1         $ layer index (1,2,...), for layer no.( 4)
    N         $ Is this a new layer type?
    2         $ layer index (1,2,...), for layer no.( 5)
    N         $ Is this a new layer type?
    0         $ NRS   = control (0 or 1) for addition of smeared stiffeners
    Y         $ Do you want output for all the nodal points in Segment( 5)
    N         $ Do you want to print out the C(i,j) at meridional stations?
    N         $ Do you want to print out distributed loads along meridian?
    H         $
    H         $ SEGMENT NUMBER    6    6    6    6    6    6    6    6
    H         $ NODAL POINT DISTRIBUTION FOLLOWS...
   21         $ NMESH = number of node points (5 = min.; 98 = max.)( 6)
    3         $ NTYPEH= control integer (1 or 3) for nodal point spacing
    H         $ REFERENCE SURFACE GEOMETRY FOLLOWS...
    2         $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
 305.7268     $ R1     = radius at beginning of segment (see p. 66)
-0.7858372E-01 $ Z1     = global axial coordinate at beginning of segment
 308.2684     $ R2     = radius at end of segment
-0.2920732    $ Z2     = global axial coordinate at end of segment
 302.9813     $ RC     = radius from axis of rev. to center of curvature
-48.00000     $ ZC     = axial coordinate of center of curvature
 1.000000     $ SROT=indicator for direction of increasing arc (-1. or +1.)
    H         $ IMPERFECTION SHAPE FOLLOWS...
    0         $ IMP   = indicator for imperfection (0=none, 1=some)
    H         $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
    3         $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01 $ ZVAL  = distance from leftmost surf. to reference surf.
    N         $ Do you want to print out r(s), r'(s), etc. for this segment?
    H         $ DISCRETE RING INPUT FOLLOWS...
    0         $ NRINGS= number (max=20) of discrete rings in this segment
 0.000000     $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
    H         $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
    2         $ NSTRES = number of meridional stations for Nx, Ny callouts
    8         $ NRLOAD = number of preloaded discrete rings in entire shell
    1         $ NTYPE = control for meaning of loading callout (2=z, 3=r)
    1         $ IPOINT(I)=segment nodal point of the Ith callout( 1)
   21         $ IPOINT(I)=segment nodal point of the Ith callout( 2)
 0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 1)
 0.000000     $ FN10  = meridional prestress at Ith callout, FN10( 2)
-2221.934     $ FN20  = circumferential prestress at Ith callout, FN20( 1)
```

```
 -2221.934        $ FN20  = circumferential prestress at Ith callout, FN20( 2)
      N           $ Do you want to print out prestresses at meridional stations?
      H           $ SHELL WALL CONSTRUCTION FOLLOWS...
         4        $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
        12        $ number of layers in the wall
         1        $ layer index (1,2,...), for layer no.( 1)
      N           $ Is this a new layer type?
         2        $ layer index (1,2,...), for layer no.( 2)
      N           $ Is this a new layer type?
         3        $ layer index (1,2,...), for layer no.( 3)
      N           $ Is this a new layer type?
         2        $ layer index (1,2,...), for layer no.( 4)
      N           $ Is this a new layer type?
         1        $ layer index (1,2,...), for layer no.( 5)
      N           $ Is this a new layer type?
         4        $ layer index (1,2,...), for layer no.( 6)
      N           $ Is this a new layer type?
         5        $ layer index (1,2,...), for layer no.( 7)
      N           $ Is this a new layer type?
         6        $ layer index (1,2,...), for layer no.( 8)
      N           $ Is this a new layer type?
         7        $ layer index (1,2,...), for layer no.( 9)
      N           $ Is this a new layer type?
         6        $ layer index (1,2,...), for layer no.(10)
      N           $ Is this a new layer type?
         5        $ layer index (1,2,...), for layer no.(11)
      N           $ Is this a new layer type?
         4        $ layer index (1,2,...), for layer no.(12)
      N           $ Is this a new layer type?
         0        $ NRS  = control (0 or 1) for addition of smeared stiffeners
      Y           $ Do you want output for all the nodal points in Segment( 6)
      N           $ Do you want to print out the C(i,j) at meridional stations?
      N           $ Do you want to print out distributed loads along meridian?
      H           $
      H           $ SEGMENT NUMBER    7    7    7    7    7    7    7    7
      H           $ NODAL POINT DISTRIBUTION FOLLOWS...
        11        $ NMESH = number of node points (5 = min.; 98 = max.)( 7)
         3        $ NTYPEH= control integer (1 or 3) for nodal point spacing
      H           $ REFERENCE SURFACE GEOMETRY FOLLOWS...
         1        $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
   305.6030       $ R1     = radius at beginning of segment (see p. 66)
 0.7699224E-01    $ Z1     = global axial coordinate at beginning of segment
   305.8054       $ R2     = radius at end of segment
   1.187772       $ Z2     = global axial coordinate at end of segment
      H           $ IMPERFECTION SHAPE FOLLOWS...
         0        $ IMP   = indicator for imperfection (0=none, 1=some)
      H           $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
         3        $ NTYPEZ= control (1 or 3) for reference surface location
 0.2600000E-01    $ ZVAL  = distance from leftmost surf. to reference surf.
      N           $ Do you want to print out r(s), r'(s), etc. for this segment?
      H           $ DISCRETE RING INPUT FOLLOWS...
         0        $ NRINGS= number (max=20) of discrete rings in this segment
   0.000000       $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
      H           $ PREBUCKLING RESULTANTS INPUT FOLLOWS...
         2        $ NSTRES = number of meridional stations for Nx, Ny callouts
         8        $ NRLOAD = number of preloaded discrete rings in entire shell
         1        $ NTYPE = control for meaning of loading callout (2=z, 3=r)
         1        $ IPOINT(I)=segment nodal point of the Ith callout( 1)
        11        $ IPOINT(I)=segment nodal point of the Ith callout( 2)
   0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 1)
   0.000000       $ FN10  = meridional prestress at Ith callout, FN10( 2)
  -533.6757       $ FN20  = circumferential prestress at Ith callout, FN20( 1)
  -533.6757       $ FN20  = circumferential prestress at Ith callout, FN20( 2)
      N           $ Do you want to print out prestresses at meridional stations?
      H           $ SHELL WALL CONSTRUCTION FOLLOWS...
         4        $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
        10        $ number of layers in the wall
         1        $ layer index (1,2,...), for layer no.( 1)
      N           $ Is this a new layer type?
         2        $ layer index (1,2,...), for layer no.( 2)
      N           $ Is this a new layer type?
         3        $ layer index (1,2,...), for layer no.( 3)
      N           $ Is this a new layer type?
         2        $ layer index (1,2,...), for layer no.( 4)
      N           $ Is this a new layer type?
         1        $ layer index (1,2,...), for layer no.( 5)
      N           $ Is this a new layer type?
         2        $ layer index (1,2,...), for layer no.( 6)
```

```
N          $ Is this a new layer type?
   1       $ layer index (1,2,...), for layer no.( 7)
N          $ Is this a new layer type?
   3       $ layer index (1,2,...), for layer no.( 8)
N          $ Is this a new layer type?
   1       $ layer index (1,2,...), for layer no.( 9)
N          $ Is this a new layer type?
   2       $ layer index (1,2,...), for layer no.(10)
N          $ Is this a new layer type?
   0       $ NRS  = control (0 or 1) for addition of smeared stiffeners
Y          $ Do you want output for all the nodal points in Segment( 7)
N          $ Do you want to print out the C(i,j) at meridional stations?
N          $ Do you want to print out distributed loads along meridian?
```

etc.

much more not listed here to save space. (There are 22 segments in this single-module local buckling model. See Figs 1-3)

Table 20 test.OPT

```
n         $ Do you want a tutorial session and tutorial output?
   0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
   0      $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
   1      $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
   5      $ How many design iterations in this run (3 to 25)?
n         $ Take "shortcuts" for perturbed designs (Y or N)?
   2      $ Choose 1 or 2 or 3 or 4 or 5 for IDESIGN
   1      $ Choose 1 or 2 or 3 or 4 or 5 for move limits, IMOVE
y         $ Do you want default (RATIO=10) for initial move limit jump?
y         $ Do you want the default perturbation (dx/x = 0.05)?
n         $ Do you want to have dx/x modified by GENOPT?
n         $ Do you want to reset total iterations to zero (Type H)?
```

Note

see p. 10

see p. 11

see p. 12

see p. 12

see pp 12-13

input for "MAINSETUP"

for optimization

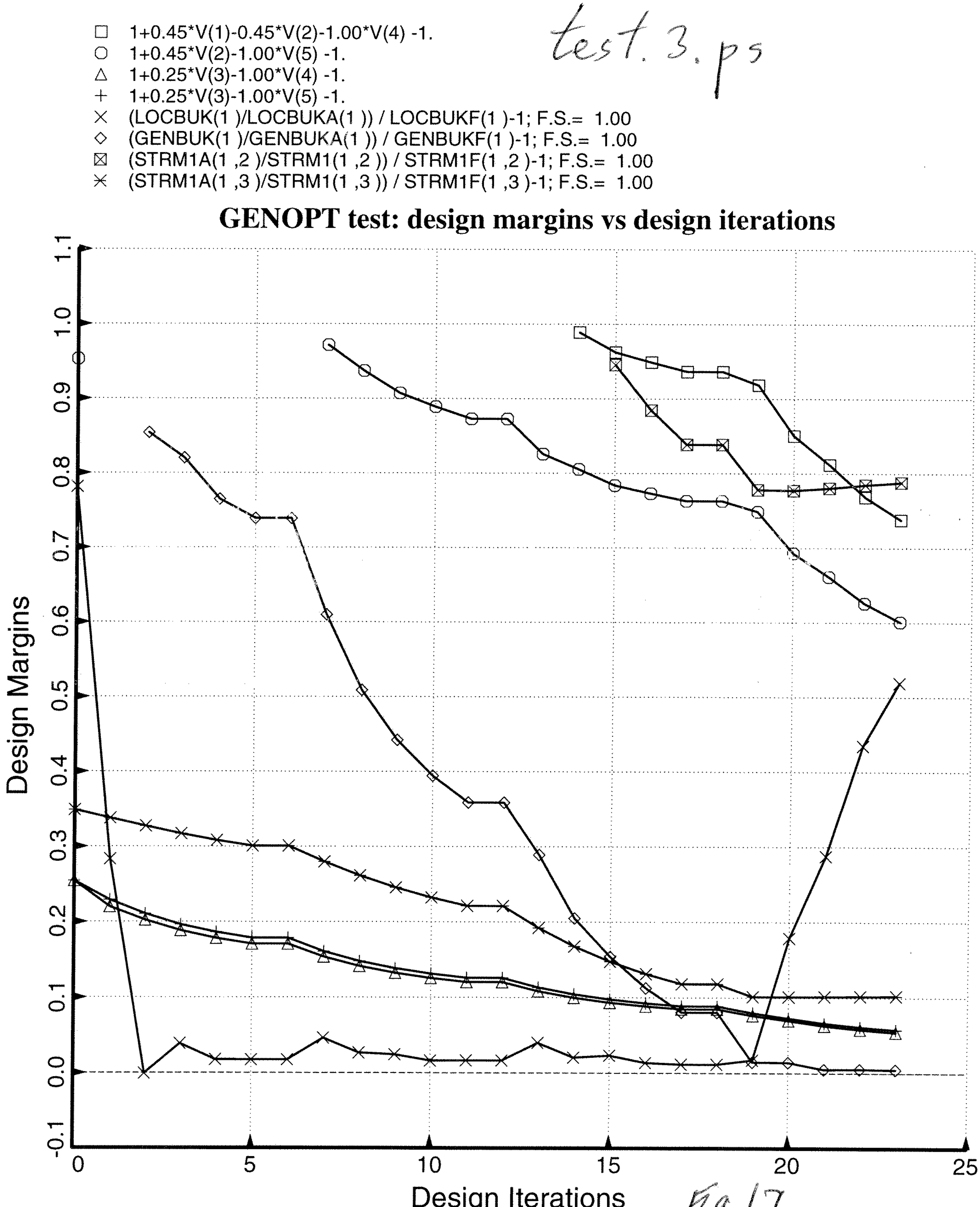
Table 21 test. CPL

```
n        $ Do you want a tutorial session and tutorial output?
y        $ Any design variables to be plotted v. iterations (Y or N)?
  6      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
  7      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
  8      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
  9      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
 10      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
 11      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y        $ Any more design variables to be plotted (Y or N) ?
 12      $ Choose a variable to be plotted v. iterations (1,2,3,..)
n        $ Any more design variables to be plotted (Y or N) ?
y        $ Any design margins to be plotted v. iterations (Y or N)?
  2      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  3      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  4      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  5      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  7      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  8      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  9      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
 10      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
 11      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
 12      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
 13      $ Choose a margin to be plotted v. iterations (1,2,3,..)
n        $ Any more margins to be plotted (Y or N) ?
  1      $ Give maximum value (positive) to be included in plot frame.
```

Input for CHOOSEPLOT.
This input leads to Figs 17-19

All Factors of Safety = 1.0

test.3.ps



152 Fig. 17

All factors of safety = 1.0

test.4.ps

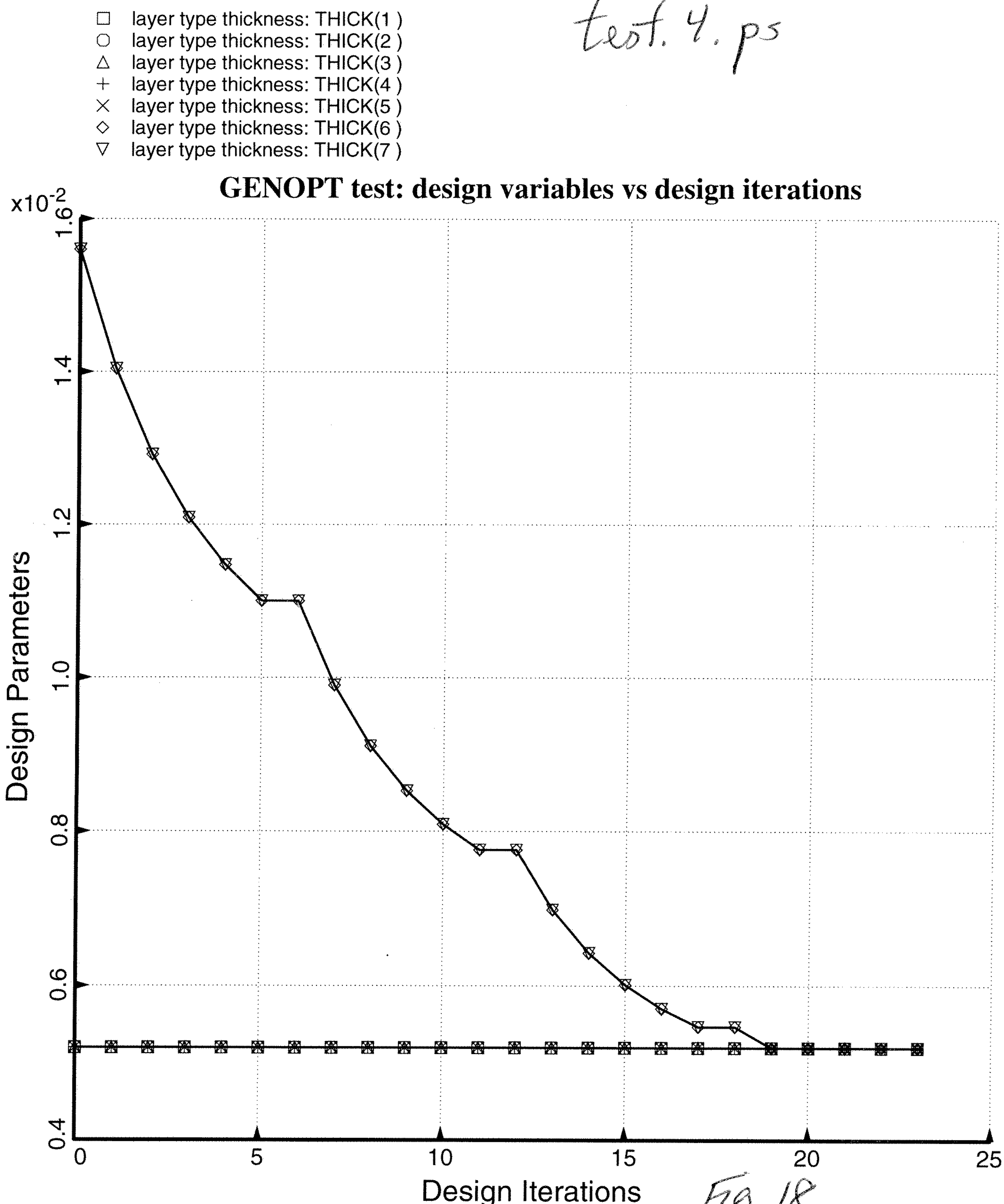


Fig. 18

All factors of safety = 1.0

test. 5. ps

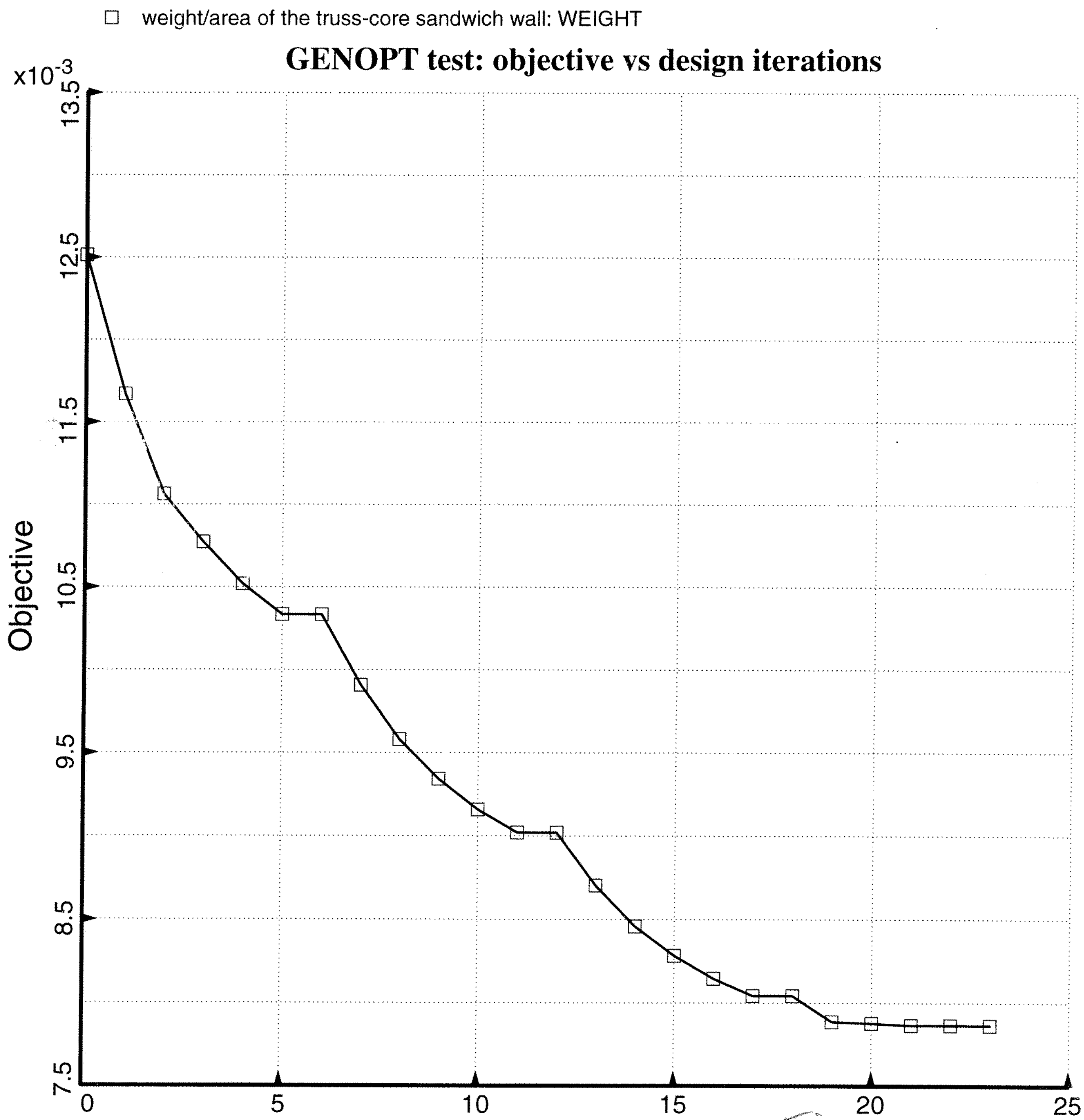


Fig. 19

Table 22 test.CPL

```
n          $ Do you want a tutorial session and tutorial output?
y          $ Any design variables to be plotted v. iterations (Y or N)?
   1       $ Choose a variable to be plotted v. iterations (1,2,3,..)
y          $ Any more design variables to be plotted (Y or N) ?
   2       $ Choose a variable to be plotted v. iterations (1,2,3,..)
n          $ Any more design variables to be plotted (Y or N) ?
n          $ Any design margins to be plotted v. iterations (Y or N)?
```

Input for CHOOSEPLOT
leads to Fig. 20

All factors of safety = 1.0

test.4.ps

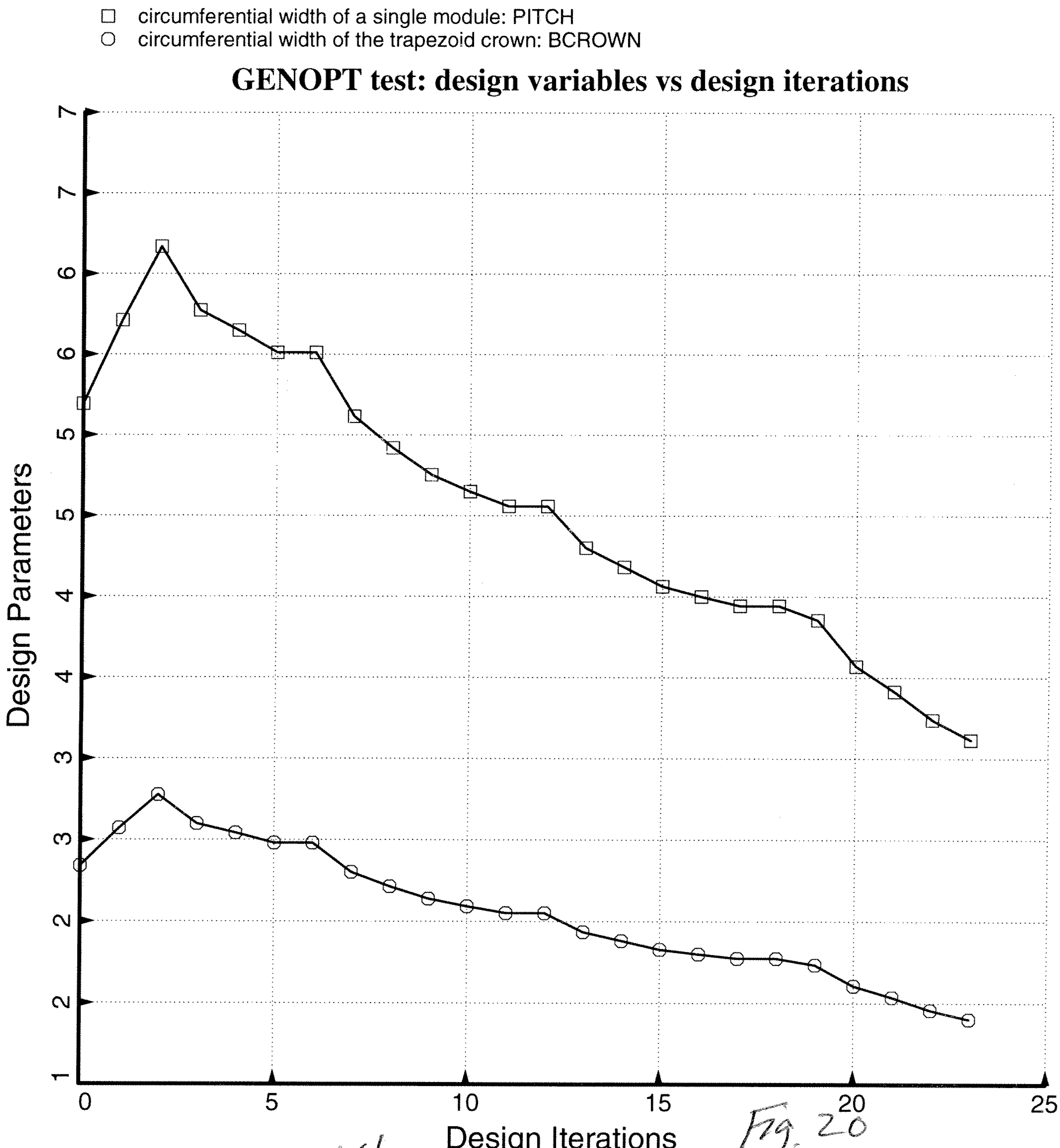


Fig. 20

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Table 23

test. CPL

```
n          $ Do you want a tutorial session and tutorial output?
y          $ Any design variables to be plotted v. iterations (Y or N)?
  3        $ Choose a variable to be plotted v. iterations (1,2,3,..)
n          $ Any more design variables to be plotted (Y or N) ?
n          $ Any design margins to be plotted v. iterations (Y or N)?
```

Input for CHOOSEPLOT leads to Fig 21

ALL factors of safety = 1.0

test.4.ps

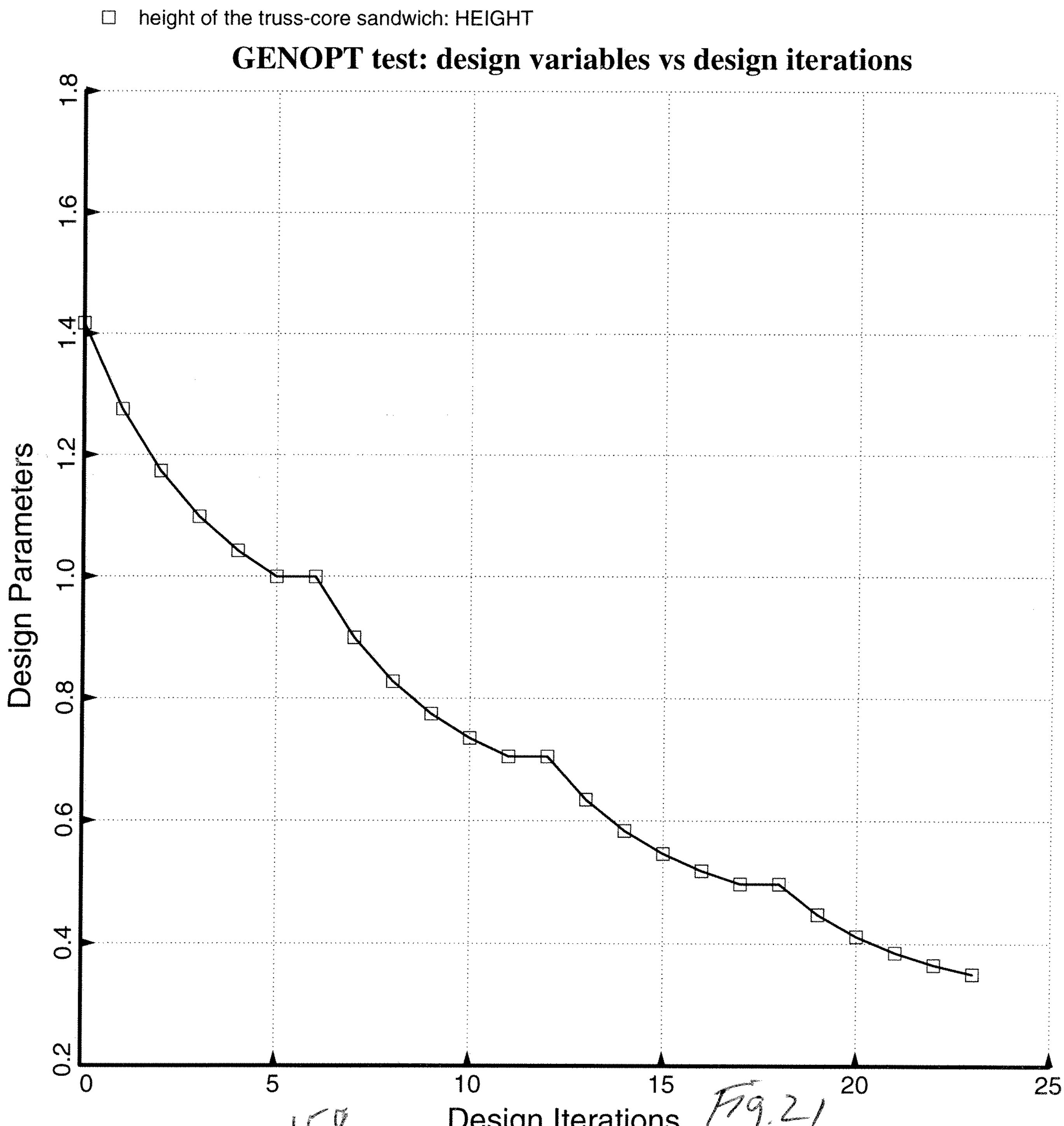

Fig. 21

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Table 24

test. CPL

```
n         $ Do you want a tutorial session and tutorial output?
y         $ Any design variables to be plotted v. iterations (Y or N)?
   4      $ Choose a variable to be plotted v. iterations (1,2,3,..)
y         $ Any more design variables to be plotted (Y or N) ?
   5      $ Choose a variable to be plotted v. iterations (1,2,3,..)
n         $ Any more design variables to be plotted (Y or N) ?
n         $ Any design margins to be plotted v. iterations (Y or N)?
```

Input for CHOOSEPLOT
leads to Fig. 22

All factors of safety = 1.0

test. 4. ps

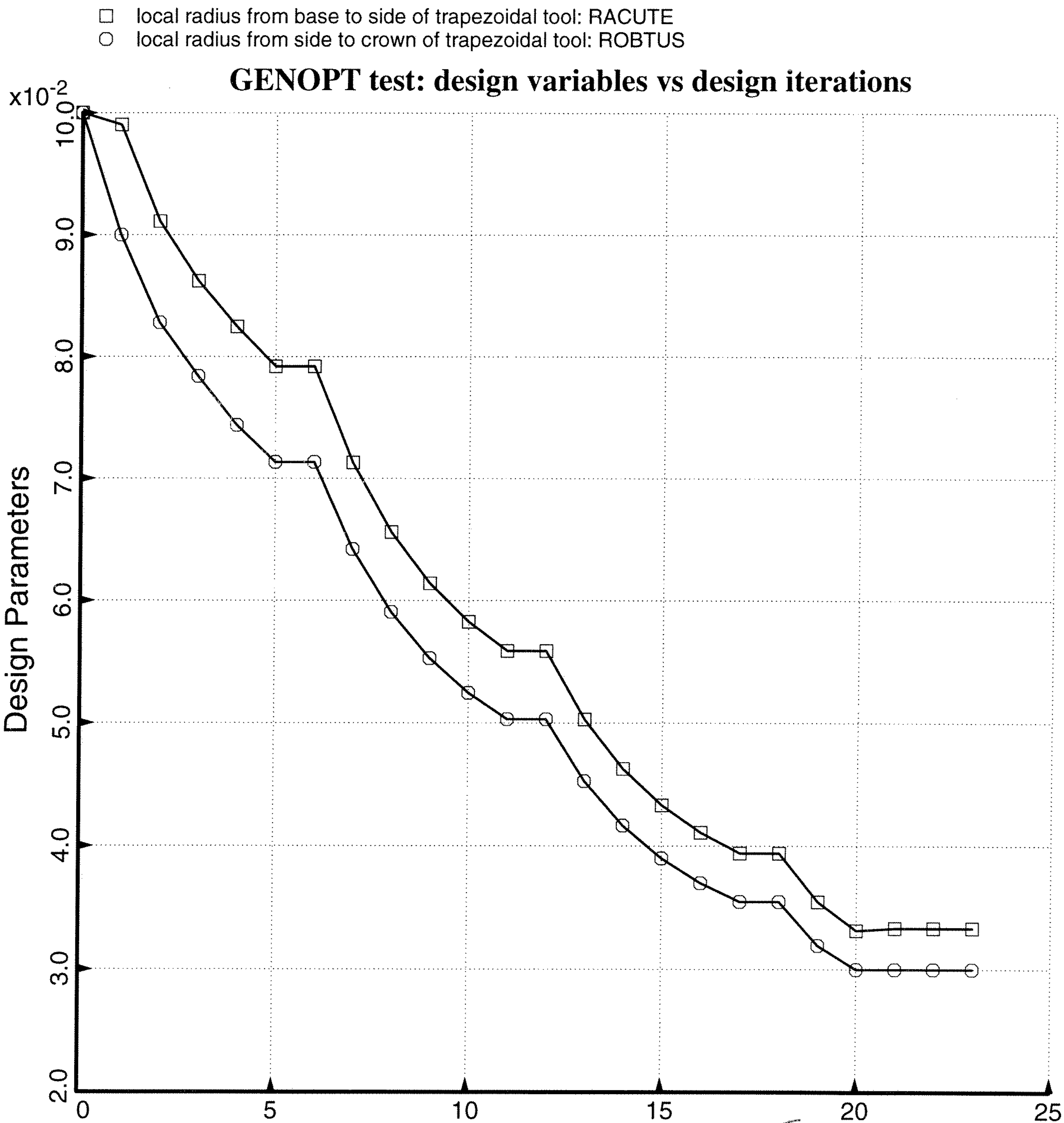


Fig. 22

Table 25 test.OPM (4 pages)

Output from "OPTIMIZE" All factors of safety = 1.0

```
test.OPM for optimum design found after a SUPEROPT run in which the
run was terminated on purpose after about 6 hours on my LINUX computer.
=====================================================================
      n         $ Do you want a tutorial session and tutorial output?
         0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
         2      $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
         2      $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
         5      $ How many design iterations in this run (3 to 25)?
      n         $ Take "shortcuts" for perturbed designs (Y or N)?
         2      $ Choose 1 or 2 or 3 or 4 or 5 for IDESIGN
         1      $ Choose 1 or 2 or 3 or 4 or 5 for move limits, IMOVE
      y         $ Do you want default (RATIO=10) for initial move limit jump?
      y         $ Do you want the default perturbation (dx/x = 0.05)?
      n         $ Do you want to have dx/x modified by GENOPT?
      n         $ Do you want to reset total iterations to zero (Type H)?

 ************ END OF THE  test.OPT  FILE ***********
 ************ JUNE, 2009 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  test.OPM  FILE *********


 *********************** MAIN PROCESSOR **********************
 The purpose of the mainprocessor, OPTIMIZE, is to perform,
 in a batch mode, the work specified by MAINSETUP for the case
 called test.  Results are stored in the file  test.OPM.
 Please inspect test.OPM before doing more design iterations.
 ***********************************************************


 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
```

VAR. NO.	DEC. VAR.	ESCAPE VAR.	LINK. VAR.	LINKED TO	LINKING CONSTANT	LOWER BOUND	CURRENT VALUE	UPPER BOUND	DEFINITION
1	Y	N	N	0	0.00E+00	2.00E+00	3.1158E+00	1.00E+01	circumferential width of» a single module: PITCH
2	Y	N	N	0	0.00E+00	1.00E+00	1.4021E+00	5.00E+00	circumferential width of» the trapezoid crown: BCROWN
3	Y	N	N	0	0.00E+00	3.00E-01	3.5051E-01	2.00E+00	height of the truss-core» sandwich: HEIGHT
4	Y	N	N	0	0.00E+00	3.00E-02	3.3330E-02	3.00E-01	local radius from base t» o side of trapezoidal tool: RACUT
5	Y	N	N	0	0.00E+00	3.00E-02	3.0000E-02	3.00E-01	local radius from side t» o crown of trapezoidal tool: ROBT
6	Y	Y	N	0	0.00E+00	5.20E-03	5.2000E-03	1.56E-02	layer type thickness: TH» ICK(1)
7	N	N	Y	6	1.00E+00	0.00E+00	5.2000E-03	0.00E+00	layer type thickness: TH» ICK(2)
8	Y	Y	N	0	0.00E+00	5.20E-03	5.2000E-03	1.56E-02	layer type thickness: TH» ICK(3)
9	Y	Y	N	0	0.00E+00	5.20E-03	5.2000E-03	1.56E-02	layer type thickness: TH» ICK(4)
10	N	N	Y	9	1.00E+00	0.00E+00	5.2000E-03	0.00E+00	layer type thickness: TH» ICK(5)
11	Y	Y	N	0	0.00E+00	5.20E-03	5.2000E-03	1.56E-02	layer type thickness: TH» ICK(6)
12	Y	Y	N	0	0.00E+00	5.20E-03	5.2000E-03	1.56E-02	layer type thickness: TH» ICK(7)

```
  BEHAVIOR FOR  1 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1
```

Optimum design after a 6-hour (terminated) SUPEROPT run

Table 25 test.OPM (p. 2 of 4)

```
 BIGBOSOR4 input file for: local buckling load
test.BEHX1

 LOCAL BUCKLING LOAD FACTORS AND MODES (BEHX1)
        4.3598E+00( 100)
        3.2431E+00( 200)
        2.7198E+00( 300)
        2.0904E+00( 400)
        1.7450E+00( 500)
        1.5788E+00( 600)
        1.5129E+00( 700)
        1.5085E+00( 800) <- critical local buckling
        1.5457E+00( 900)
 Critical buckling load factor, LOCBUK=  1.5085E+00
 Critical number of circumferential waves, NWVCRT=  800
    1        1.508486      local buckling load factor: LOCBUK(1 )


 BIGBOSOR4 input file for: general buckling load
test.BEHX2

 GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX2)
        1.2862E+00( 100)
        1.1139E+00( 200)
        1.0491E+00( 300)
        1.0120E+00( 400)
        9.9806E-01( 500) <- critical general buckling
 Critical buckling load factor, GENBUK=  9.9806E-01
 Critical number of circumferential waves, NWVCRT=  500
    2       0.9980586      general buckling load factor: GENBUK(1 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX3 (Material type 1):
 0 deg. tension  7.493939E+04
 0 deg. comp.    1.039841E+05
90 deg. tension  7.575509E+03
90 deg. comp.    2.232920E+03
 in-plane shear  8.522260E+03
    3        74939.39      stress component in material 1: STRM1(1 ,1 )
    4        103984.1      stress component in material 1: STRM1(1 ,2 )
    5        7575.509      stress component in material 1: STRM1(1 ,3 )
    6        2232.920      stress component in material 1: STRM1(1 ,4 )
    7        8522.260      stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX4 (Material type 2):
 0 deg. tension  0.000000E+00
 0 deg. comp.    0.000000E+00
90 deg. tension  0.000000E+00
90 deg. comp.    0.000000E+00
 in-plane shear  0.000000E+00
    8       0.1000000E-09  stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10       0.1000000E-09  stress component in material 2: STRM2(1 ,3 )
   11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

 Objective =weight per surface area from OBJECT =  7.865037E-03
 PHI,ALPHA,AREA1,AREA2,RADACU,RADOBT=
  5.7626E-01  9.9453E-01  1.9160E-03  2.3074E-04  5.9330E-02  5.6000E-02

 ***** RESULTS FOR LOAD SET NO.  1  ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)

 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.508E+00    local buckling load factor: LOCBUK(1 )
  2    9.981E-01    general buckling load factor: GENBUK(1 )
  3    7.494E+04    stress component in material 1: STRM1(1 ,1 )
  4    1.040E+05    stress component in material 1: STRM1(1 ,2 )
  5    7.576E+03    stress component in material 1: STRM1(1 ,3 )
  6    2.233E+03    stress component in material 1: STRM1(1 ,4 )
  7    8.522E+03    stress component in material 1: STRM1(1 ,5 )
  8    1.000E-10    stress component in material 2: STRM2(1 ,1 )
  9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10    1.000E-10    stress component in material 2: STRM2(1 ,3 )
```

Table 25 test.opm (p.3 of 4)

```
11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
12    1.000E-10    stress component in material 2: STRM2(1 ,5 )

******* NOTE ******* NOTE ******* NOTE ****** NOTE ******
The phrase, "NOT APPLY", for MARGIN VALUE means that that
particular margin value is exactly zero.
*** END NOTE *** END NOTE *** END NOTE *** END NOTE *****


***** RESULTS FOR LOAD SET NO.  1  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)

MARGIN CURRENT
NO.     VALUE              DEFINITION
 1     9.894E-06  1-1.00*V(2)+0.45*V(1) -1.
 2     7.378E-01  1+0.45*V(1)-0.45*V(2)-1.00*V(4) -1.
 3     6.009E-01  1+0.45*V(2)-1.00*V(5) -1.
 4     5.430E-02  1+0.25*V(3)-1.00*V(4) -1.
 5     5.763E-02  1+0.25*V(3)-1.00*V(5) -1.
 6    -2.980E-06  1-1.00*V(5)+0.90*V(4) -1.
 7     5.085E-01  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.00
 8    -1.941E-03  (GENBUK(1 )/GENBUKA(1 )) / GENBUKF(1 )-1; F.S.=  1.00
 9     1.679E+00  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
10     7.880E-01  (STRM1A(1 ,2 )/STRM1(1 ,2 )) / STRM1F(1 ,2 )-1; F.S.=  1.00
11     1.022E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
12     6.345E+00  (STRM1A(1 ,4 )/STRM1(1 ,4 )) / STRM1F(1 ,4 )-1; F.S.=  1.00
13     1.037E+00  (STRM1A(1 ,5 )/STRM1(1 ,5 )) / STRM1F(1 ,5 )-1; F.S.=  1.00

****************************************************
******************** DESIGN OBJECTIVE *******************
*************                          ***********
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:

VAR.   CURRENT
NO.     VALUE              DEFINITION
 1     7.865E-03  weight/area of the truss-core sandwich wall: WEIGHT

*************                     ************
******************** DESIGN OBJECTIVE *******************
******************************************************
***********  ALL 1 LOAD CASES PROCESSED ***********
******************************************************


PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.

VAR.   CURRENT
NO.     VALUE              DEFINITION
 1     9.600E+01  length of the cylindrical shell: LENGTH
 2     1.000E-01  fraction of LENGTH for local buckling: FACLEN
 3     4.800E+01  radius of the cylindrical shell: RADIUS
 4     1.851E+07  axial modulus of a corner "noodle": ENOODL
 5     5.700E-02  weight density of the "noodle" material: DNOODL
 6     0.000E+00  elastic foam "Winkler" foundation stiffness: EFOUND
 7     0.000E+00  elastic "noodle" Winkler foundation modulus: EFNOOD
 8     1.851E+07  elastic modulus in the fiber direction: EMOD1(1 )
 9     1.640E+06  elastic modulus transverse to fibers: EMOD2(1 )
10     8.706E+05  in-plane shear modulus: G12(1 )
11     8.706E+05  out-of-plane x-z shear modulus: G13(1 )
12     8.706E+05  out-of-plain y-z shear modulus: G23(1 )
13     2.660E-02  minor (small) Poisson ratio: NU(1 )
14     2.500E-07  coef. of thermal expansion along the fibers: ALPHA1(1 )
15     1.620E-05  coef. of thermal expansion transverse to fibers: ALPHA2(1 )
16     2.400E+02  curing temperature difference: TEMCUR(1 )
17     5.700E-02  weight density of material: DENSTY(1 )
18     4.500E+01  layer type layup angle: ANGLE(1 )
19    -4.500E+01  layer type layup angle: ANGLE(2 )
20     9.000E+01  layer type layup angle: ANGLE(3 )
21     4.500E+01  layer type layup angle: ANGLE(4 )
22    -4.500E+01  layer type layup angle: ANGLE(5 )
23     0.000E+00  layer type layup angle: ANGLE(6 )
24     9.000E+01  layer type layup angle: ANGLE(7 )
PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR.   CURRENT
NO.     VALUE              DEFINITION
 1    -1.508E+06  total axial load (2 x pi x r x resultant): PX(1 )
 2     0.000E+00  pressure (negative for external pressure): PRESS(1 )
```

Table 25

test.OPM (p. 4 of 4)

```
  3     0.000E+00  total "Load Set B" load: PX0(1 )
  4     0.000E+00  "Load Set B" pressure (external=negative): PRESS0(1 )
 PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)

 VAR.   CURRENT
 NO.     VALUE              DEFINITION
  1     1.000E+00  allowable for local buckling load factor: LOCBUKA(1 )
  2     1.000E+00  allowable for general buckling load factor: GENBUKA(1 )
  3     2.008E+05  allowable stress in material 1: STRM1A(1 ,1 )
  4     1.859E+05  allowable stress in material 1: STRM1A(1 ,2 )
  5     8.350E+03  allowable stress in material 1: STRM1A(1 ,3 )
  6     1.640E+04  allowable stress in material 1: STRM1A(1 ,4 )
  7     1.736E+04  allowable stress in material 1: STRM1A(1 ,5 )
  8     2.008E+05  allowable for stress in material 2: STRM2A(1 ,1 )
  9     1.859E+05  allowable for stress in material 2: STRM2A(1 ,2 )
 10     8.350E+03  allowable for stress in material 2: STRM2A(1 ,3 )
 11     1.640E+04  allowable for stress in material 2: STRM2A(1 ,4 )
 12     1.736E+04  allowable for stress in material 2: STRM2A(1 ,5 )
 PARAMETERS WHICH ARE FACTORS OF SAFETY

 VAR.   CURRENT
 NO.     VALUE              DEFINITION
  1     1.000E+00  factor of safety for local buckling: LOCBUKF(1 )
  2     1.000E+00  general buckling factor of safety: GENBUKF(1 )
  3     1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,1 )
  4     1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,2 )
  5     1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,3 )
  6     1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,4 )
  7     1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,5 )
  8     1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,1 )
  9     1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,2 )
 10     1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,3 )
 11     1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,4 )
 12     1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,5 )

    6 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED

  1 <1-1.00*V(2)+0.45*V(1)
  1 <1+0.45*V(1)-0.45*V(2)-1.00*V(4)
  1 <1+0.45*V(2)-1.00*V(5)
  1 <1+0.25*V(3)-1.00*V(4)
  1 <1+0.25*V(3)-1.00*V(5)
  1 <1-1.00*V(5)+0.90*V(4)


 DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

 test.NAM = This file contains only the name of the case.
 test.OPM = Output data. Please list this file and inspect
            carefully before proceeding.
 test.OPP = Output file containing evolution of design and
            margins since the beginning of optimization cycles.
 test.CBL = Labelled common blocks for analysis.
            (This is an unformatted sequential file.)
 test.OPT = This file contains the input data for MAINSETUP
             as well as OPTIMIZE. The batch command OPTIMIZE
             can be given over and over again without having
             to return to MAINSETUP because test.OPT exists.
 URPROMPT.DAT= Prompt file for interactive input.

 For further information about files used and generated
 during operation of GENOPT, give the command HELPG FILES.

 Menu of commands: CHOOSEPLOT, OPTIMIZE, MAINSETUP, CHANGE,
                   DECIDE, SUPEROPT

 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  "OPTIMIZE"  MANY TIMES DURING AN OPTIMIZATION AND/OR USE
 THE "GLOBAL" OPTIMIZING SCRIPT, "SUPEROPT".
 ******************** END OF test.OPM FILE ****************
```

End of output from "OPTIMIZE" for fixed (optimum) design
All factors of safety = 1.0

Table 26   test. 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, . .)
 3.115800    $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   2         $ Number of parameter to change (1, 2, 3, . .)
 1.402100    $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   3         $ Number of parameter to change (1, 2, 3, . .)
0.3505100    $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   4         $ Number of parameter to change (1, 2, 3, . .)
0.3333000E-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, . .)
0.3000000E-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, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   7         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   8         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
   9         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
  10         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
  11         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 y           $ Want to change any other parameters in this set?
  12         $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
 n           $ Want to change any other parameters in this set?
 n           $ Do you want to change values of any "fixed" parameters?
 n           $ Do you want to change any loads?
 n           $ Do you want to change values of allowables?
 n           $ Do you want to change any factors of safety?
```

All factors of safety = 1.0

Input for CHANGE

We use "CHANGE" to save the optimum design. This is the optimum obtained with all factors of safety = 1.0, not a good practice in this project because imperfections are not accounted for.

Output from BIGBOSOR4
from the input file, test.BEHX1
All factors of safety = 1.0

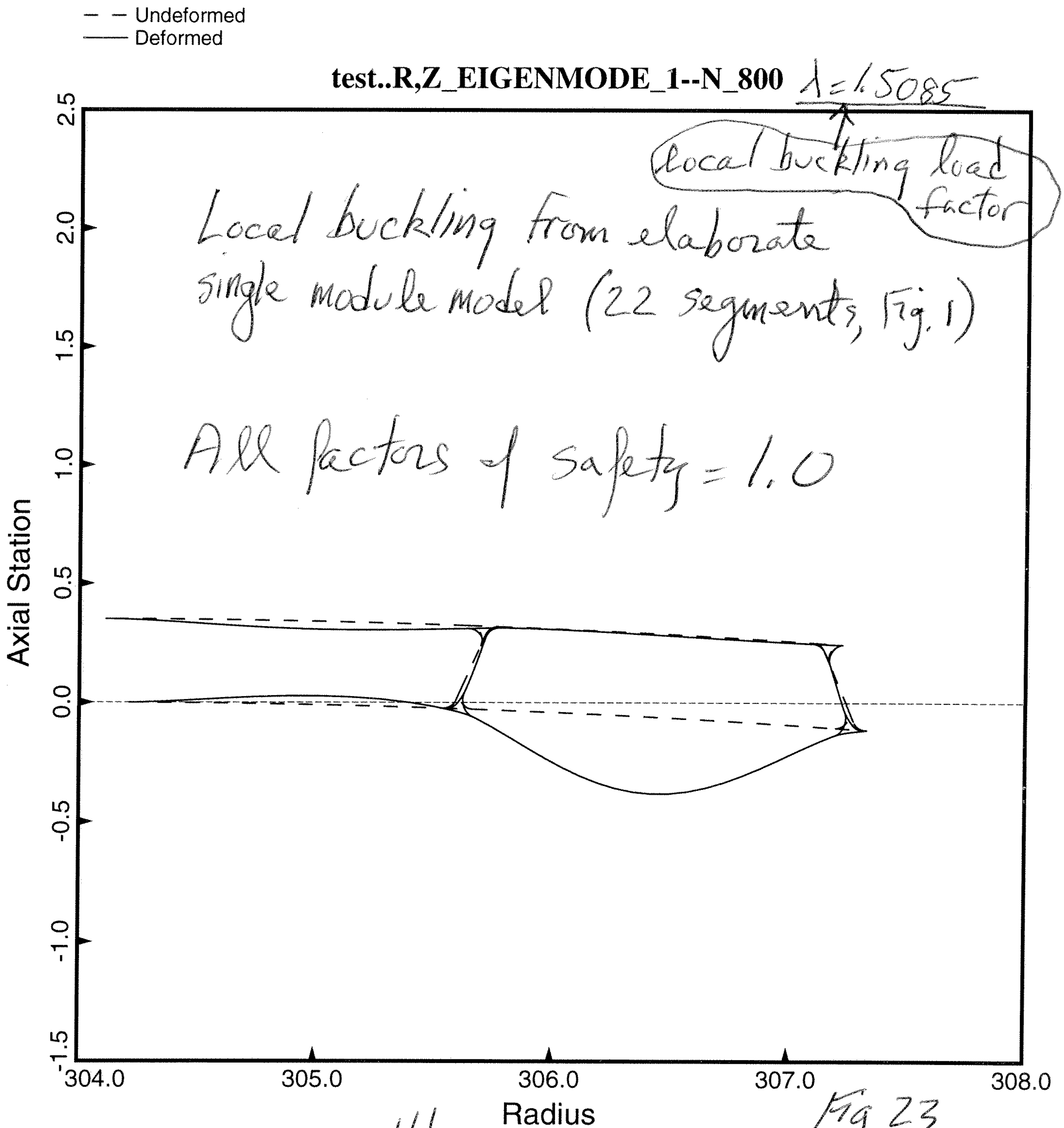
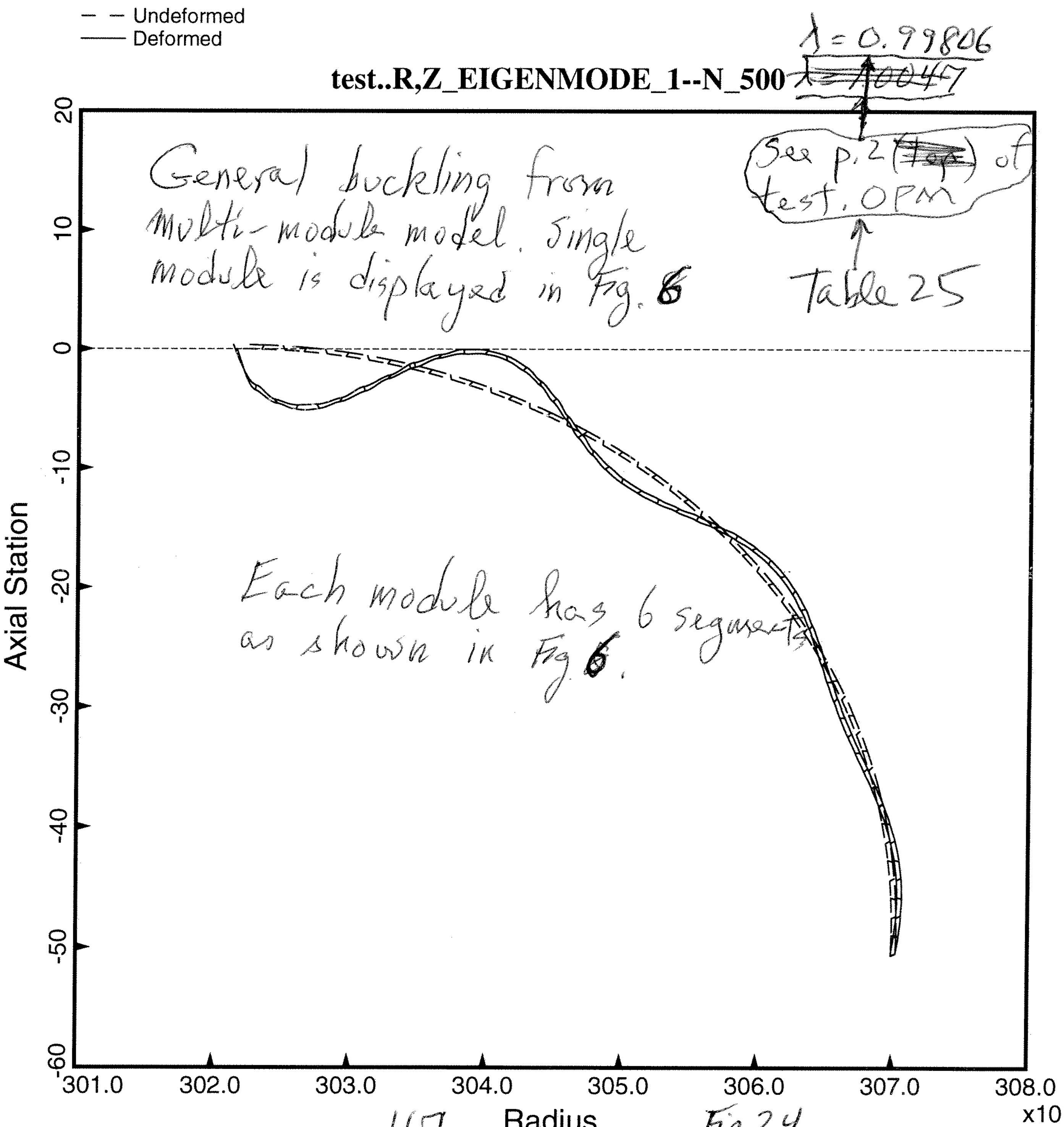


Fig. 23

Output from BIGBOSOR4
from input file, test.BEHX2

All factors of safety = 1.0



167 Fig. 24

Table 27 test.BEG (small part)

The modified part of test.BEG in which the
factors of safety have been increased in order
to compensate for possible initial imperfections.
The GENOPT/BIGBOSOR4 model described in this
report cannot handle initial imperfections
directly. Therefore, factors of safety greater
than unity must be used to compensate for that
lack of capability.

```
===========================================================================
   1.000000     $ allowable for local buckling load factor: LOCBUKA( 1)
   1.500000     $ factor of safety for local buckling: LOCBUKF( 1)
   1.000000     $ allowable for general buckling load factor: GENBUKA( 1)
   2.000000     $ general buckling factor of safety: GENBUKF( 1)
         5      $ Number JSTRM1  of columns in the array, STRM1: JSTRM1
   200798.0     $ allowable stress in material 1: STRM1A( 1, 1)
    185925      $ allowable stress in material 1: STRM1A( 1, 2)
   8350.000     $ allowable stress in material 1: STRM1A( 1, 3)
   16400.00     $ allowable stress in material 1: STRM1A( 1, 4)
   17357.00     $ allowable stress in material 1: STRM1A( 1, 5)
   1.500000     $ factor of safety for stress in material 1: STRM1F( 1, 1)
   1.500000     $ factor of safety for stress in material 1: STRM1F( 1, 2)
   1.100000     $ factor of safety for stress in material 1: STRM1F( 1, 3)
   1.500000     $ factor of safety for stress in material 1: STRM1F( 1, 4)
   1.500000     $ factor of safety for stress in material 1: STRM1F( 1, 5)
===========================================================================
```

Some input for "BEGIN", showing reasonable factors of safety used to compensate for initial imperfections, which cannot be handled directly by the GENOPT/BIGBOSOR4 "huge torus" model.

Output from SUPEROPT, which requires about 3 days on my LINUX computer

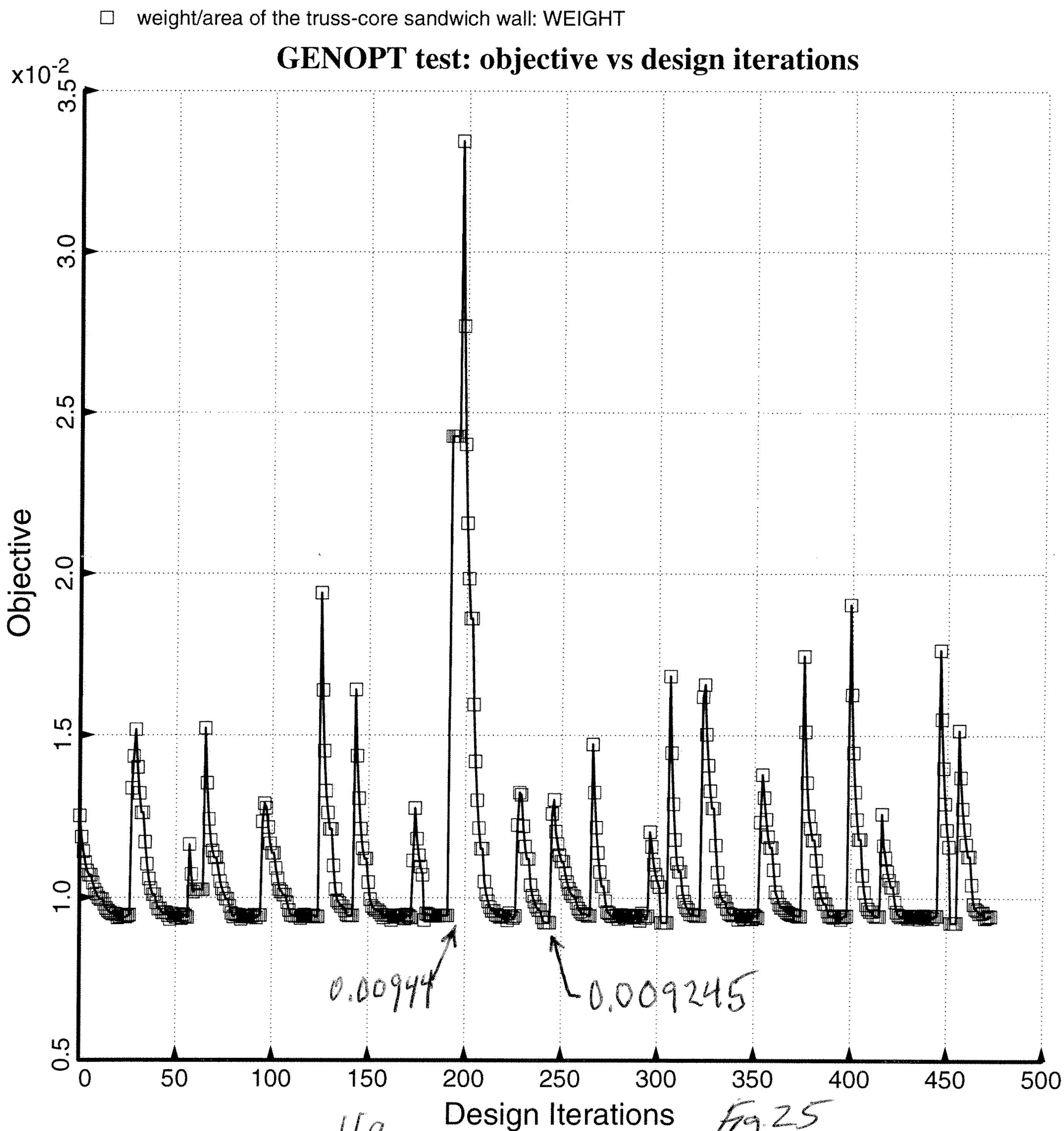


Fig. 25

test.OPM

Table 28 (4 pages) Output from "OPTIMIZE" for the analysis of the fixed optimized design from SUPEROPT

```
test.OPM for case with all factors of safety greater than 1.0. This
is the optimum design after one execution of SUPEROPT
=====================================================================
      n        $ Do you want a tutorial session and tutorial output?
         0     $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
         2     $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
         2     $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
         5     $ How many design iterations in this run (3 to 25)?
      n        $ Take "shortcuts" for perturbed designs (Y or N)?
         2     $ Choose 1 or 2 or 3 or 4 or 5 for IDESIGN
         1     $ Choose 1 or 2 or 3 or 4 or 5 for move limits, IMOVE
      y        $ Do you want default (RATIO=10) for initial move limit jump?
      y        $ Do you want the default perturbation (dx/x = 0.05)?
      n        $ Do you want to have dx/x modified by GENOPT?
      n        $ Do you want to reset total iterations to zero (Type H)?
```

Note →

```
 ************ END OF THE  test.OPT  FILE ***********
 ************ JUNE, 2009 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  test.OPM  FILE *********


 *********************** MAIN PROCESSOR **********************
 The purpose of the mainprocessor, OPTIMIZE, is to perform,
 in a batch mode, the work specified by MAINSETUP for the case
 called test.  Results are stored in the file  test.OPM.
 Please inspect test.OPM before doing more design iterations.
 **************************************************************



 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 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  2.00E+00 2.8106E+00  1.00E+01  circumferential width of»
 a single module: PITCH
   2   Y     N     N      0    0.00E+00  1.00E+00 1.0004E+00  5.00E+00  circumferential width of»
 the trapezoid crown: BCROWN
   3   Y     N     N      0    0.00E+00  3.00E-01 8.8872E-01  2.00E+00  height of the truss-core»
 sandwich: HEIGHT
   4   Y     N     N      0    0.00E+00  3.00E-02 4.3746E-02  3.00E-01  local radius from base t»
o side of trapezoidal tool: RACUT
   5   Y     N     N      0    0.00E+00  3.00E-02 3.9371E-02  3.00E-01  local radius from side t»
o crown of trapezoidal tool: ROBT
   6   Y     N     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(1 )
   7   N     N     Y      6    1.00E+00  0.00E+00 5.2000E-03  0.00E+00  layer type thickness: TH»
ICK(2 )
   8   Y     N     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(3 )
   9   Y     N     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(4 )
  10   N     N     Y      9    1.00E+00  0.00E+00 5.2000E-03  0.00E+00  layer type thickness: TH»
ICK(5 )
  11   Y     Y     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(6 )
  12   Y     Y     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(7 )
  BEHAVIOR FOR  1 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1


 BIGBOSOR4 input file for: local buckling load
test.BEHX1
```

"global" optimum design (factors of safety > 1.0)

Table 28 (P. 2 of 4)

```
 LOCAL BUCKLING LOAD FACTORS AND MODES (BEHX1)
        9.3595E+00( 100)
        4.4118E+00( 200)
        2.6284E+00( 300)
        1.9540E+00( 400)
        1.6638E+00( 500)
        1.5419E+00( 600)
        1.5094E+00( 700)  <- critical local buckling
        1.5322E+00( 800)
        1.5936E+00( 900)
 Critical buckling load factor, LOCBUK=  1.5094E+00
 Critical number of circumferential waves, NWVCRT=  700
    1        1.509426      local buckling load factor: LOCBUK(1 )


 BIGBOSOR4 input file for: general buckling load
test.BEHX2

 GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX2)
        2.5384E+00( 100)
        2.0644E+00( 200)
        2.0048E+00( 300)  <- critical general buckling
        2.1052E+00( 400)
        2.2525E+00( 500)
 Critical buckling load factor, GENBUK=  2.0048E+00
 Critical number of circumferential waves, NWVCRT=  300
    2        2.004798      general buckling load factor: GENBUK(1 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX3 (Material type 1):
 0 deg. tension  6.665335E+04
 0 deg. comp.    9.164739E+04
90 deg. tension  7.446640E+03
90 deg. comp.    1.231269E+03
 in-plane shear  7.539983E+03
    3        66653.35      stress component in material 1: STRM1(1 ,1 )
    4        91647.39      stress component in material 1: STRM1(1 ,2 )
    5        7446.640      stress component in material 1: STRM1(1 ,3 )
    6        1231.269      stress component in material 1: STRM1(1 ,4 )
    7        7539.983      stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  number of stress constraints

 Maximum stress components from BEHX4 (Material type 2):
 0 deg. tension  0.000000E+00
 0 deg. comp.    0.000000E+00
90 deg. tension  0.000000E+00
90 deg. comp.    0.000000E+00
 in-plane shear  0.000000E+00
    8      0.1000000E-09  stress component in material 2: STRM2(1 ,1 )
    9      0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10      0.1000000E-09  stress component in material 2: STRM2(1 ,3 )
   11      0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12      0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

 Objective =weight per surface area from OBJECT =  9.244974E-03
 PHI,ALPHA,AREA1,AREA2,RADACU,RADOBT=
  5.7166E-01  9.9914E-01  2.7014E-03  3.0620E-04  6.9746E-02  6.5371E-02

 ***** RESULTS FOR LOAD SET NO.  1  ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)

 BEH.   CURRENT
 NO.     VALUE           DEFINITION
  1     1.509E+00    local buckling load factor: LOCBUK(1 )
  2     2.005E+00    general buckling load factor: GENBUK(1 )
  3     6.665E+04    stress component in material 1: STRM1(1 ,1 )
  4     9.165E+04    stress component in material 1: STRM1(1 ,2 )
  5     7.447E+03    stress component in material 1: STRM1(1 ,3 )
  6     1.231E+03    stress component in material 1: STRM1(1 ,4 )
  7     7.540E+03    stress component in material 1: STRM1(1 ,5 )
  8     1.000E-10    stress component in material 2: STRM2(1 ,1 )
  9     1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10     1.000E-10    stress component in material 2: STRM2(1 ,3 )
 11     1.000E-10    stress component in material 2: STRM2(1 ,4 )
 12     1.000E-10    stress component in material 2: STRM2(1 ,5 )
```

Table 28 (p. 3 of 4)

```
******* NOTE ******* NOTE ******* NOTE ****** NOTE ******
The phrase, "NOT APPLY", for MARGIN VALUE means that that
particular margin value is exactly zero.
*** END NOTE *** END NOTE *** END NOTE *** END NOTE *****


***** RESULTS FOR LOAD SET NO.  1  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)

MARGIN CURRENT
NO.     VALUE            DEFINITION
 1    2.643E-01  1-1.00*V(2)+0.45*V(1) -1.
 2    7.708E-01  1+0.45*V(1)-0.45*V(2)-1.00*V(4) -1.
 3    4.108E-01  1+0.45*V(2)-1.00*V(5) -1.
 4    1.784E-01  1+0.25*V(3)-1.00*V(4) -1.
 5    1.828E-01  1+0.25*V(3)-1.00*V(5) -1.
 6    NOT APPLY  1-1.00*V(5)+0.90*V(4) -1.
 7    6.284E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.50
 8    2.399E-03  (GENBUK(1 )/GENBUKA(1 )) / GENBUKF(1 )-1; F.S.=  2.00
 9    1.008E+00  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.50
10    3.525E-01  (STRM1A(1 ,2 )/STRM1(1 ,2 )) / STRM1F(1 ,2 )-1; F.S.=  1.50
11    1.937E-02  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.10
12    7.880E+00  (STRM1A(1 ,4 )/STRM1(1 ,4 )) / STRM1F(1 ,4 )-1; F.S.=  1.50
13    5.347E-01  (STRM1A(1 ,5 )/STRM1(1 ,5 )) / STRM1F(1 ,5 )-1; F.S.=  1.50
```

Critical margins

This is from curing

```
****************************************************
******************** DESIGN OBJECTIVE *******************
*************                           ***********
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    9.245E-03  weight/area of the truss-core sandwich wall: WEIGHT

*************                       ************
******************** DESIGN OBJECTIVE *******************
****************************************************
***********  ALL 1 LOAD CASES PROCESSED ***********
****************************************************
```

"global" optimum design

```
PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    9.600E+01  length of the cylindrical shell: LENGTH
 2    1.000E-01  fraction of LENGTH for local buckling: FACLEN
 3    4.800E+01  radius of the cylindrical shell: RADIUS
 4    1.851E+07  axial modulus of a corner "noodle": ENOODL
 5    5.700E-02  weight density of the "noodle" material: DNOODL
 6    0.000E+00  elastic foam "Winkler" foundation stiffness: EFOUND
 7    0.000E+00  elastic "noodle" Winkler foundation modulus: EFNOOD
 8    1.851E+07  elastic modulus in the fiber direction: EMOD1(1 )
 9    1.640E+06  elastic modulus transverse to fibers: EMOD2(1 )
10    8.706E+05  in-plane shear modulus: G12(1 )
11    8.706E+05  out-of-plane x-z shear modulus: G13(1 )
12    8.706E+05  out-of-plain y-z shear modulus: G23(1 )
13    2.660E-02  minor (small) Poisson ratio: NU(1 )
14    2.500E-07  coef. of thermal expansion along the fibers: ALPHA1(1 )
15    1.620E-05  coef. of thermal expansion transverse to fibers: ALPHA2(1 )
16    2.400E+02  curing temperature difference: TEMCUR(1 )
17    5.700E-02  weight density of material: DENSTY(1 )
18    4.500E+01  layer type layup angle: ANGLE(1 )
19   -4.500E+01  layer type layup angle: ANGLE(2 )
20    9.000E+01  layer type layup angle: ANGLE(3 )
21    4.500E+01  layer type layup angle: ANGLE(4 )
22   -4.500E+01  layer type layup angle: ANGLE(5 )
23    0.000E+00  layer type layup angle: ANGLE(6 )
24    9.000E+01  layer type layup angle: ANGLE(7 )
PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1   -1.508E+06  total axial load (2 x pi x r x resultant): PX(1 )
 2    0.000E+00  pressure (negative for external pressure): PRESS(1 )
 3    0.000E+00  total "Load Set B" load: PX0(1 )
 4    0.000E+00  "Load Set B" pressure (external=negative): PRESS0(1 )
```

Table 28 (p.4 of 4)

PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.000E+00	allowable for local buckling load factor: LOCBUKA(1)
2	1.000E+00	allowable for general buckling load factor: GENBUKA(1)
3	2.008E+05	allowable stress in material 1: STRM1A(1 ,1)
4	1.859E+05	allowable stress in material 1: STRM1A(1 ,2)
5	8.350E+03	allowable stress in material 1: STRM1A(1 ,3)
6	1.640E+04	allowable stress in material 1: STRM1A(1 ,4)
7	1.736E+04	allowable stress in material 1: STRM1A(1 ,5)
8	2.008E+05	allowable for stress in material 2: STRM2A(1 ,1)
9	1.859E+05	allowable for stress in material 2: STRM2A(1 ,2)
10	8.350E+03	allowable for stress in material 2: STRM2A(1 ,3)
11	1.640E+04	allowable for stress in material 2: STRM2A(1 ,4)
12	1.736E+04	allowable for stress in material 2: STRM2A(1 ,5)

PARAMETERS WHICH ARE FACTORS OF SAFETY

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.500E+00	factor of safety for local buckling: LOCBUKF(1)
2	2.000E+00	general buckling factor of safety: GENBUKF(1)
3	1.500E+00	factor of safety for stress in material 1: STRM1F(1 ,1)
4	1.500E+00	factor of safety for stress in material 1: STRM1F(1 ,2)
5	1.100E+00	factor of safety for stress in material 1: STRM1F(1 ,3)
6	1.500E+00	factor of safety for stress in material 1: STRM1F(1 ,4)
7	1.500E+00	factor of safety for stress in material 1: STRM1F(1 ,5)
8	1.000E+00	factor of safety for stress in material 2: STRM2F(1 ,1)
9	1.000E+00	factor of safety for stress in material 2: STRM2F(1 ,2)
10	1.000E+00	factor of safety for stress in material 2: STRM2F(1 ,3)
11	1.000E+00	factor of safety for stress in material 2: STRM2F(1 ,4)
12	1.000E+00	factor of safety for stress in material 2: STRM2F(1 ,5)

6 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED

```
1 <1-1.00*V(2)+0.45*V(1)
1 <1+0.45*V(1)-0.45*V(2)-1.00*V(4)
1 <1+0.45*V(2)-1.00*V(5)
1 <1+0.25*V(3)-1.00*V(4)
1 <1+0.25*V(3)-1.00*V(5)
1 <1-1.00*V(5)+0.90*V(4)
```

DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

```
test.NAM = This file contains only the name of the case.
test.OPM = Output data. Please list this file and inspect
           carefully before proceeding.
test.OPP = Output file containing evolution of design and
           margins since the beginning of optimization cycles.
test.CBL = Labelled common blocks for analysis.
           (This is an unformatted sequential file.)
test.OPT = This file contains the input data for MAINSETUP
            as well as OPTIMIZE. The batch command OPTIMIZE
            can be given over and over again without having
            to return to MAINSETUP because test.OPT exists.
URPROMPT.DAT= Prompt file for interactive input.
```

For further information about files used and generated during operation of GENOPT, give the command HELPG FILES.

Menu of commands: CHOOSEPLOT, OPTIMIZE, MAINSETUP, CHANGE, DECIDE, SUPEROPT

IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO RUN "OPTIMIZE" MANY TIMES DURING AN OPTIMIZATION AND/OR USE THE "GLOBAL" OPTIMIZING SCRIPT, "SUPEROPT".

******************** END OF test.OPM FILE ****************

End of test.OPM for the fixed optimized design with all factors of safety greater than 1.0 (as in Table 27)

Table 29 input for "CHANGE", test.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, . .)
 2.810600      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       2       $ Number of parameter to change (1, 2, 3, . .)
 1.000400      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       3       $ Number of parameter to change (1, 2, 3, . .)
0.8887200      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       4       $ Number of parameter to change (1, 2, 3, . .)
0.4374600E-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, . .)
0.3937100E-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, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       7       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       8       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       9       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      10       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      11       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      12       $ Number of parameter to change (1, 2, 3, . .)
0.5200000E-02 $ New value of the parameter
    n          $ Want to change any other parameters in this set?
    n          $ Do you want to change values of any "fixed" parameters?
    n          $ Do you want to change any loads?
    n          $ Do you want to change values of allowables?
    n          $ Do you want to change any factors of safety?
```

Input data for "CHANGE", used as a means to save the optimum design.

(Factors of safety are all greater than 1.0, as in Table 27)

Output from BIGBOSOR4
for local buckling
(test.BEHX1 is the input
for BIGBOSOR4)

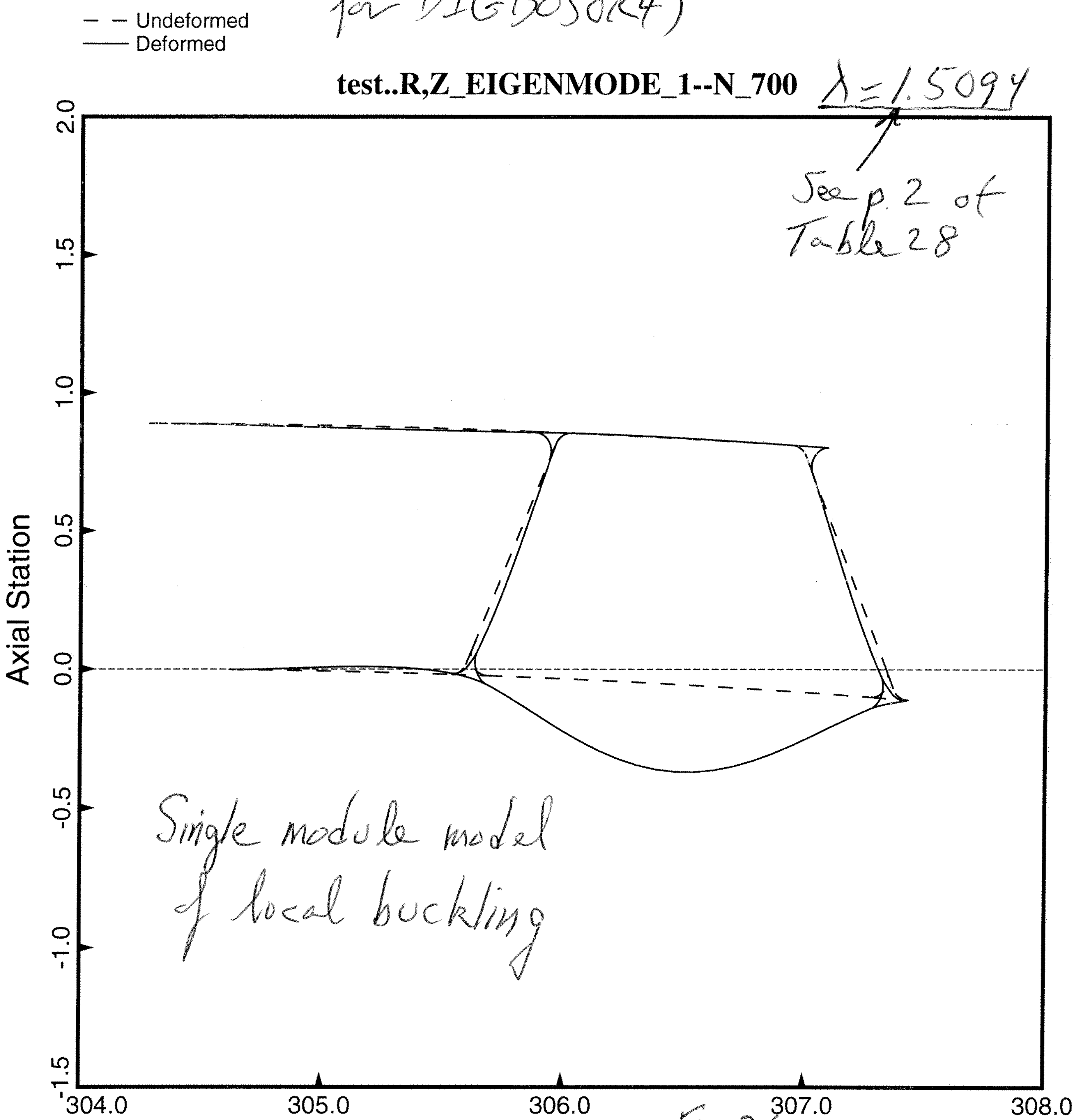
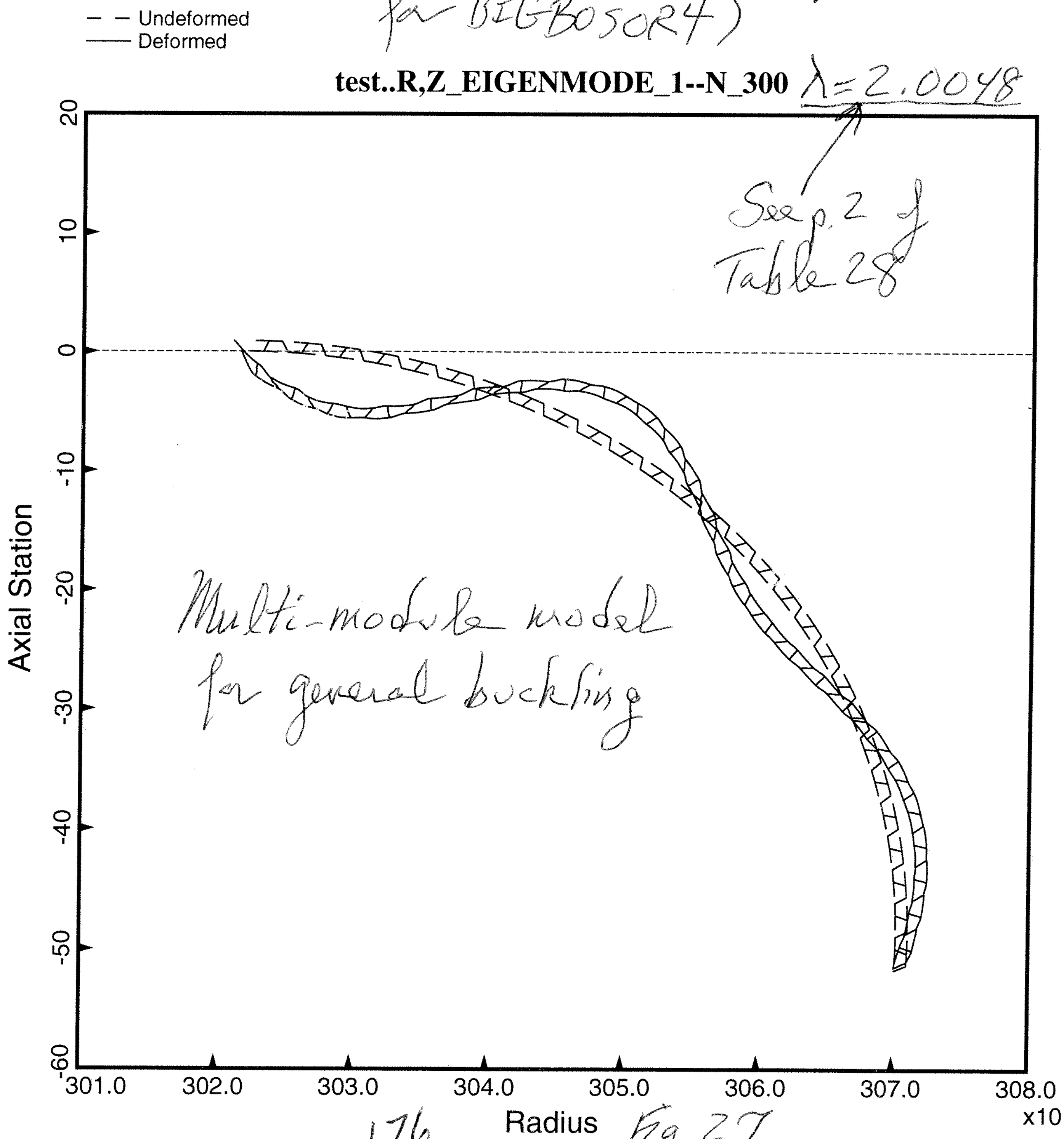


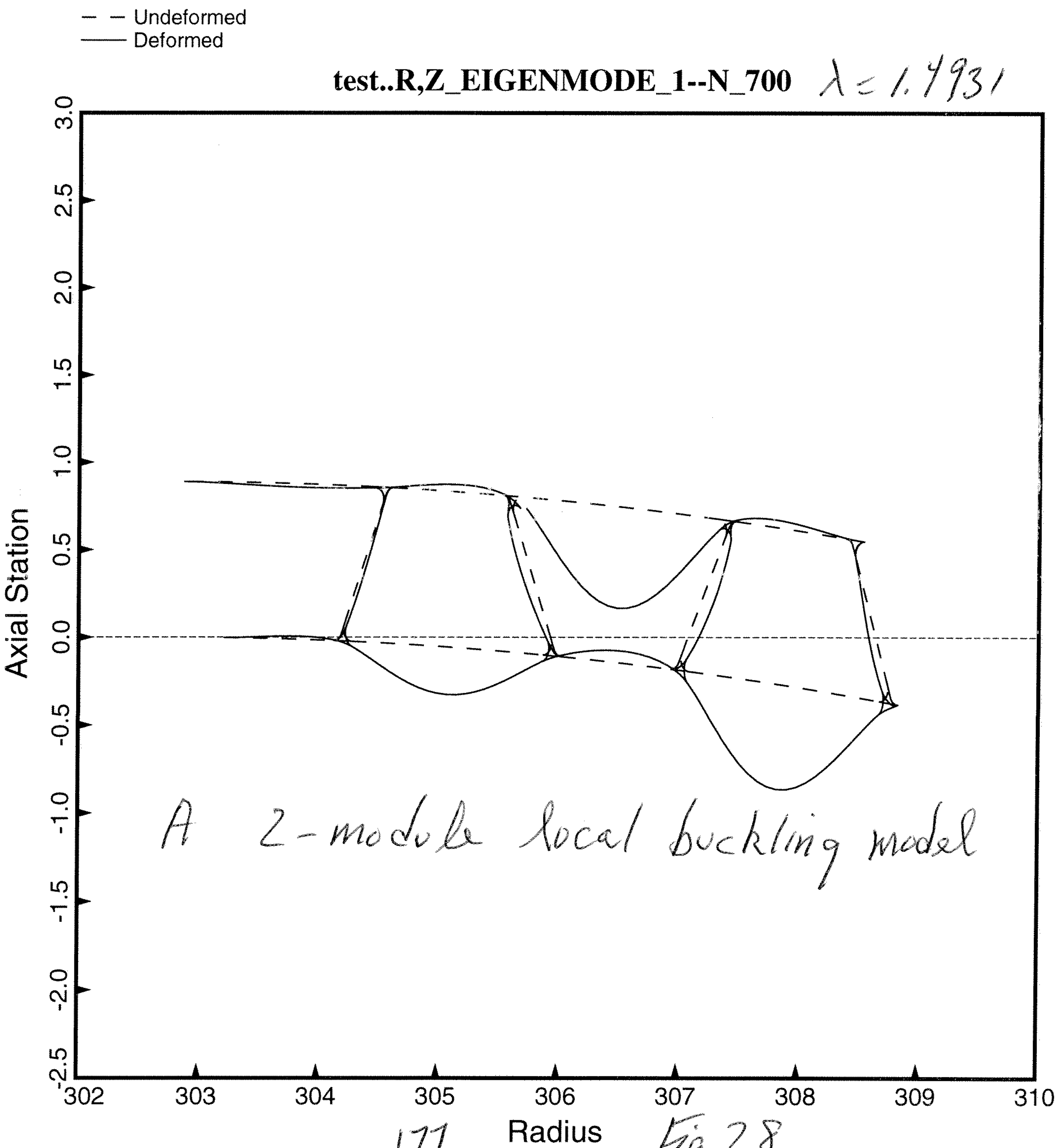
Fig. 26

Output from BIGBOSOR4 for general buckling (test. BEHX2 is the input for BIGBOSOR4)



176 Fig. 27

Output from BIGBOSOR4
for local buckling



177 Fig. 28

Output from BIGBOSOR4
for local buckling

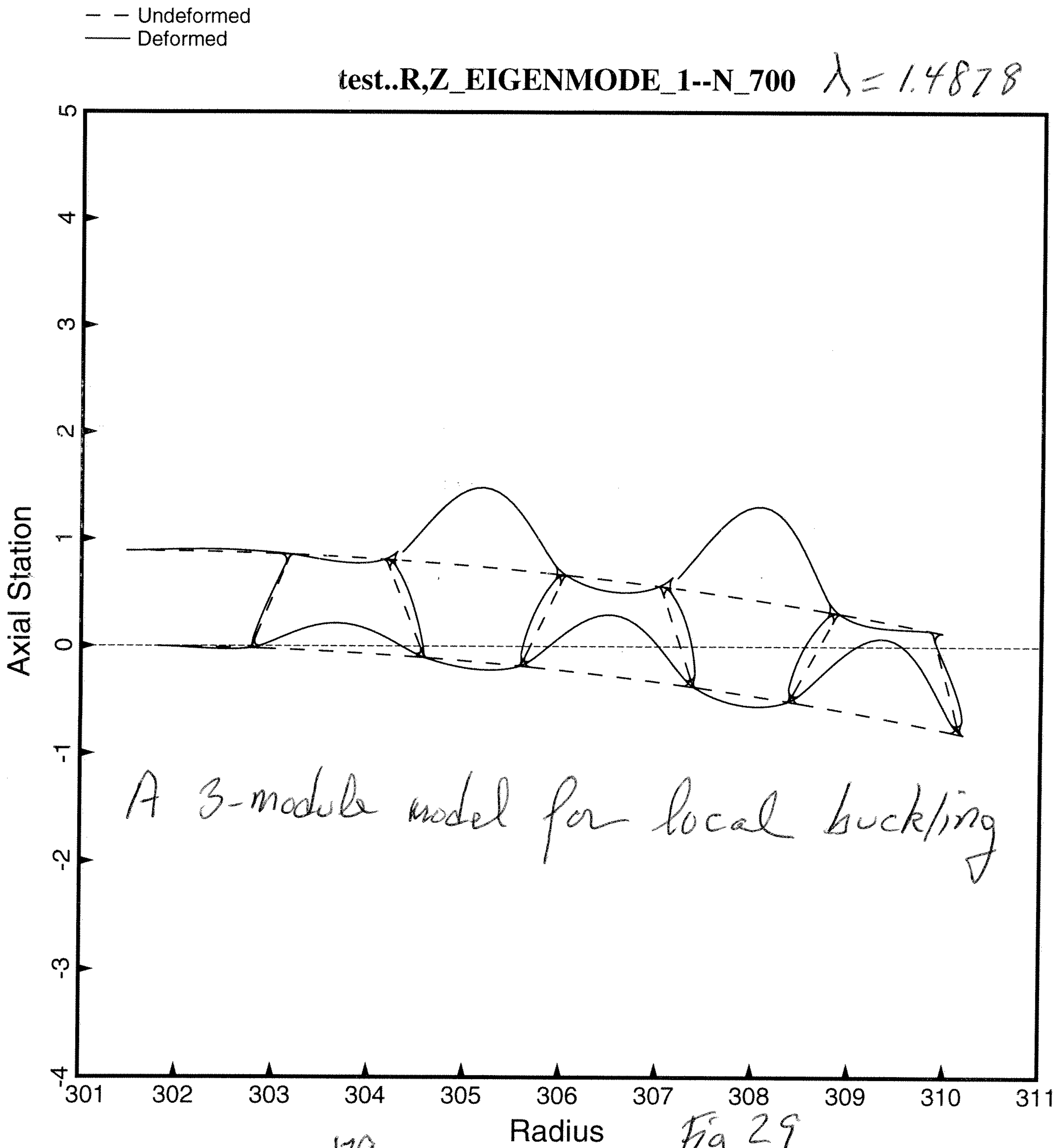


Fig. 29

Output from BIGBOSOR4
for local buckling

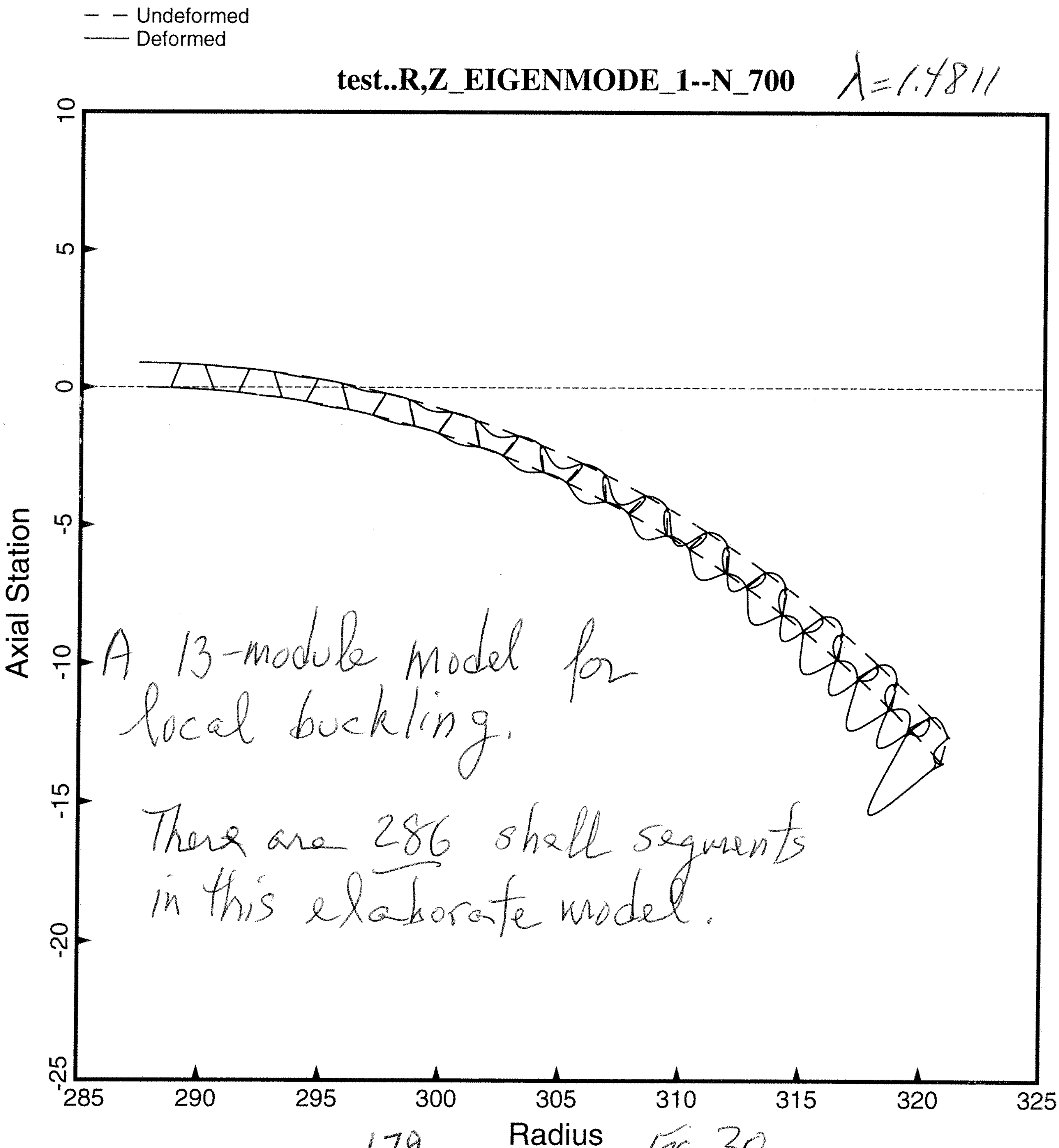


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Fig. 30

Table 3D test.OPM

test.OPM file (abridged) for another somewhat heavier optimum design

```
A somewhat heavier "optimum" design that SUPEROPT often converges to:
 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.    0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 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  2.00E+00 3.3496E+00  1.00E+01  circumferential width of»
 a single module: PITCH
   2   Y     N     N      0    0.00E+00  1.00E+00 1.5073E+00  5.00E+00  circumferential width of»
 the trapezoid crown: BCROWN
   3   Y     N     N      0    0.00E+00  3.00E-01 1.2175E+00  2.00E+00  height of the truss-core»
 sandwich: HEIGHT
   4   Y     N     N      0    0.00E+00  3.00E-02 3.3464E-02  3.00E-01  local radius from base t»
o side of trapezoidal tool: RACUT
   5   Y     N     N      0    0.00E+00  3.00E-02 3.0117E-02  3.00E-01  local radius from side t»
o crown of trapezoidal tool: ROBT
   6   Y     N     N      0    0.00E+00  5.20E-03 5.2875E-03  1.56E-02  layer type thickness: TH»
ICK(1 )
   7   N     N     Y      6    1.00E+00  0.00E+00 5.2875E-03  0.00E+00  layer type thickness: TH»
ICK(2 )
   8   Y     N     N      0    0.00E+00  5.20E-03 5.4151E-03  1.56E-02  layer type thickness: TH»
ICK(3 )
   9   Y     N     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(4 )
  10   N     N     Y      9    1.00E+00  0.00E+00 5.2000E-03  0.00E+00  layer type thickness: TH»
ICK(5 )
  11   Y     Y     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(6 )
  12   Y     Y     N      0    0.00E+00  5.20E-03 5.2000E-03  1.56E-02  layer type thickness: TH»
ICK(7 )
 LOCAL BUCKLING LOAD FACTORS AND MODES (BEHX1)
        1.2214E+01( 100)
        5.0188E+00( 200)
        2.7858E+00( 300)
        2.0054E+00( 400)
        1.6752E+00( 500)
        1.5337E+00( 600)
        1.4395E+00( 700) ← critical local buckling, local optimum design
        1.5041E+00( 800)
        1.5591E+00( 900)
 Critical buckling load factor, LOCBUK=  1.4895E+00
 Critical number of circumferential waves, NWVCRT=  700

 GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX2)
        2.0230E+00( 100)
        1.9740E+00( 200) ← critical general buckling, local optimum design
        2.1708E+00( 300)
        2.5074E+00( 400)
        2.8903E+00( 500)
 Critical buckling load factor, GENBUK=  1.9740E+00
 Critical number of circumferential waves, NWVCRT=  200

 ***** RESULTS FOR LOAD SET NO.  1  ******
 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)

 MARGIN CURRENT
 NO.     VALUE             DEFINITION
  1    2.003E-05  1-1.00*V(2)+0.45*V(1) -1.
  2    7.956E-01  1+0.45*V(1)-0.45*V(2)-1.00*V(4) -1.
  3    6.482E-01  1+0.45*V(2)-1.00*V(5) -1.
  4    2.709E-01  1+0.25*V(3)-1.00*V(4) -1.
  5    2.743E-01  1+0.25*V(3)-1.00*V(5) -1.
  6    5.960E-07  1-1.00*V(5)+0.90*V(4) -1.
  7   -6.983E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.50
  8   -1.302E-02  (GENBUK(1 )/GENBUKA(1 )) / GENBUKF(1 )-1; F.S.=  2.00
  9    9.631E-01  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.50
 10    3.183E-01  (STRM1A(1 ,2 )/STRM1(1 ,2 )) / STRM1F(1 ,2 )-1; F.S.=  1.50
 11    1.446E-02  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.10
 12    6.678E+00  (STRM1A(1 ,4 )/STRM1(1 ,4 )) / STRM1F(1 ,4 )-1; F.S.=  1.50
 13    4.977E-01  (STRM1A(1 ,5 )/STRM1(1 ,5 )) / STRM1F(1 ,5 )-1; F.S.=  1.50

******************* DESIGN OBJECTIVE ******************
*************                          ***********
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
```

Weight/area = 9.418×10^{-3} for this local optimum

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Output from BIGBOSOR4
for local buckling of
the heavier "local" optimum
design

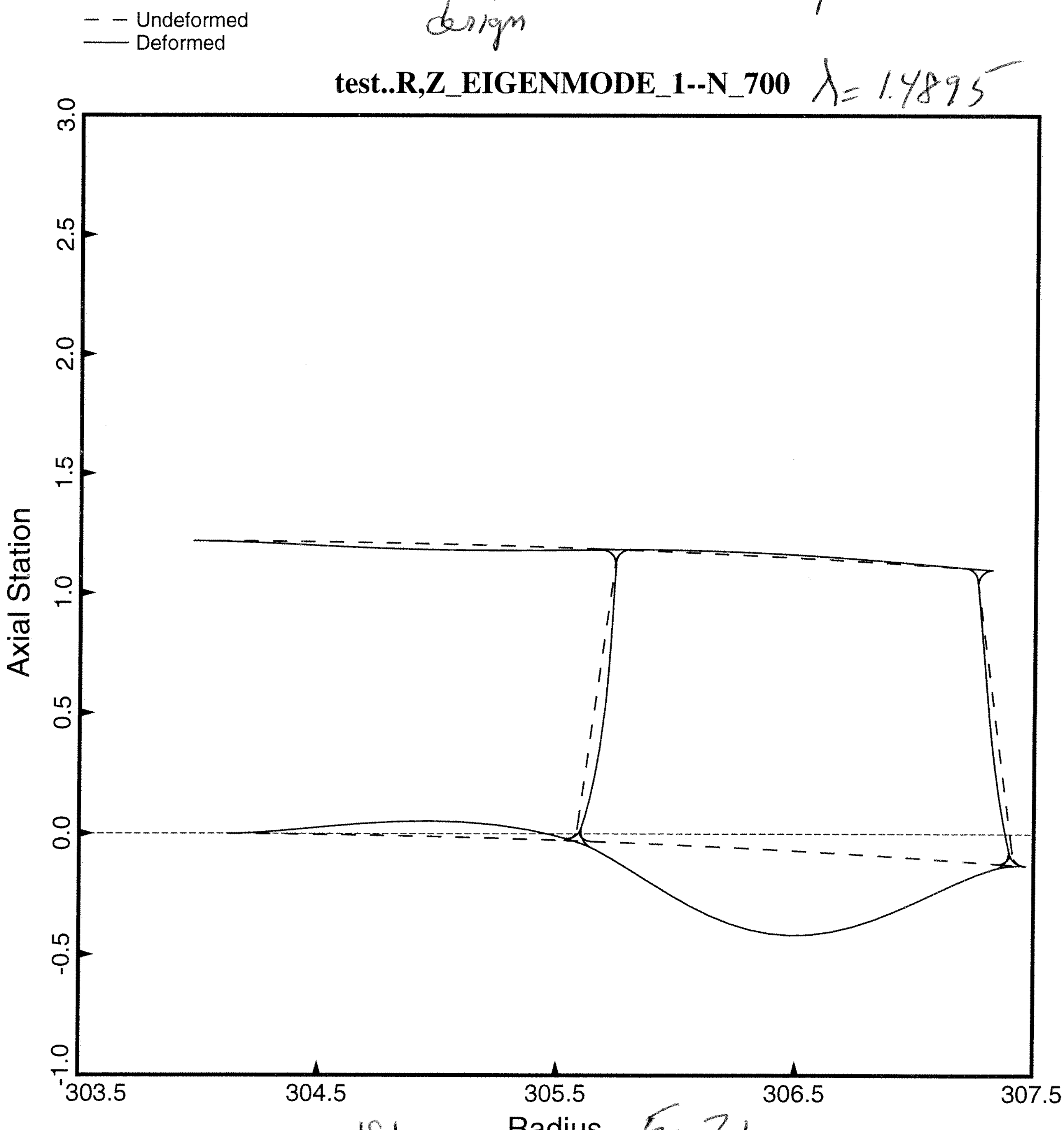

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Fig. 31

Output from BIGBOSOR4 for general buckling of the heavier "local" optimum design.

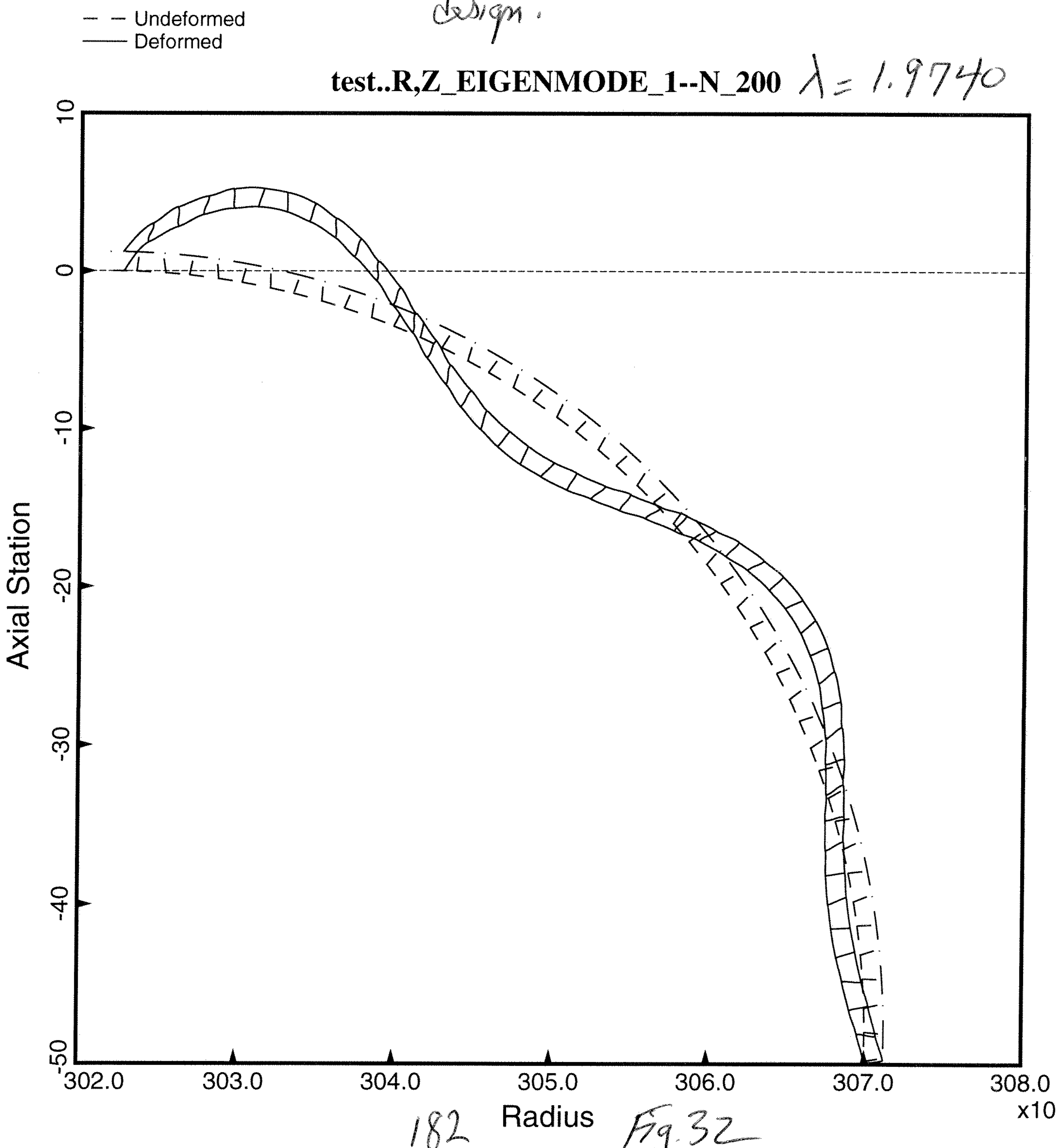

Fig. 32

Output from BIGBOSOR4 for a configuration for which BIGBOSOR4 bombed because shell seg. 7 (Fig. 1) has a length of zero.

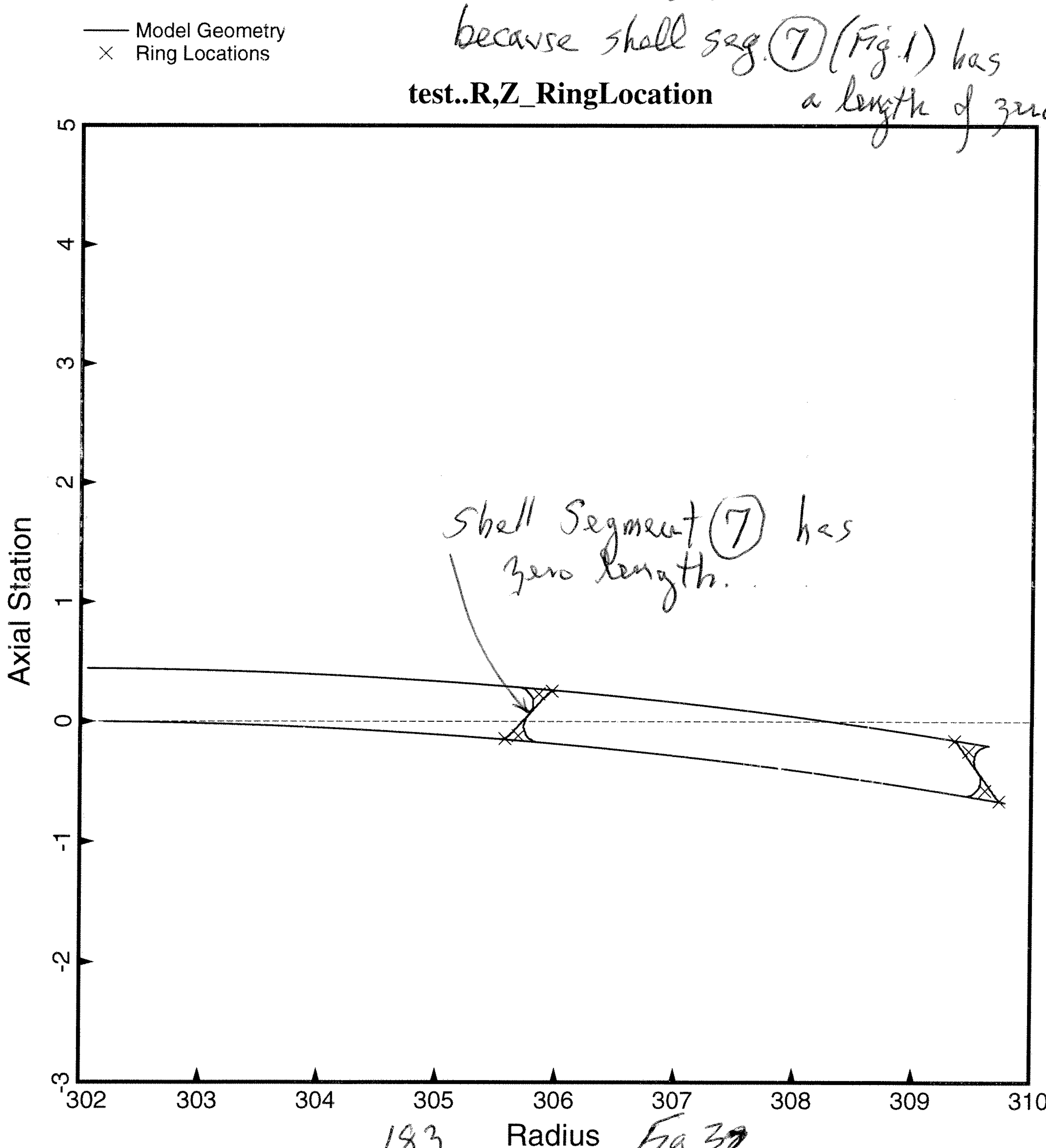

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Fig. 33

Table 31 Comparison of BIGBOSOR4 & PANDA2 for Local buckling

```
OUTPUT FROM BIGBOSOR4 FOR THE "trusscomp" GENERAL BUCKLING MODEL
WITH HIGH WAVE NUMBERS N IN ORDER TO SIMULATE LOCAL BUCKLING WITH
USE OF THE "trusscomp" GENERAL BUCKLING MULTI-MODULE MODEL

Abridged test.OUT file: General buckling multi-module model
with use of high wave numbers in order to simulate local
buckling with the general buckling model. We use essentially
zero axial stiffness for the "noodle" in this model. In these ways
the general buckling "trusscomp" model comes to resemble the single
discretized module local buckling model used by PANDA2.

NOTE: transverse shear deformation is not accounted for
in any BIGBOSOR4 models.

In the test.ALL file, we have for the wave number range the
following:
-----------------------------------------------------------
      H         $ GLOBAL DATA BEGINS...
        0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
      N         $ Are there any regions for which you want expanded plots?
     6000       $ N0B   = starting number of circ. waves (buckling analysis)
     6000       $ NMINB = minimum number of circ. waves  (buckling analysis)
     7000       $ NMAXB = maximum number of circ. waves  (buckling analysis)
      250       $ INCRB = increment in number of circ. waves (buckling)
        3       $ NVEC  = number of eigenvalues for each wave number
============================================================

Abridged test.OUT file from execution of BIGBOSOR4 with use of the
test.BEHX2 file for input data, with wave number range, wave number
increment, and number of eigenvalues changed from the values in
test.BEHX2 to the new values listed above:

 BUCKLING LOADS (eigenvalues) FOLLOW

 CIRCUMFERENTIAL WAVE NUMBER, N = 6000  (60.0 axial half-waves over 96-inch LENGTH)
    1.19102E+00    1.30183E+00    1.31424E+00

 CIRCUMFERENTIAL WAVE NUMBER, N = 6250  (62.5 axial half-waves over 96-inch LENGTH)
    1.18751E+00    1.29117E+00    1.30392E+00

 CIRCUMFERENTIAL WAVE NUMBER, N = 6500  (65.0 axial half-waves over 96-inch LENGTH)
    1.18724E+00    1.28454E+00    1.29750E+00         Fig. 34

 CIRCUMFERENTIAL WAVE NUMBER, N = 6750  (67.5 axial half-waves over 96-inch LENGTH)
Fig.35  1.18988E+00    1.28149E+00    1.29450E+00    Fig. 36

 CIRCUMFERENTIAL WAVE NUMBER, N = 7000  (70.0 axial half-waves over 96-inch LENGTH)
    1.19516E+00    1.28165E+00    1.29452E+00
============================================================
In the above list the first two eigenvalues for each wave number
correspond to local buckling adjacent to an edge of the
multi-module model, as shown in Figs 34 and 35. The third
eigenvalue is true local buckling. The critical (lowest true
local buckling eigenvalue from this "trusscomp" general buckling
model is 1.29450, corresponding to 6750 circumferential waves
around the huge torus, which means 67.5 axial half-waves over
the 96-inch length, LENGTH, of the cylindrical shell. This true
local buckling mode is shown in Fig. 36.

For the optimized "trusscomp" configuration (Table 28), PANDA2
yields the following for local bucking of the single discretized
PANDA2 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
   57      1.26900E+00       1.00000E+00      9.97192E-01      1.26543E+00
   61      1.24883E+00       1.00000E+00      9.97192E-01      1.24532E+00
   66      1.24861E+00       1.00000E+00      9.97192E-01      1.24510E+00
   71      1.23999E+00       1.00000E+00      9.97192E-01      1.23651E+00
   76      1.25295E+00       1.00000E+00      9.97192E-01      1.24943E+00
 Buckling load factor before t.s.d.=  1.2365E+00 After t.s.d.=  1.1674E+00
   70      1.23999E+00       9.44586E-01      9.97192E-01      1.16736E+00
--------------------------------------------------------------------
```

Compare 1.2945 ("trusscomp") with 1.23999 (PANDA2) for local buckling

Output from BIGBOSOR4 for the multi-module general buckling model with 0-stiffness "noodles" and with use of high N.

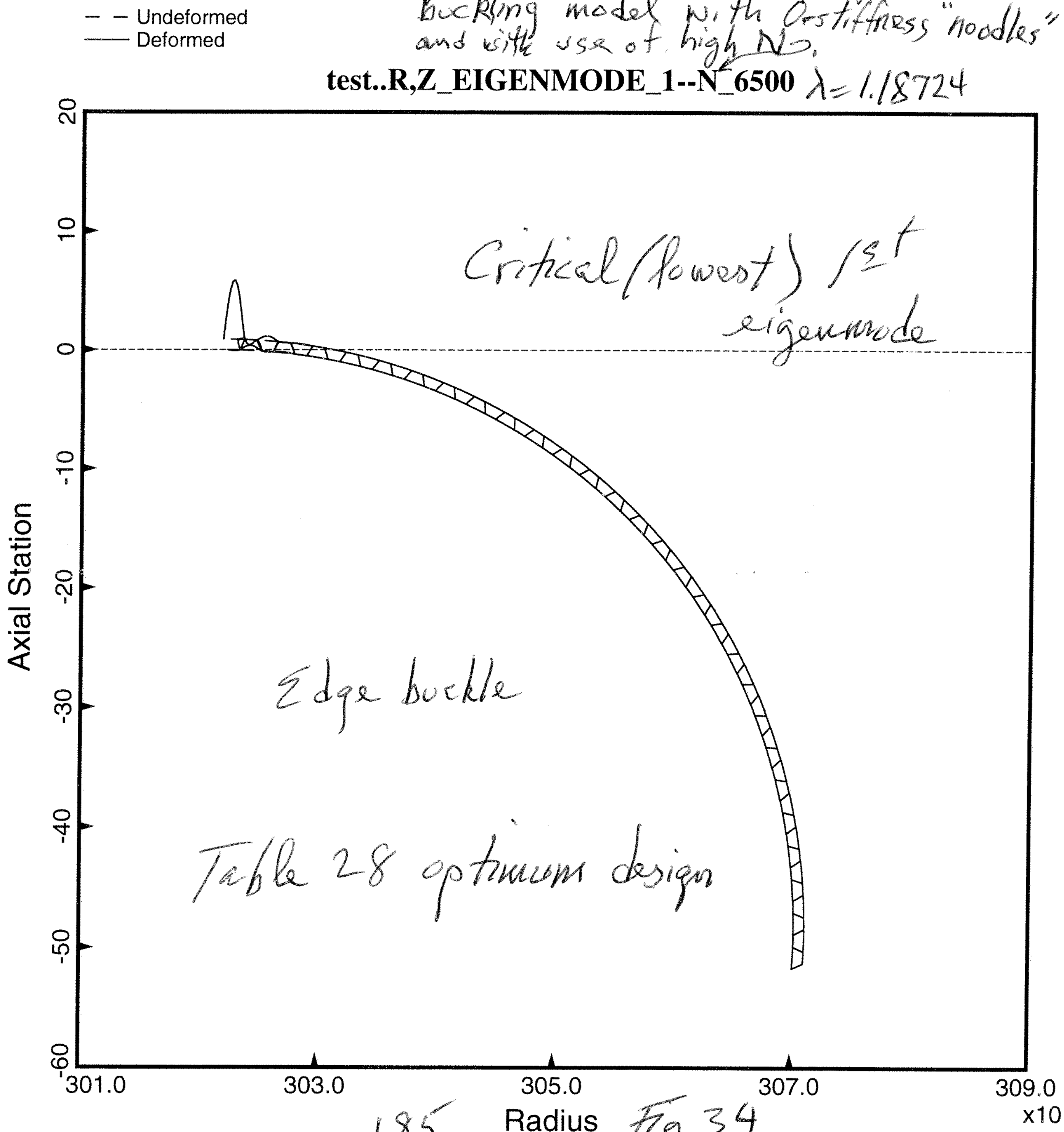

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Fig. 34

Output from BIGBOSOR4 for the Table 28 optimum design.

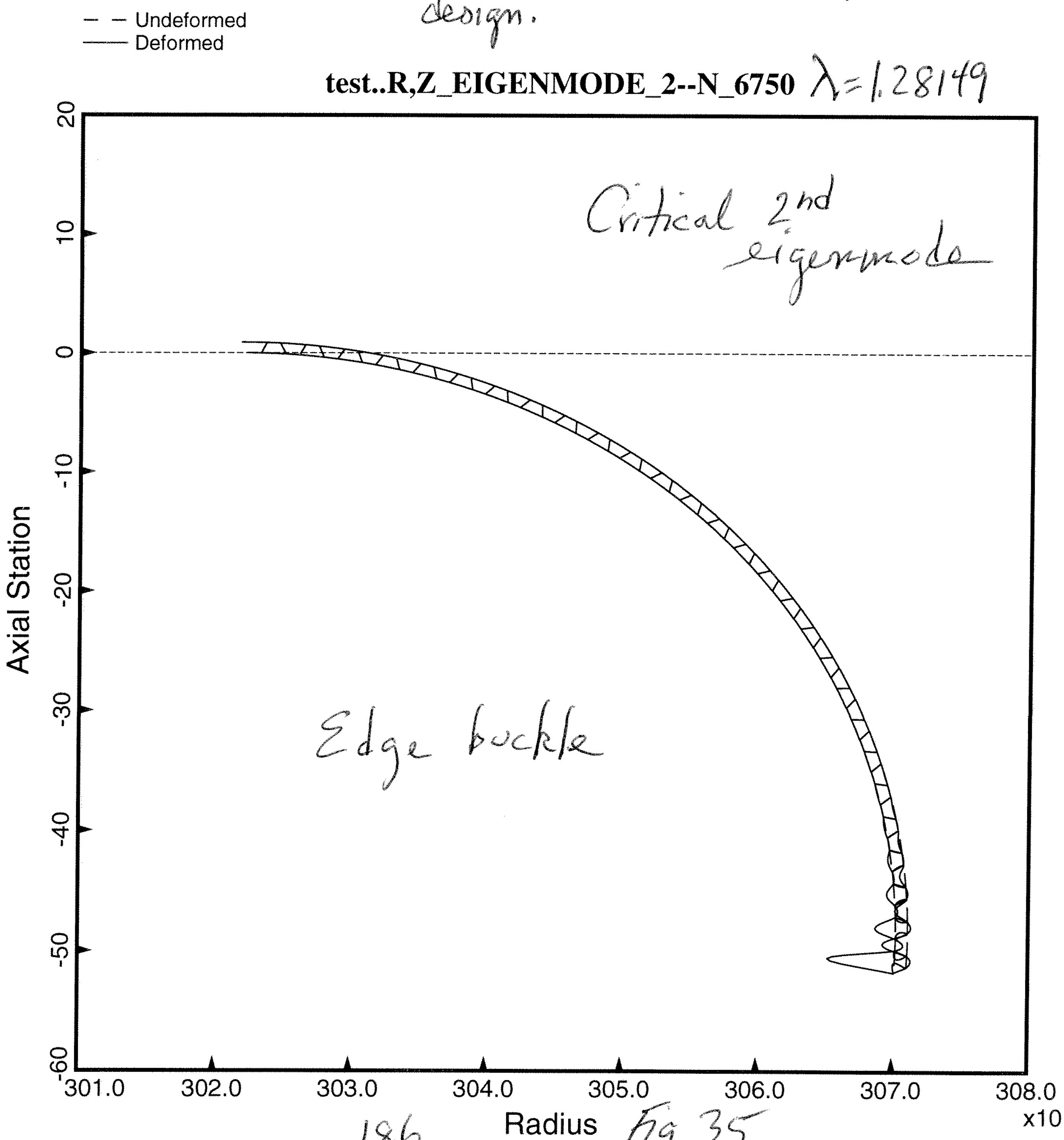

Fig. 35

Output from BIGBOSOR4 for Table 28 optimum design.

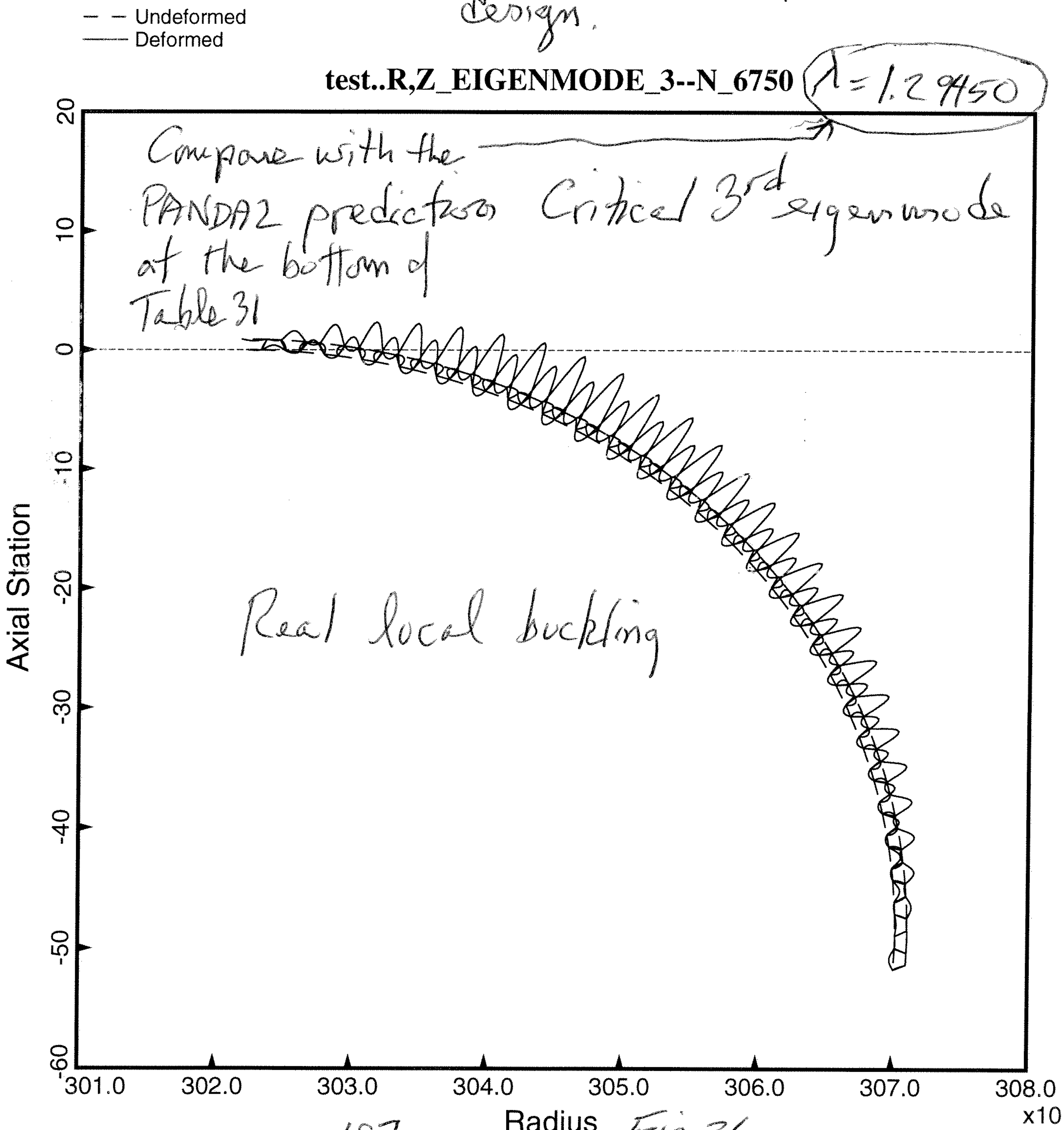

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Fig. 36

APPENDIX 1- "huge torus" model

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.

From AIAA paper 2007-2216, 48th Structures Meeting, April, 2007 [7]

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, [illegible], 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.

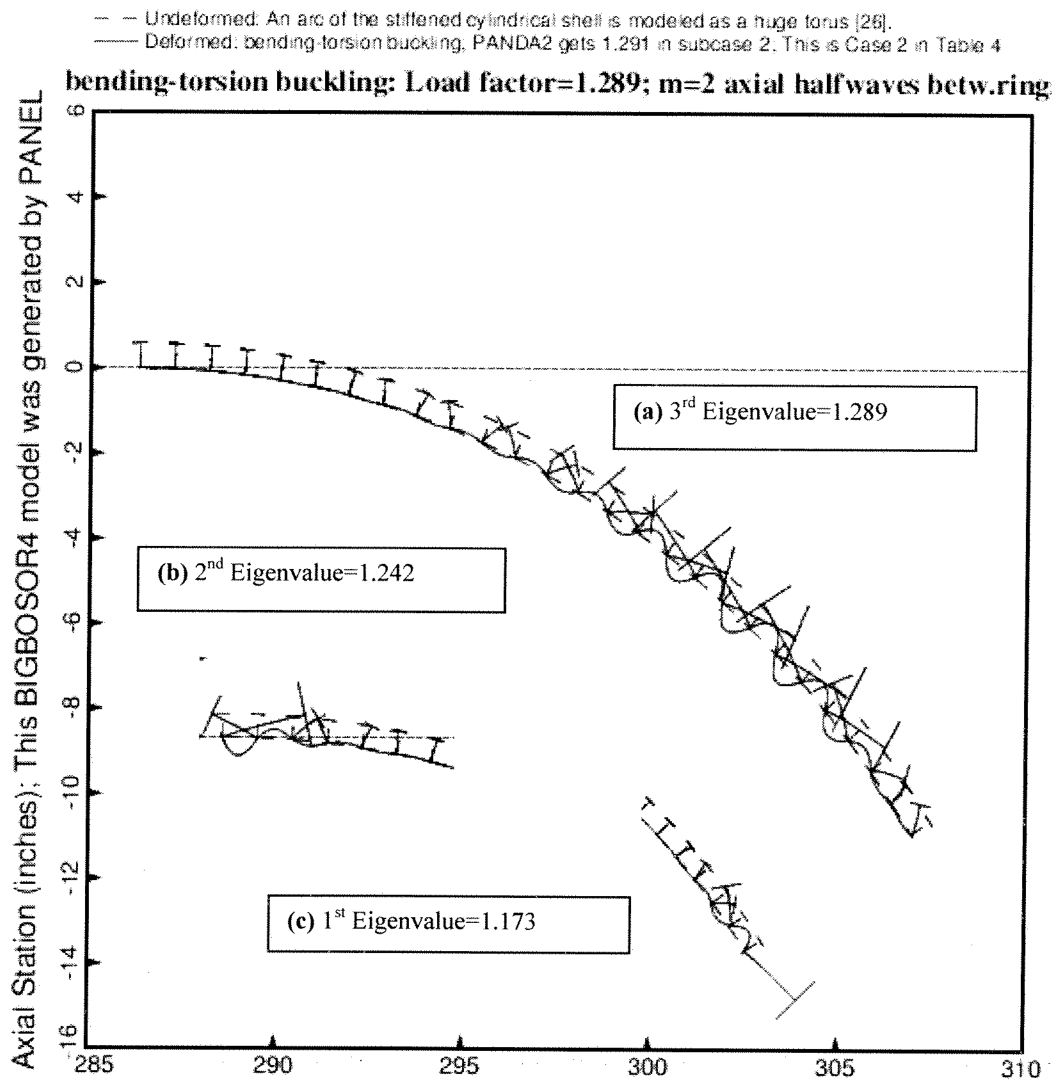

FIG. 20b BIGBOSOR4 [14] model of buckling between rings; Radius (inche

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.

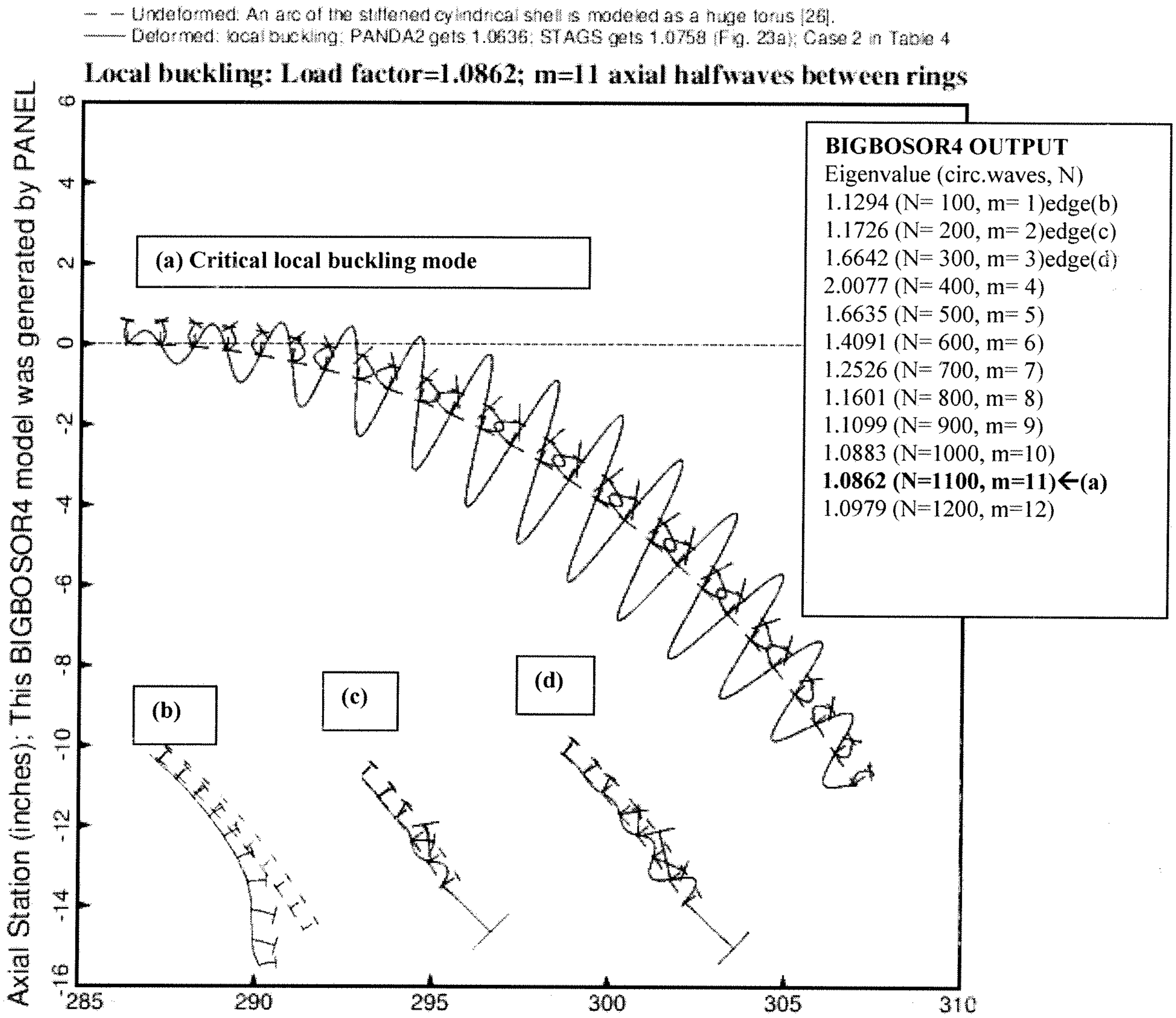

FIG. 23b BIGBOSOR4 [14] model of buckling between rings; Radius (inche

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.