Table 1 Linearly optimized design, behaviors, margins and fixed parameters for the specific case called “mich8” (Eight major segments over half the length, WIDTH/2=50 inches)

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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	Y	N	0	0.00E+00	3.00E-02	3.8420E-02	1.00E-01	wall thickness of the major segment: THICK(1)
2	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(2)
3	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(3)
4	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(4)
5	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(5)
6	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(6)
7	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(7)
8	N	N	Y	1	1.00E+00	0.00E+00	3.8420E-02	0.00E+00	wall thickness of the major segment: THICK(8)
9	Y	N	N	0	0.00E+00	2.00E+00	3.5220E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(1)
10	Y	N	N	0	0.00E+00	2.00E+00	7.9880E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(2)
11	Y	N	N	0	0.00E+00	2.00E+00	6.4780E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(3)
12	Y	N	N	0	0.00E+00	2.00E+00	8.0070E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(4)
13	Y	N	N	0	0.00E+00	2.00E+00	6.1070E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(5)
14	Y	N	N	0	0.00E+00	2.00E+00	7.9900E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(6)
15	Y	N	N	0	0.00E+00	2.00E+00	6.1330E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(7)
16	Y	N	N	0	0.00E+00	2.00E+00	3.7010E+00	2.00E+01	projected width (x-width) of major segment: SUBWID(8)
17	Y	N	N	0	0.00E+00	1.00E+01	3.7540E+01	8.00E+01	half-angle (deg.) of major corrugation: PHISEG(1)
18	Y	N	N	0	0.00E+00	2.00E+01	6.1140E+01	8.00E+01	half-angle (deg.) of major corrugation: PHISEG(2)

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  19   Y     N     N      0    0.00E+00  2.00E+01 4.7630E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(3 )
  20   Y     N     N      0    0.00E+00  2.00E+01 6.1900E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(4 )
  21   Y     N     N      0    0.00E+00  2.00E+01 4.8330E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(5 )
  22   Y     N     N      0    0.00E+00  2.00E+01 6.5410E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(6 )
  23   Y     N     N      0    0.00E+00  2.00E+01 4.8330E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(7 )
  24   Y     N     N      0    0.00E+00  1.00E+01 2.8090E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(8 )
  25   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
  26   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(2 )
  27   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(3 )
  28   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(4 )
  29   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(5 )
  30   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(6 )
  31   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(7 )
  32   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(8 )
  33   Y     N     N      0    0.00E+00  3.45E+01 3.4950E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
  34   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
  35   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(3 )
  36   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(4 )
  37   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(5 )
  38   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(6 )
  39   Y     N     N      0    0.00E+00  3.25E+01 3.2450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(7 )
  40   Y     N     N      0    0.00E+00  3.25E+01 3.2460E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(8 )
  41   Y     N     N      0    0.00E+00  3.05E+01 3.0450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(9 )
  42   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG
```

```
 ***** RESULTS FOR LOAD SET NO.  1  ******
PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1     1.592E+00    local buckling load factor: LOCBUK(1 ) (STAGS = 1.621)
  2     1.419E+00    symmetric general buckling: BUKSYM(1 )(no STAGS model)
  3     1.408E+00    antisymmtric general buckling: BUKASY(1 )(STAGS=1.451)
  4     1.000E+10    classical buckling load factor: CYLBUK(1 ,1 )
  5     1.000E+10    classical buckling load factor: CYLBUK(1 ,2 )
  6     1.000E+10    classical buckling load factor: CYLBUK(1 ,3 )
  7     1.000E+10    classical buckling load factor: CYLBUK(1 ,4 )
  8     1.000E+10    classical buckling load factor: CYLBUK(1 ,5 )
  9     1.000E+10    classical buckling load factor: CYLBUK(1 ,6 )
 10     1.000E+10    classical buckling load factor: CYLBUK(1 ,7 )
 11     1.000E+10    classical buckling load factor: CYLBUK(1 ,8 )
 12     5.406E+04    maximum effective stress: STRESS(1 )  (STAGS = 53120)

MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     5.740E-02  6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)-
0.10*V(13)-0
  2    -2.400E-03  -
3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)+0.10*V(13)+
  3    -4.838E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  4     1.368E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  5     5.499E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  6     2.333E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************** DESIGN OBJECTIVE ******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     4.614E+01  weight of the corrugated panel: WEIGHT

***********  ALL 1 LOAD CASES PROCESSED ***********


 PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     1.000E+02  total width of the corrugated panel: WIDTH
  2     1.000E+00  axial length of the corrugated panel: LENGTH
  3     3.000E+00  fraction of LENGTH for local buckling model: FACLEN
  4     1.000E+07  elastic modulus of the material: EMOD
  5     3.000E-01  Poisson ratio of the panel material: NU
  6     1.000E-01  weight density of the panel material: DENSTY
```

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 PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1   -2.000E+01  total axial load (e.g. lb) over WIDTH: TOTLOD(1 )

 PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.000E+00  allowable for local buckling: LOCBUKA(1 )
  2    1.000E+00  allowable for sym. general buckling: BUKSYMA(1 )
  3    1.000E+00  allowable for antisym. general buckling: BUKASYA(1 )
 12    1.000E+05  allowable effective stress: STRESSA(1 )

 PARAMETERS WHICH ARE FACTORS OF SAFETY
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.600E+00  factor of safety for local buckling: LOCBUKF(1 )
  2    1.400E+00  f.s. for symmetric general buckling: BUKSYMF(1 )
  3    1.400E+00  f.s. for antisym. general buckling: BUKASYF(1 )
 12    1.500E+00  factor of safety for stress: STRESSF(1 )

    2 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
  1 <6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)-0.10*V(13)
-0.10*V(14)..etc.
  1 <-3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)+0.10*V(13)
+0.10*V(14)..etc.
===========================================================================
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Table 2 Nonlinearly optimized design, behaviors and margins for the specific case called "mich8" (Eight major segments over half the length, WIDTH/2=50 inches)

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===========================================================================
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     Y     N      0    0.00E+00  3.00E-02 4.1420E-02  1.00E-01
wall thickness of the major segment: THICK(1 )
   2   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(2 )
   3   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(3 )
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   4   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(4 )
   5   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(5 )
   6   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(6 )
   7   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(7 )
   8   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00
wall thickness of the major segment: THICK(8 )
   9   Y     N     N      0    0.00E+00  2.00E+00 2.7410E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(1 )
  10   Y     N     N      0    0.00E+00  2.00E+00 8.5650E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(2 )
  11   Y     N     N      0    0.00E+00  2.00E+00 5.9980E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(3 )
  12   Y     N     N      0    0.00E+00  2.00E+00 8.9330E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(4 )
  13   Y     N     N      0    0.00E+00  2.00E+00 5.6410E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(5 )
  14   Y     N     N      0    0.00E+00  2.00E+00 8.4400E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(6 )
  15   Y     N     N      0    0.00E+00  2.00E+00 5.7090E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(7 )
  16   Y     N     N      0    0.00E+00  2.00E+00 3.9480E+00  2.00E+01
projected width (x-width) of major segment: SUBWID(8 )
  17   Y     N     N      0    0.00E+00  1.00E+01 3.6230E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(1 )
  18   Y     N     N      0    0.00E+00  2.00E+01 5.9770E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(2 )
  19   Y     N     N      0    0.00E+00  2.00E+01 4.0020E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(3 )
  20   Y     N     N      0    0.00E+00  2.00E+01 6.5680E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(4 )
  21   Y     N     N      0    0.00E+00  2.00E+01 4.2940E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(5 )
  22   Y     N     N      0    0.00E+00  2.00E+01 7.2920E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(6 )
  23   Y     N     N      0    0.00E+00  2.00E+01 4.7380E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(7 )
  24   Y     N     N      0    0.00E+00  1.00E+01 3.4330E+01  8.00E+01
half-angle (deg.) of major corrugation: PHISEG(8 )
  25   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
  26   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(2 )
  27   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(3 )
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  28   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(4 )
  29   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(5 )
  30   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(6 )
  31   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(7 )
  32   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(8 )
  33   Y     N     N      0    0.00E+00  3.45E+01 3.5820E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
  34   Y     N     N      0    0.00E+00  3.35E+01 3.3470E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
  35   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(3 )
  36   Y     N     N      0    0.00E+00  3.35E+01 3.3470E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(4 )
  37   Y     N     N      0    0.00E+00  3.35E+01 3.3520E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(5 )
  38   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(6 )
  39   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(7 )
  40   Y     N     N      0    0.00E+00  3.35E+01 3.3520E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(8 )
  41   Y     N     N      0    0.00E+00  3.00E+01 3.0770E+01  5.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(9 )
  42   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG


 ***** RESULTS FOR LOAD SET NO.  1  ******

PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1     1.590E+00    local buckling load factor: LOCBUK(1 )(STAGS = 1.6364)
  2     1.423E+00    symmetric general buckling: BUKSYM(1 )(no STAGS model)
  3     1.397E+00    antisymmtric general buckling: BUKASY(1)(STAGS=1.2259)
  4     1.000E+10    classical buckling load factor: CYLBUK(1 ,1 )
  5     1.000E+10    classical buckling load factor: CYLBUK(1 ,2 )
  6     1.000E+10    classical buckling load factor: CYLBUK(1 ,3 )
  7     1.000E+10    classical buckling load factor: CYLBUK(1 ,4 )
  8     1.000E+10    classical buckling load factor: CYLBUK(1 ,5 )
  9     1.000E+10    classical buckling load factor: CYLBUK(1 ,6 )
 10     1.000E+10    classical buckling load factor: CYLBUK(1 ,7 )
 11     1.000E+10    classical buckling load factor: CYLBUK(1 ,8 )
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 12    5.266E+04    maximum effective stress: STRESS(1 ) (STAGS=51859 psi)

MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MAR.   CURRENT
 NO.     VALUE            DEFINITION
1    5.250E-02  6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)
-0.10*V(13)-0
  2    2.500E-03  -3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)
+0.10*V(13)+
  3   -6.525E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  4    1.609E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  5   -2.217E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  6    2.661E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************** DESIGN OBJECTIVE *******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    5.183E+01  weight of the corrugated panel: WEIGHT
  *****************************************************

 PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.000E+02  total width of the corrugated panel: WIDTH
  2    1.300E+01  axial length of the corrugated panel: LENGTH
  3    3.000E+00  fraction of LENGTH for local buckling model: FACLEN

    2 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
  1 <6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)-0.10*V(13)
-0.10*V(14)..etc.
  1 <-3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)+0.10*V(13)
+0.10*V(14)..etc.
=======================================================================
```

Table 3a Nonlinearly optimized design, behaviors and margins for the specific case called "mich8u" (Uniform corrugations; 8 major segments over half the length, WIDTH/2 = 50 inches). This optimum design was obtained with ISTRAT = 7

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STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
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```
 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  3.00E-02 4.4480E-02  1.00E-01
wall thickness of the major segment: THICK(1 )
   2   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(2 )
   3   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(3 )
   4   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(4 )
   5   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(5 )
   6   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(6 )
   7   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(7 )
   8   N     N     Y      1    1.00E+00  0.00E+00 4.4480E-02  0.00E+00
wall thickness of the major segment: THICK(8 )
   9   N     N     N      0    0.00E+00  0.00E+00 3.5710E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(1 )
  10   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(2 )
  11   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(3 )
  12   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(4 )
  13   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(5 )
  14   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(6 )
  15   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(7 )
  16   N     N     N      0    0.00E+00  0.00E+00 3.5710E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(8 )
  17   Y     N     N      0    0.00E+00  2.00E+01 3.1320E+01  5.00E+01
half-angle (deg.) of major corrugation: PHISEG(1 )
  18   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(2 )
  19   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(3 )
  20   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(4 )
  21   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(5 )
  22   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(6 )
```

```
  23   N     N     Y     17    2.00E+00  0.00E+00 6.2640E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(7 )
  24   N     N     Y     17    1.00E+00  0.00E+00 3.1320E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(8 )
  25   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
  26   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(2 )
  27   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(3 )
  28   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(4 )
  29   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(5 )
  30   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(6 )
  31   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(7 )
  32   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(8 )
  33   N     N     N      0    0.00E+00  0.00E+00 3.4550E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
  34   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
  35   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(3 )
  36   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(4 )
  37   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(5 )
  38   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(6 )
  39   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(7 )
  40   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(8 )
  41   N     N     N      0    0.00E+00  0.00E+00 3.0450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(9 )
  42   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG

 ***** RESULTS FOR LOAD SET NO.  1 OPTAINED WITH ISTRAT = 7 ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.586E+00    local buckling load factor: LOCBUK(1 )[STAGS=1.5713]
  2    1.499E+00    symmetric general buckling: BUKSYM(1 )[STAGS=1.2750]
  3    1.413E+00    antisymmetric general buckling: BUKASY(1 )
```

```
 12    3.193E+04    maximum effective stress: STRESS(1 )[STAGS=32490 psi]

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.=FACTOR OF SAFETY)ISTRAT=7
 MARGIN CURRENT
 NO.     VALUE             DEFINITION
  1   -8.635E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  2    7.050E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  3    9.276E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  4    1.088E+00  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************** DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    5.571E+01  weight of the corrugated panel: WEIGHT
 ***********  ALL 1 LOAD CASES PROCESSED ***********

PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    1.000E+02  total width of the corrugated panel: WIDTH
  2    7.000E+00  axial length of the corrugated panel: LENGTH
  3    3.000E+00  fraction of LENGTH for local buckling model: FACLEN

    0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
=========================================================================
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Table 3b Nonlinearly optimized design, behaviors and margins for the specific case called "mich8u" (Uniform corrugations; 8 major segments over half the length, WIDTH/2 = 50 inches). This optimum design was obtained with ISTRAT = 13

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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     Y     N      0    0.00E+00  3.00E-02 4.6470E-02  1.00E-01
wall thickness of the major segment: THICK(1 )
   2   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(2 )
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   3   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(3 )
   4   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(4 )
   5   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(5 )
   6   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(6 )
   7   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(7 )
   8   N     N     Y      1    1.00E+00  0.00E+00 4.6470E-02  0.00E+00
wall thickness of the major segment: THICK(8 )
   9   N     N     N      0    0.00E+00  0.00E+00 3.5710E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(1 )
  10   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(2 )
  11   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(3 )
  12   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(4 )
  13   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(5 )
  14   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(6 )
  15   N     N     N      0    0.00E+00  0.00E+00 7.1430E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(7 )
  16   N     N     N      0    0.00E+00  0.00E+00 3.5710E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(8 )
  17   Y     N     N      0    0.00E+00  2.00E+01 3.1170E+01  5.00E+01
half-angle (deg.) of major corrugation: PHISEG(1 )
  18   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(2 )
  19   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(3 )
  20   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(4 )
  21   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(5 )
  22   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(6 )
  23   N     N     Y     17    2.00E+00  0.00E+00 6.2350E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(7 )
  24   N     N     Y     17    1.00E+00  0.00E+00 3.1170E+01  0.00E+00
half-angle (deg.) of major corrugation: PHISEG(8 )
  25   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
  26   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(2 )
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```
  27   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(3 )
  28   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(4 )
  29   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(5 )
  30   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(6 )
  31   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(7 )
  32   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(8 )
  33   N     N     N      0    0.00E+00  0.00E+00 3.4550E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
  34   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
  35   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(3 )
  36   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(4 )
  37   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(5 )
  38   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(6 )
  39   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(7 )
  40   N     N     N      0    0.00E+00  0.00E+00 3.2450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(8 )
  41   N     N     N      0    0.00E+00  0.00E+00 3.0450E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(9 )
  42   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG

 ***** RESULTS FOR LOAD SET NO.  1 OPTAINED WITH ISTRAT = 13 ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE           DEFINITION
  1    1.600E+00    local buckling load factor: LOCBUK(1 ) (STAGS = 1.677)
  2    1.505E+00    symmetric general buckling: BUKSYM(1 )(no STAGS model)
  3    1.419E+00    antisymmtric general buckling: BUKASY(1 )(STAGS=1.296)
  4    1.000E+10    classical buckling load factor: CYLBUK(1 ,1 )
  5    1.000E+10    classical buckling load factor: CYLBUK(1 ,2 )
  6    1.000E+10    classical buckling load factor: CYLBUK(1 ,3 )
  7    1.000E+10    classical buckling load factor: CYLBUK(1 ,4 )
  8    1.000E+10    classical buckling load factor: CYLBUK(1 ,5 )
  9    1.000E+10    classical buckling load factor: CYLBUK(1 ,6 )
 10    1.000E+10    classical buckling load factor: CYLBUK(1 ,7 )
 11    1.000E+10    classical buckling load factor: CYLBUK(1 ,8 )
```

```
 12    3.039E+04    maximum effective stress: STRESS(1 )  (STAGS = 29560)

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.=FACTOR OF SAFETY)ISTRAT=13
 MARGIN CURRENT
 NO.     VALUE             DEFINITION
  1   -2.980E-07  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  2    7.529E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  3    1.369E-02  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  4    1.193E+00  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************** DESIGN OBJECTIVE ******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    5.810E+01  weight of the corrugated panel: WEIGHT
 ***********  ALL 1 LOAD CASES PROCESSED ***********

PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    1.000E+02  total width of the corrugated panel: WIDTH
  2    1.300E+01  axial length of the corrugated panel: LENGTH
  3    3.000E+00  fraction of LENGTH for local buckling model: FACLEN

    0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
========================================================================
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Table 4 Nonlinearly optimized design, behaviors and margins for the specific case called "mich1" (The one major segment curves outward)

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=======================================================================
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     Y     N      0    0.00E+00  4.00E-02 4.5780E-02  1.00E-01
wall thickness of the major segment: THICK(1 )
   2   N     N     N      0    0.00E+00  0.00E+00 4.6000E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(1 )
   3   Y     N     N      0    0.00E+00  2.00E+01 3.5140E+01  5.00E+01
half-angle (deg.) of major corrugation: PHISEG(1 )
   4   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
```

```
   5   Y     N     N      0    0.00E+00  3.10E+01 3.3980E+01  4.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
   6   Y     N     N      0    0.00E+00  3.10E+01 3.1000E+01  4.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
   7   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG

 ***** RESULTS FOR LOAD SET NO.  1  ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1     1.581E+00    local buckling load factor: LOCBUK(1 ) (STAGS = 1.618)
  2     1.418E+00    symmetric general buckling: BUKSYM(1 )(no STAGS model)
  3     1.414E+00    antisymmtric general buckling: BUKASY(1 )(STAGS=1.257)
  4     1.000E+10    classical buckling load factor: CYLBUK(1 ,1 )
  5     4.641E+04    maximum effective stress: STRESS(1 )   (STAGS = 43789)

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1   -1.160E-02  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  2    1.300E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  3    1.029E-02  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  4    4.366E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************* DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     6.585E+00  weight of the corrugated panel: WEIGHT
**********  ALL 1 LOAD CASES PROCESSED ***********


 PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     9.200E+00  total width of the corrugated panel: WIDTH
  2     1.300E+01  axial length of the corrugated panel: LENGTH
  3     9.000E+00  fraction of LENGTH for local buckling model: FACLEN

    0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
======================================================================
```

Table 5 Nonlinearly optimized design, behaviors and margins for the specific case called "mich1b" (The one major segment curves inward)

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=======================================================================

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     Y     N      0    0.00E+00  3.50E-02 3.9620E-02  7.00E-02
wall thickness of the major segment: THICK(1 )
   2   N     N     N      0    0.00E+00  0.00E+00 4.5500E+00  0.00E+00
projected width (x-width) of major segment: SUBWID(1 )
   3   Y     N     N      0    0.00E+00  2.00E+01 3.7970E+01  6.00E+01
half-angle (deg.) of major corrugation: PHISEG(1 )
   4   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00
half-angle (deg.) of sub-corrugation: PHISUB(1 )
   5   N     N     N      0    0.00E+00  0.00E+00 3.4000E+01  0.00E+00
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
   6   Y     N     N      0    0.00E+00  3.00E+01 3.0750E+01  4.00E+01
vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
   7   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00
half-angle (deg.) of overall arching: PHIBIG

 ***** RESULTS FOR LOAD SET NO.  1  ******


 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1     1.650E+00    local buckling load factor: LOCBUK(1 ) (STAGS = 1.642)
  2     1.425E+00    symmetric general buckling: BUKSYM(1 )(no STAGS model)
  3     1.396E+00    antisymmtric general buckling: BUKASY(1 )(STAGS=1.171)
  4     1.000E+10    classical buckling load factor: CYLBUK(1 ,1 )
  5     3.560E+04    maximum effective stress: STRESS(1 )   (STAGS = 34684)

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1     3.122E-02  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  2     1.775E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  3    -2.560E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  4     8.729E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************** DESIGN OBJECTIVE *******************
     CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1     5.877E+00  weight of the corrugated panel: WEIGHT
```

```
 *********** ALL 1 LOAD CASES PROCESSED ***********


 PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    9.100E+00  total width of the corrugated panel: WIDTH
  2    1.300E+01  axial length of the corrugated panel: LENGTH
  3    9.000E+01  fraction of LENGTH for local buckling model: FACLEN

    0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
============================================================
```

NOTES:

The results listed above are for a "mich1b" optimized design in which "mmm9" BIGBOSOR4 general buckling models of the type displayed in Fig. 37 were used. An "mmm27" BIGBOSOR4 general buckling model was used after optimization with the "mmm9" design in order to check if the "mmm9" model is long enough to capture general buckling of a very long circumferentially corrugated shell with sufficient accuracy. The smallest general buckling load factor from the "mmm9" model is 1.3964, as listed above. The smallest general buckling load factor from the "mmm27" model of the same "mich1b" design is 1.2965, as listed in Fig. 39. Therefore, the adequacy of the "mmm9" general buckling model is questionable. The "mich1b" case was therefore re-optimized, starting from the "mmm9" optimum design listed above and using the "mmm27" BIGBOSOR4 model in the optimization loop. The new, nonlinearly re-optimized "mich1b" design, behavioral constraints, design margins and objective are as follows:

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. CURRENT          DEFINITION
  NO.  VALUE
   1  3.9140E-02 wall thickness of the major segment: THICK(1 )
   2  4.5500E+00 projected width (x-width) of major segment: SUBWID(1 )
   3  3.8020E+01 half-angle (deg.) of major corrugation: PHISEG(1 )
   4  7.0000E+01 half-angle (deg.) of sub-corrugation: PHISUB(1 )
   5  3.4000E+01 vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
   6  3.0700E+01 vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
   7  1.0000E-02 half-angle (deg.) of overall arching: PHIBIG

 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.594E+00    local buckling load factor: LOCBUK(1 )
  2    1.390E+00    symmetric general buckling: BUKSYM(1 )
  3    1.390E+00    antisymmtric general buckling: BUKASY(1)(STAGS=1.2765)
  4    1.000E+10    classical buckling load factor: CYLBUK(1,1 )
  5    3.651E+04    maximum effective stress: STRESS(1 )

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MAR.   CURRENT
 NO.     VALUE            DEFINITION
```

```
  1   -3.711E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  2   -7.218E-03  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
  3   -6.834E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
  4    8.258E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50

 ******************* DESIGN OBJECTIVE ******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    5.835E+00  weight of the corrugated panel: WEIGHT
```

The general buckling load factors from STAGS for the RE-OPTIMIZED "mich1b" design are as follows:

```
"antiantigenbuck" STAGS model yields a buckling load factor = 1.2765
"symantigenbuck"  STAGS model yields a buckling load factor = 1.3028
```

The STAGS general buckling mode shapes are similar to that shown in Fig. 40.

Table 6 An example of the gradients of the behavioral constraints, LOCBUK, BUKSYM, BUKASY and STRESS, computed for the specific case called "mich1". (The design listed below is somewhat different from the nonlinearly optimized "mich1" design listed in Table 4. However, the behavioral constraint gradients associated with the design listed here are typical of those encountered in all of the specific cases presented in this paper.)

```
============================================================================
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
VAR. DEC. CURRENT        DEFINITION
 NO. VAR.  VALUE
  1   Y  4.4753E-02 wall thickness of the major segment: THICK(1)
  2   N  4.6000E+00 projected width (x-width) of major segment: SUBWID(1)
  3   Y  3.7073E+01 half-angle (deg.) of major corrugation: PHISEG(1)
  4   N  7.0000E+01 half-angle (deg.) of sub-corrugation: PHISUB(1)
  5   Y  3.3933E+01 vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(1)
  6   Y  3.1000E+01 vertical y above (x,y,z) origin if PHIBIG=0: YPLATE(2)
  7   N  1.0000E-02 half-angle (deg.) of overall arching: PHIBIG

 CONSTRAINTS AND GRADIENTS OF THEM FROM MAIN (UNSCALED)...
----------------------------------------------------------------------------
 NO.    CON-     G R A D I E N T S   O F   C O N S T R A I N T S
      STRAINT   D E C I S I O N   V A R I A B L E   N U M B E R
                   1          2          3          4        NAME OF
```

```
                THICK(1)   PHISEG(1)  YPLATE(1)  YPLATE(2)   CONSTRAINT
-------------------------------------------------------------------------
  1   9.76E-01   3.21E+00   8.35E-01  -1.18E+01  -1.01E+01    (LOCBUK)
  2   1.01E+00   1.35E+00   1.98E+00   4.55E+01  -3.61E+01    (BUKSYM)
  3   1.00E+00   1.16E+00   1.78E+00   4.60E+01  -3.56E+01    (BUKASY)
  4   1.41E+00   9.07E-01  -7.05E-01  -1.82E+01   2.12E+01    (STRESS)
-------------------------------------------------------------------------
 Absolute value of maximum constraint gradient for iteration no 1
 = GRADMX( 1)=  4.6025E+01
 Absolute values of maximum constraint gradients for each active
constraint:
  1.1785E+01  4.5484E+01  4.6025E+01  2.1233E+01
==========================================================================
```

Notes:

1. The “behavioral constraints” listed under the heading ‘CONSTRAINT” are equal to design margins plus 1.0.
2. The very high behavioral constraint gradients associated with YPLATE(1) and YPLATE(2) (bold face) make it difficult to find “global” optimum designs.
3. YPLATE(i), i=1,2 are the radii from the axis of revolution to the shell reference surface at the bottom and top of the one major segment shown in Fig. 34.
4. The data listed under the heading, “CONSTRAINTS AND GRADIENS OF THEM…” appear in the output file, *.OPM, when NPRINT=2 and ITYPE=1 in the *.OPT file. (See Table A5 for a list of a typical *.OPT file.)

Table A1 Glossary of variables used in both of the generic cases, “span9” and “michelin”. (This is part of the michelin.DEF file, created automatically by the GENOPT processor, GENTEXT, with use of information, variable names and one-line definitions provided by the GENOPT user.)

```
C===========================================================================================
C  ARRAY   NUMBER OF          PROMPT
C    ?   (ROWS,COLS)  ROLE  NUMBER   NAME                  DEFINITION OF VARIABLE
C                           (span9.PRO)
C===========================================================================================
C    n   (    0,    0)    2      10   WIDTH    = total width of the corrugated panel (axial length)
C    n   (    0,    0)    2      15   LENGTH   = axial length of the corrugated panel (ISTRAT)
C    n   (    0,    0)    2      25   FACLEN   = fraction of LENGTH for local buckling model (MMM)
C    n   (    0,    0)    2      30   NSEG     = number of major segments in WIDTH/2
C    n   (    0,    0)    2      40   EMOD     = elastic modulus of the material
C    n   (    0,    0)    2      45   NU       = Poisson ratio of the panel material
C    n   (    0,    0)    2      50   DENSTY   = weight density of the panel material
C    n   (    0,    0)    2      60   MLOWGS   = low end of M-range: symmetric GENERAL buckling
C    n   (    0,    0)    2      65   MHIGHGS  = high end of M-range: symmetric GENERAL buckling
C    n   (    0,    0)    2      70   MLOWGA   = low end of M-range: antisymmetric GENERAL buckling
C    n   (    0,    0)    2      75   MHIGHGA  = high end of M-range: antisymmetric GENERAL buckling
C    n   (    0,    0)    2      80   MLOWL    = low end of the M-range: LOCAL buckling
C    n   (    0,    0)    2      85   MHIGHL   = high end of the M-range: LOCAL buckling
C    n   (    0,    0)    2      95   IELMNT   = finite element used in STAGS model
C    n   (    0,    0)    2     105   INSUBSE  = major segment number in NSUBSEG(INSUBSE)
C    y   (   19,    0)    2     110   NSUBSEG  = number of sub-segments in major segment
C    y   (   19,    0)    2     120   UPDOWN   = 1 = convex surface up; 2 = convex down
```

```
C    n   (   0,   0)    2      130   JUPDWNS  = major segment number in UPDWNS(IUPDWNS,JUPDWNS)
C    n   (   0,   0)    2      135   IUPDWNS  = sub-segment number in UPDWNS(IUPDWNS,JUPDWNS)
C    y   (  50,  19)    2      140   UPDWNS   = 1=convex up; 2=convex down (subsegments)
C    n   (   0,   0)    2      150   UPDNBIG  = 1=convex up (hill); 2=convex down (valley)
C    n   (   0,   0)    2      160   ITHICK   = major segment number in THICK(ITHICK)
C    y   (  19,   0)    1      165   THICK    = wall thickness of the major segment
C    y   (  19,   0)    1      170   SUBWID   = projected width (x-width) of major segment
C    y   (  19,   0)    1      175   PHISEG   = half-angle (deg.) of major corrugation
C    y   (  19,   0)    1      180   PHISUB   = half-angle (deg.) of sub-corrugation
C    n   (   0,   0)    2      190   IYPLATE  = vertical displacement number in YPLATE(IYPLATE)
C    y   (  20,   0)    1      195   YPLATE   = vertical y above (x,y,z) origin if PHIBIG=0
C    n   (   0,   0)    1      200   PHIBIG   = half-angle (deg.) of overall arching
C    n   (   0,   0)    2      210   NCASES   = Number of load cases (number of environments)  in
TOTLOD(NCASES)
C    y   (  20,   0)    3      215   TOTLOD   = total axial load (e.g. lb) over WIDTH (external p)
C    y   (  20,   0)    4      225   LOCBUK   = local buckling load factor
C    y   (  20,   0)    5      235   LOCBUKA  = allowable for local buckling
C    y   (  20,   0)    6      240   LOCBUKF  = factor of safety for local buckling
C    y   (  20,   0)    4      245   BUKSYM   = symmetric general buckling
C    y   (  20,   0)    5      250   BUKSYMA  = allowable for sym. general buckling
C    y   (  20,   0)    6      255   BUKSYMF  = f.s. for symmetric general buckling
C    y   (  20,   0)    4      260   BUKASY   = antisymmetric general buckling
C    y   (  20,   0)    5      265   BUKASYA  = allowable for antisym. general buckling
C    y   (  20,   0)    6      270   BUKASYF  = f.s. for antisym. general buckling
C    n   (   0,   0)    2      280   JCYLBUK  = segment number in CYLBUK(NCASES,JCYLBUK)
C    y   (  20,  19)    4      285   CYLBUK   = classical buckling load factor
C    y   (  20,  19)    5      290   CYLBUKA  = allowable for classical buckling
C    y   (  20,  19)    6      295   CYLBUKF  = factor of safety for classical buckling
C    y   (  20,   0)    4      300   STRESS   = maximum effective stress
C    y   (  20,   0)    5      305   STRESSA  = allowable effective stress
C    y   (  20,   0)    6      310   STRESSF  = factor of safety for stress
C    n   (   0,   0)    7      315   WEIGHT   = weight of the corrugated panel (weight of WIDTH/2)
=========================================================================================
```

Table A2 Input for the GENOPT "BEGIN" processor: the mich8.BEG file for the specific case called "mich8" with nonlinear analysis for strategy index, ISTRAT = 13 . The starting design is similar to that of the final nonlinearly optimized design of the specific case called "mich8u" (mich8u = circumferentially corrugated shell with uniform corrugations, Table 3b).

```
=========================================================================================
      n          $ Do you want a tutorial session and tutorial output?
   100.0000      $ total width of the corrugated plate: WIDTH
   13.0          $ axial length of the corrugated plate: LENGTH
    3.0          $ fraction of LENGTH for local buckling model: FACLEN
         8       $ number of major segments in WIDTH/2: NSEG
  0.1000000E+08 $ elastic modulus of the material: EMOD
  0.3000000      $ Poisson ratio of the plate material: NU
  0.1000000      $ weight density of the plate material: DENSTY
         0       $ low end of M-range: symmetric GENERAL buckling: MLOWGS
        10       $ high end of M-range: symmetric GENERAL buckling: MHIGHGS
         0       $ low end of M-range: antisymmetric GENERAL buckling: MLOWGA
        10       $ high end of M-range: antisymmetric GENERAL buckling: MHIGHGA
```

```
      10       $ low end of the M-range: LOCAL buckling: MLOWL
     200       $ high end of the M-range: LOCAL buckling: MHIGHL
     480       $ finite element used in STAGS model: IELMNT
       8       $ Number INSUBSE of rows in the array  NSUBSEG: INSUBSE
       0       $ number of sub-segments in major segment: NSUBSEG(  1)
       0       $ number of sub-segments in major segment: NSUBSEG(  2)
       0       $ number of sub-segments in major segment: NSUBSEG(  3)
       0       $ number of sub-segments in major segment: NSUBSEG(  4)
       0       $ number of sub-segments in major segment: NSUBSEG(  5)
       0       $ number of sub-segments in major segment: NSUBSEG(  6)
       0       $ number of sub-segments in major segment: NSUBSEG(  7)
       0       $ number of sub-segments in major segment: NSUBSEG(  8)
       1       $ 1 = convex surface up; 2 = convex down: UPDOWN(  1)
       2       $ 1 = convex surface up; 2 = convex down: UPDOWN(  2)
       1       $ 1 = convex surface up; 2 = convex down: UPDOWN(  3)
       2       $ 1 = convex surface up; 2 = convex down: UPDOWN(  4)
       1       $ 1 = convex surface up; 2 = convex down: UPDOWN(  5)
       2       $ 1 = convex surface up; 2 = convex down: UPDOWN(  6)
       1       $ 1 = convex surface up; 2 = convex down: UPDOWN(  7)
       2       $ 1 = convex surface up; 2 = convex down: UPDOWN(  8)
       0       $ Number JUPDWNS of columns in the array, UPDWNS: JUPDWNS
       1       $ 1=convex up (hill); 2=convex down (valley): UPDNBIG
       8       $ Number ITHICK  of rows in the array  THICK: ITHICK
 0.0459400     $ wall thickness of the major segment: THICK(  1)
 0.0459400     $ wall thickness of the major segment: THICK(  2)
 0.0459400     $ wall thickness of the major segment: THICK(  3)
 0.0459400     $ wall thickness of the major segment: THICK(  4)
 0.0459400     $ wall thickness of the major segment: THICK(  5)
 0.0459400     $ wall thickness of the major segment: THICK(  6)
 0.0459400     $ wall thickness of the major segment: THICK(  7)
 0.0459400     $ wall thickness of the major segment: THICK(  8)
  3.571        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  7.143        $ projected width (x-width) of sub-plate: SUBWID(  1)
  3.571        $ projected width (x-width) of sub-plate: SUBWID(  1)
  32.14000     $ half-angle (deg.) of major corrugation: PHISEG(  1)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  2)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  3)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  4)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  5)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  6)
  64.28000     $ half-angle (deg.) of major corrugation: PHISEG(  7)
  32.14000     $ half-angle (deg.) of major corrugation: PHISEG(  8)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  1)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  2)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  3)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  4)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  5)
  70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  6)
```

```
   70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  7)
   70.00000     $ half-angle (deg.) of sub-corrugation: PHISUB(  8)
        9       $ Number IYPLATE of rows in the array  YPLATE: IYPLATE
   36.55000     $ vertical distance above (x,y,z) origin: YPLATE(  1)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  2)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  3)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  4)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  5)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  6)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  7)
   34.45000     $ vertical distance above (x,y,z) origin: YPLATE(  8)
   32.45000     $ vertical distance above (x,y,z) origin: YPLATE(  9)
   0.010000     $ half-angle (deg.) of overall arching: PHIBIG
        1       $ Number NCASES  of load cases (environments): NCASES
     -20.0      $ total axial load (e.g. lb): TOTLOD(  1)
   1.000000     $ allowable for local buckling: LOCBUKA(  1)
   1.600000     $ factor of safety for local buckling: LOCBUKF(  1)
   1.000000     $ allowable for sym. general buckling: BUKSYMA(  1)
   1.400000     $ f.s. for symmetric general buckling: BUKSYMF(  1)
   1.000000     $ allowable for antisym. general buckling: BUKASYA(  1)
   1.400000     $ f.s. for antisym. general buckling: BUKASYF(  1)
        8       $ Number JCYLBUK of columns in the array, CYLBUK: JCYLBUK
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  1)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  2)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  3)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  4)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  5)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  6)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  7)
   1.000000     $ allowable for classical buckling: CYLBUKA(  1,  8)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  1)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  2)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  3)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  4)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  5)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  6)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  7)
   1.000000     $ factor of safety for classical buckling: CYLBUKF(  1,  8)
   100000.0     $ allowable effective stress: STRESSA(  1)
   1.500000     $ factor of safety for stress: STRESSF(  1)
===============================================================================
```

Table A3 Input for the GENOPT "CHANGE" processor: the mich8.CHG file for the specific case called "mich8". This file regenerates the nonlinearly optimized "mich8" configuration listed in Table 2.

==

```
    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, . .)
0.414200E-01   $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       2       $ Number of parameter to change (1, 2, 3, . .)
0.414200E-01   $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       3       $ Number of parameter to change (1, 2, 3, . .)
0.414200E-01   $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       4       $ Number of parameter to change (1, 2, 3, . .)
0.4142000E-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, . .)
0.4142000E-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, . .)
0.4142000E-01  $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       7       $ Number of parameter to change (1, 2, 3, . .)
0.4142000E-01  $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       8       $ Number of parameter to change (1, 2, 3, . .)
0.4142000E-01  $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       9       $ Number of parameter to change (1, 2, 3, . .)
 2.741000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      10       $ Number of parameter to change (1, 2, 3, . .)
 8.565000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      11       $ Number of parameter to change (1, 2, 3, . .)
 5.998000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      12       $ Number of parameter to change (1, 2, 3, . .)
 8.933000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      13       $ Number of parameter to change (1, 2, 3, . .)
 5.641000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      14       $ Number of parameter to change (1, 2, 3, . .)
 8.440000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      15       $ Number of parameter to change (1, 2, 3, . .)
 5.709000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      16       $ Number of parameter to change (1, 2, 3, . .)
```

```
3.9480         $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     17        $ Number of parameter to change (1, 2, 3, . .)
36.23000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     18        $ Number of parameter to change (1, 2, 3, . .)
59.77000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     19        $ Number of parameter to change (1, 2, 3, . .)
40.02000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     20        $ Number of parameter to change (1, 2, 3, . .)
65.68000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     21        $ Number of parameter to change (1, 2, 3, . .)
42.94000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     22        $ Number of parameter to change (1, 2, 3, . .)
72.92000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     23        $ Number of parameter to change (1, 2, 3, . .)
47.38000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     24        $ Number of parameter to change (1, 2, 3, . .)
34.33000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     33        $ Number of parameter to change (1, 2, 3, . .)
35.82000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     34        $ Number of parameter to change (1, 2, 3, . .)
33.47000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     35        $ Number of parameter to change (1, 2, 3, . .)
33.45000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     36        $ Number of parameter to change (1, 2, 3, . .)
33.47000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     37        $ Number of parameter to change (1, 2, 3, . .)
33.52000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     38        $ Number of parameter to change (1, 2, 3, . .)
33.45000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     39        $ Number of parameter to change (1, 2, 3, . .)
33.45000       $ New value of the parameter
   y           $ Want to change any other parameters in this set?
     40        $ Number of parameter to change (1, 2, 3, . .)
```

```
   33.52000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        41      $ Number of parameter to change (1, 2, 3, . .)
   30.77000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        42      $ Number of parameter to change (1, 2, 3, . .)
  0.0100000     $ 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?
================================================================
```

Table A4 Input for the GENOPT "DECIDE" processor: the mich8.DEC file for the specific case called "mich8"

```
======================================================================
      n         $ Do you want a tutorial session and tutorial output?
         1      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  1)
  0.1000000     $ Upper bound of variable no.(  1)
      n         $ Do you want especially to restrict variable no.(  1)
      y         $ Any more decision variables (Y or N) ?
         9      $ Choose a decision variable (1,2,3,...)
         2      $ Lower bound of variable no.(  9)
        20      $ Upper bound of variable no.(  9)
      n         $ Do you want especially to restrict variable no.(  9)
      y         $ Any more decision variables (Y or N) ?
        10      $ Choose a decision variable (1,2,3,...)
         2      $ Lower bound of variable no.( 10)
        20      $ Upper bound of variable no.( 10)
      n         $ Do you want especially to restrict variable no.( 10)
      y         $ Any more decision variables (Y or N) ?
        11      $ Choose a decision variable (1,2,3,...)
         2      $ Lower bound of variable no.( 11)
        20      $ Upper bound of variable no.( 11)
      n         $ Do you want especially to restrict variable no.( 11)
      y         $ Any more decision variables (Y or N) ?
        12      $ Choose a decision variable (1,2,3,...)
         2      $ Lower bound of variable no.( 12)
        20      $ Upper bound of variable no.( 12)
      n         $ Do you want especially to restrict variable no.( 12)
      y         $ Any more decision variables (Y or N) ?
```

```
    13       $ Choose a decision variable (1,2,3,...)
     2       $ Lower bound of variable no.( 13)
    20       $ Upper bound of variable no.( 13)
 n           $ Do you want especially to restrict variable no.( 13)
 y           $ Any more decision variables (Y or N) ?
    14       $ Choose a decision variable (1,2,3,...)
     2       $ Lower bound of variable no.( 14)
    20       $ Upper bound of variable no.( 14)
 n           $ Do you want especially to restrict variable no.( 14)
 y           $ Any more decision variables (Y or N) ?
    15       $ Choose a decision variable (1,2,3,...)
     2       $ Lower bound of variable no.( 15)
    20       $ Upper bound of variable no.( 15)
 n           $ Do you want especially to restrict variable no.( 15)
 y           $ Any more decision variables (Y or N) ?
    16       $ Choose a decision variable (1,2,3,...)
     2       $ Lower bound of variable no.( 16)
    20       $ Upper bound of variable no.( 16)
 n           $ Do you want especially to restrict variable no.( 16)
 y           $ Any more decision variables (Y or N) ?
    17       $ Choose a decision variable (1,2,3,...)
    10       $ Lower bound of variable no.( 17)
    80       $ Upper bound of variable no.( 17)
 n           $ Do you want especially to restrict variable no.( 17)
 y           $ Any more decision variables (Y or N) ?
    18       $ Choose a decision variable (1,2,3,...)
    20       $ Lower bound of variable no.( 18)
    80       $ Upper bound of variable no.( 18)
 n           $ Do you want especially to restrict variable no.( 18)
 y           $ Any more decision variables (Y or N) ?
    19       $ Choose a decision variable (1,2,3,...)
    20       $ Lower bound of variable no.( 19)
    80       $ Upper bound of variable no.( 19)
 n           $ Do you want especially to restrict variable no.( 19)
 y           $ Any more decision variables (Y or N) ?
    20       $ Choose a decision variable (1,2,3,...)
    20       $ Lower bound of variable no.( 20)
    80       $ Upper bound of variable no.( 20)
 n           $ Do you want especially to restrict variable no.( 20)
 y           $ Any more decision variables (Y or N) ?
    21       $ Choose a decision variable (1,2,3,...)
    20       $ Lower bound of variable no.( 21)
    80       $ Upper bound of variable no.( 21)
 n           $ Do you want especially to restrict variable no.( 21)
 y           $ Any more decision variables (Y or N) ?
    22       $ Choose a decision variable (1,2,3,...)
    20       $ Lower bound of variable no.( 22)
    80       $ Upper bound of variable no.( 22)
```

```
n         $ Do you want especially to restrict variable no.( 22)
y         $ Any more decision variables (Y or N) ?
  23      $ Choose a decision variable (1,2,3,...)
  20      $ Lower bound of variable no.( 23)
  80      $ Upper bound of variable no.( 23)
n         $ Do you want especially to restrict variable no.( 23)
y         $ Any more decision variables (Y or N) ?
  24      $ Choose a decision variable (1,2,3,...)
  10      $ Lower bound of variable no.( 24)
  80      $ Upper bound of variable no.( 24)
n         $ Do you want especially to restrict variable no.( 24)
y         $ Any more decision variables (Y or N) ?
  33      $ Choose a decision variable (1,2,3,...)
  34.5    $ Lower bound of variable no.( 33)
  50      $ Upper bound of variable no.( 33)
n         $ Do you want especially to restrict variable no.( 33)
y         $ Any more decision variables (Y or N) ?
  34      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 34)
  50      $ Upper bound of variable no.( 34)
n         $ Do you want especially to restrict variable no.( 34)
y         $ Any more decision variables (Y or N) ?
  35      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 35)
  50      $ Upper bound of variable no.( 35)
n         $ Do you want especially to restrict variable no.( 35)
y         $ Any more decision variables (Y or N) ?
  36      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 36)
  50      $ Upper bound of variable no.( 36)
n         $ Do you want especially to restrict variable no.( 36)
y         $ Any more decision variables (Y or N) ?
  37      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 37)
  50      $ Upper bound of variable no.( 37)
n         $ Do you want especially to restrict variable no.( 37)
y         $ Any more decision variables (Y or N) ?
  38      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 38)
  50      $ Upper bound of variable no.( 38)
n         $ Do you want especially to restrict variable no.( 38)
y         $ Any more decision variables (Y or N) ?
  39      $ Choose a decision variable (1,2,3,...)
  33.5    $ Lower bound of variable no.( 39)
  50      $ Upper bound of variable no.( 39)
n         $ Do you want especially to restrict variable no.( 39)
y         $ Any more decision variables (Y or N) ?
  40      $ Choose a decision variable (1,2,3,...)
```

```
   33.5    $ Lower bound of variable no.( 40)
   50      $ Upper bound of variable no.( 40)
  n        $ Do you want especially to restrict variable no.( 40)
  y        $ Any more decision variables (Y or N) ?
   41      $ Choose a decision variable (1,2,3,...)
   30      $ Lower bound of variable no.( 41)
   50      $ Upper bound of variable no.( 41)
  n        $ Do you want especially to restrict variable no.( 41)
  n        $ Any more decision variables (Y or N) ?
  y        $ Any linked variables (Y or N) ?
    2      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
    1      $ To which variable is this variable linked?
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) ?
    3      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
    1      $ To which variable is this variable linked?
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) ?
    4      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
    1      $ To which variable is this variable linked?
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) ?
    5      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
    1      $ To which variable is this variable linked?
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) ?
    6      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
    1      $ To which variable is this variable linked?
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) ?
         7      $ Choose a linked variable (1,2,3,...)
         1      $ Choose type of linking (1=polynomial; 2=user-defined)
         1      $ To which variable is this variable linked?
   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) ?
         8      $ Choose a linked variable (1,2,3,...)
         1      $ Choose type of linking (1=polynomial; 2=user-defined)
         1      $ To which variable is this variable linked?
   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)
   6.050000     $ Give a value to the constant, C0
         9      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000     $ 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 +...
        10      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000     $ 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 +...
        11      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000     $ 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 +...
        12      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000     $ 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 +...
        13      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000     $ 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 +...
```

```
       14      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000    $ 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 +...
       15      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000    $ 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 +...
       16      $ Choose a variable from the list above (1, 2, 3,...)
 -0.1000000    $ 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)
  -3.995000    $ Give a value to the constant, C0
        9      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       10      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       11      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       12      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       13      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       14      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
```

```
       15      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
       16      $ Choose a variable from the list above (1, 2, 3,...)
  0.1000000    $ 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 +...
      n        $ Are there any more inequality expressions?
      y        $ Any escape variables (Y or N) ?
      y        $ Want to have escape variables chosen by default?
====================================================================
```

Table A5 Input for the GENOPT "MAINSETUP" processor: the mich8.OPT file for the specific case called "mich8". This file corresponds to the so-called "xx62" strategy with 12 iterations/OPTIMIZE. "xx" stands for the number of executions of OPTIMIZE for each execution of AUTOCHANGE.

```
================================================================================
      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
        12     $ 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
         6     $ Choose 1 or 2 or 3 or 4 or 5 or 6 for move limits, IMOVE
      n        $ Do you want default (RATIO=10) for initial move limit jump?
    100000     $ Provide a value for the "move limit jump" ratio, RATIO
      n        $ Do you want the default perturbation (dx/x = 0.05)?
  0.1000000E-01 $ Amount by which decision variables are perturbed, dx/x
      n        $ Do you want to have dx/x modified by GENOPT?
      n        $ Do you want to reset total iterations to zero (Type H)?
         2     $ Choose IAUTOF=1 or 2 or 3 or 4 or 5 or 6 or 7 to change X(i)
=================================================================================
```

Table A6 Output from the GENOPT "OPTIMIZE" processor: a somewhat abridged mich8.OPM file for the specific case called "mich8" with nonlinear analysis corresponding to the strategy index, ISTRAT = 13 . This is the nonlinearly optimized design listed in Table 2, in which the mich8.OPM file is presented in a more severely abridged form than the less abridged mich8.OPM file presented here. The most important output lines here are in bold face.

```
================================================================================
      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
        12      $ 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
         6      $ Choose 1 or 2 or 3 or 4 or 5 or 6 for move limits, IMOVE
      n         $ Do you want default (RATIO=10) for initial move limit jump?
    100000      $ Provide a value for the "move limit jump" ratio, RATIO
      n         $ Do you want the default perturbation (dx/x = 0.05)?
  0.1000000E-01 $ Amount by which decision variables are perturbed, dx/x
      n         $ Do you want to have dx/x modified by GENOPT?
      n         $ Do you want to reset total iterations to zero (Type H)?
         2      $ Choose IAUTOF=1 or 2 or 3 or 4 or 5 or 6 or 7 to change X(i)

 ************ END OF THE  mich8.OPT  FILE ***********
 ************ April 2014 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  mich8.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 mich8.  Results are stored in the file  mich8.OPM.
 Please inspect mich8.OPM before doing more design iterations.
 ************************************************************

 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.   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     Y     N      0   0.00E+00  3.00E-02 4.1420E-02  1.00E-01  wall
thickness of the major segment: THICK(1 )
   2   N     N     Y      1   1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(2 )
   3   N     N     Y      1   1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(3 )
   4   N     N     Y      1   1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(4 )
   5   N     N     Y      1   1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(5 )
```

```
   6   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(6 )
   7   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(7 )
   8   N     N     Y      1    1.00E+00  0.00E+00 4.1420E-02  0.00E+00  wall
thickness of the major segment: THICK(8 )
   9   Y     N     N      0    0.00E+00  2.00E+00 2.7410E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(1 )
  10   Y     N     N      0    0.00E+00  2.00E+00 8.5650E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(2 )
  11   Y     N     N      0    0.00E+00  2.00E+00 5.9980E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(3 )
  12   Y     N     N      0    0.00E+00  2.00E+00 8.9330E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(4 )
  13   Y     N     N      0    0.00E+00  2.00E+00 5.6410E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(5 )
  14   Y     N     N      0    0.00E+00  2.00E+00 8.4400E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(6 )
  15   Y     N     N      0    0.00E+00  2.00E+00 5.7090E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(7 )
  16   Y     N     N      0    0.00E+00  2.00E+00 3.9480E+00  2.00E+01  projected
width (x-width) of major segment: SUBWID(8 )
  17   Y     N     N      0    0.00E+00  1.00E+01 3.6230E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(1 )
  18   Y     N     N      0    0.00E+00  2.00E+01 5.9770E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(2 )
  19   Y     N     N      0    0.00E+00  2.00E+01 4.0020E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(3 )
  20   Y     N     N      0    0.00E+00  2.00E+01 6.5680E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(4 )
  21   Y     N     N      0    0.00E+00  2.00E+01 4.2940E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(5 )
  22   Y     N     N      0    0.00E+00  2.00E+01 7.2920E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(6 )
  23   Y     N     N      0    0.00E+00  2.00E+01 4.7380E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(7 )
  24   Y     N     N      0    0.00E+00  1.00E+01 3.4330E+01  8.00E+01  half-
angle (deg.) of major corrugation: PHISEG(8 )
  25   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(1 )
  26   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(2 )
  27   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(3 )
  28   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(4 )
  29   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(5 )
  30   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(6 )
  31   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(7 )
```

```
  32   N     N     N      0    0.00E+00  0.00E+00 7.0000E+01  0.00E+00  half-
angle (deg.) of sub-corrugation: PHISUB(8 )
  33   Y     N     N      0    0.00E+00  3.45E+01 3.5820E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(1 )
  34   Y     N     N      0    0.00E+00  3.35E+01 3.3470E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(2 )
  35   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(3 )
  36   Y     N     N      0    0.00E+00  3.35E+01 3.3470E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(4 )
  37   Y     N     N      0    0.00E+00  3.35E+01 3.3520E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(5 )
  38   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(6 )
  39   Y     N     N      0    0.00E+00  3.35E+01 3.3450E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(7 )
  40   Y     N     N      0    0.00E+00  3.35E+01 3.3520E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(8 )
  41   Y     N     N      0    0.00E+00  3.00E+01 3.0770E+01  5.00E+01  vertical
y above (x,y,z) origin if PHIBIG=0: YPLATE(9 )
  42   N     N     N      0    0.00E+00  0.00E+00 1.0000E-02  0.00E+00  half-
angle (deg.) of overall arching: PHIBIG

 ****** UNPERTURBED DESIGN *******
 ******** IMODX= 0 ********



 Critical local buckling load factor from quasi-linear
 theory (INDIC = 1): LOCLIN =   1.6639E+00
 Critical number of circumferential waves from quasi-linear
 theory (INDIC = 1): NWVCRT=   75
   75 is used as a starting value for the number of
 circ. waves in a subsequent nonlinear (INDIC = -2) analysis.

BIGBOSOR4 input file for: local buckling load
mich8.BEHX1

 LOCAL BUCKLING LOAD FACTORS AND MODES (BEHX1)
       1.5896E+00(  75)
 Critical buckling load factor, LOCBUK=  1.5896E+00
 Critical number of circumferential waves, NWVCRT=   75
 ISTRAT>=8. Therefore, the local buckling load factor is
 taken as the minimum from quasi-linear and nonlinear theory.
 Local buckling load factor from quasi-linear theory=1.6639E+00
 Local buckling load factor from    nonlinear theory=1.5896E+00
    1        1.589560      local buckling load factor: LOCBUK(1)
-------------------------------------------------------------------------------
```

```
 Critical "symsymgenbuck" general buckling load factor from
 quasi-linear theory (INDIC = 1): GENLIN =   1.6364E+00
 Critical number of circumferential waves from quasi-linear
 theory (INDIC = 1): NWVCRT=    2
    2 is used as a starting value for the number of
 circ. waves in a subsequent nonlinear (INDIC = -2) analysis.
```

STAGS input file for michelin:
mich8.inp3

BIGBOSOR4 input file for: general symmetric buckling load (long shell)

mich8.BEHX2

```
 GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX2)
 symmetry at the bottom; symmetry at the top.
        1.4225E+00(   2)
 Critical buckling load factor, BUKSYM=  1.4225E+00
 Critical number of circumferential waves, NWVCRT=    2
 The symsymgenbuck general buckling load factor is
 taken as the minimum from quasi-linear and nonlinear theory.
 General buckling load factor from quasi-linear theory=
1.6364E+00
 General buckling load factor from    nonlinear theory=
1.4225E+00
    2        1.422529      symmetric general buckling: BUKSYM(1)
-------------------------------------------------------------------
```

STAGS input file for michelin:
mich8.inp4

```
 Critical "symantigenbuck" general buckling load factor from
 quasi-linear theory (INDIC = 1): GENLIN =   1.7083E+00
 Critical number of circumferential waves from quasi-linear
 theory (INDIC = 1): NWVCRT=    2
    2 is used as a starting value for the number of
 circ. waves in a subsequent nonlinear (INDIC = -2) analysis.
```

BIGBOSOR4 input file for: general antisymmetric buckling load (long shell)

mich8.BEHX3

```
GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX3)
 symmetry at the bottom; anti-symmetry at the top.
        1.5019E+00(   2)
 Critical buckling load factor, BUKASY=  1.5019E+00
```

Critical number of circumferential waves, NWVCRT= 2
The symantigenbuck general buckling load factor is
taken as the minimum from quasi-linear and nonlinear theory.
General buckling load factor from quasi-linear theory=
1.7083E+00
General buckling load factor from nonlinear theory=
1.5019E+00

STAGS input file for michelin:
mich8.inp5

```
 Critical "antiantigenbuck" general buckling load factor from
 quasi-linear theory (INDIC = 1): GENLIN =   1.6182E+00
 Critical number of circumferential waves from quasi-linear
 theory (INDIC = 1): NWVCRT=    2
    2 is used as a starting value for the number of
 circ. waves in a subsequent nonlinear (INDIC = -2) analysis.

 BIGBOSOR4 input file for: general antisymmetric buckling load2 (long shell)
```

mich8.BEHX32

GENERAL BUCKLING LOAD FACTORS AND MODES (BEHX32)
anti-symmetry at the bottom; anti-symmetry at the top.
1.3969E+00(2)
Critical buckling load factor, BUKASY= 1.3969E+00
Critical number of circumferential waves, NWVCRT= 2
The antiantigenbuck general buckling load factor is
taken as the minimum from quasi-linear and nonlinear theory.
General buckling load factor from quasi-linear theory=
1.6182E+00
General buckling load factor from nonlinear theory=
1.3969E+00
3 1.396896 antisymmetric general buckling: BUKASY(1)

```
  BEHAVIOR OVER J =  segment number
    4       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,1 )
    5       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,2 )
    6       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,3 )
    7       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,4 )
    8       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,5 )
    9       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,6 )
   10       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,7 )
   11       0.1000000E+11  classical buckling load factor: CYLBUK(1 ,8 )
```

```
------------------------------------------------------------------

maximum stress in michelin shell from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  0.0000E+00 in which JCOL = 1
mich8.BEHX5

 ****** MAX. END SHORTENING, LOAD SET A ************
 ENDUVS(1)= -1.0307E+00
 ******************************************************

 ****** MAX. EFF. STRESS IN ISOTROPIC WALL,LOAD A ******
 STRMAX =  5.2657E+04
 ****************************************************
   12        52657.11      maximum effective stress: STRESS(1 )
------------------------------------------------------------------

***** RESULTS FOR LOAD SET NO.  1  ******
PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)
 BEH.   CURRENT
 NO.     VALUE             DEFINITION
  1    1.590E+00    local buckling load factor: LOCBUK(1 )
  2    1.423E+00    symmetric general buckling: BUKSYM(1 )
  3    1.397E+00    antisymmetric general buckling: BUKASY(1 )
  4    1.000E+10    classical buckling load factor: CYLBUK(1,1 )
  5    1.000E+10    classical buckling load factor: CYLBUK(1,2 )
  6    1.000E+10    classical buckling load factor: CYLBUK(1,3 )
  7    1.000E+10    classical buckling load factor: CYLBUK(1,4 )
  8    1.000E+10    classical buckling load factor: CYLBUK(1,5 )
  9    1.000E+10    classical buckling load factor: CYLBUK(1,6 )
 10    1.000E+10    classical buckling load factor: CYLBUK(1,7 )
 11    1.000E+10    classical buckling load factor: CYLBUK(1,8 )
12    5.266E+04    maximum effective stress: STRESS(1 )
------------------------------------------------------------------

***** RESULTS FOR LOAD SET NO.  1  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    5.250E-02  6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)
-0.10*V(13)-0
  2    2.500E-03  -3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)
+0.10*V(13)+
  3   -6.525E-03  (LOCBUK(1 )/LOCBUKA(1 )) / LOCBUKF(1 )-1; F.S.=  1.60
  4    1.609E-02  (BUKSYM(1 )/BUKSYMA(1 )) / BUKSYMF(1 )-1; F.S.=  1.40
```

```
 5   -2.217E-03  (BUKASY(1 )/BUKASYA(1 )) / BUKASYF(1 )-1; F.S.=  1.40
 6    2.661E-01  (STRESSA(1 )/STRESS(1 )) / STRESSF(1 )-1; F.S.=  1.50
------------------------------------------------------------------------

 ***************************************************
 ******************* DESIGN OBJECTIVE ******************
 *************                    ***********
```

CURRENT VALUE OF THE OBJECTIVE FUNCTION:

VAR. NO.	CURRENT VALUE	DEFINITION
1	5.183E+01	weight of the corrugated panel: WEIGHT

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

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

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.000E+02	total width of the corrugated panel: WIDTH
2	1.300E+01	axial length of the corrugated panel: LENGTH
3	3.000E+00	fraction of LENGTH for local buckling model: FACLEN
4	1.000E+07	elastic modulus of the material: EMOD
5	3.000E-01	Poisson ratio of the panel material: NU
6	1.000E-01	weight density of the panel material: DENSTY

PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR. NO.	CURRENT VALUE	DEFINITION
1	-2.000E+01	total axial load (e.g. lb) over WIDTH: TOTLOD(1)

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

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.000E+00	allowable for local buckling: LOCBUKA(1)
2	1.000E+00	allowable for sym. general buckling: BUKSYMA(1)
3	1.000E+00	allowable for antisym. general buckling: BUKASYA(1)
4	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,1)
5	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,2)
6	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,3)
7	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,4)
8	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,5)
9	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,6)
10	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,7)
11	1.000E+00	allowable for classical buckling: CYLBUKA(1 ,8)
12	**1.000E+05**	**allowable effective stress: STRESSA(1)**

```
PARAMETERS WHICH ARE FACTORS OF SAFETY
 VAR.   CURRENT
 NO.      VALUE              DEFINITION
  1     1.600E+00  factor of safety for local buckling:LOCBUKF(1)
  2     1.400E+00  f.s. for symmetric general buckling:BUKSYMF(1)
  3     1.400E+00  f.s. for antisym. general buckling: BUKASYF(1)
  4     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,1 )
  5     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,2 )
  6     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,3 )
  7     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,4 )
  8     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,5 )
  9     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,6 )
 10     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,7 )
 11     1.000E+00  factor of safety for classical buckling: CYLBUKF(1 ,8 )
 12     1.500E+00  factor of safety for stress: STRESSF(1 )

    2 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED
  1 <6.05-0.10*V(9)-0.10*V(10)-0.10*V(11)-0.10*V(12)-0.10*V(13)
-0.10*V(14)..etc.
  1 <-3.99+0.10*V(9)+0.10*V(10)+0.10*V(11)+0.10*V(12)+0.10*V(13)
+0.10*V(14)..etc.
```

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

 mich8.NAM = This file contains only the name of the case.
 mich8.OPM = Output data. Please list this file and inspect
            carefully before proceeding.
 mich8.OPP = Output file containing evolution of design and
            margins since the beginning of optimization cycles.
 mich8.CBL = Labelled common blocks for analysis.
            (This is an unformatted sequential file.)
 mich8.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 mich8.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".
 **** NOTE: It is almost always best to set the number of ****
 **** iterations per execution of "OPTIMIZE" equal to 5   ****
```

```
 **** in response to the following prompt in "MAINSETUP": ****
 **** "How many design iterations in this run (3 to 25)?" ****
 **** Hence, the *.OPT file should almost always have the ****
 **** following line in it:                               ****
 **** "5   $ How many design iterations in this run (3 to 25)?"
 ******************** END OF mich8.OPM FILE ****************

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

Table A7a Abridged output from BIGBOSOR4 for analysis type INDIC = -2 . Added comments in bold face are inserted. (This list output is part of the BIGBOSOR4 output file, mich8.OUT.)

===

(Results from many load steps given in the mich8.OUT file are not listed here in order to save space. Only the last two load steps are listed, as follows):

```
PRESSURE MULTIPLIER, P=   1.399999E+00
 ITERATION NO.  0 MAXIMUM DISPLACEMENT=  8.4501E+00
 ITERATION NO.  1 MAXIMUM DISPLACEMENT=  8.4497E+00
 NUMBER OF CIRCUMFERENTIAL WAVES =      2      2      2      2
 IDETCT,KTM,KROOTS=          0       384       384
 VALUE OF STABILITY DETERMINANT =  5.7181E+07
 TIMES TEN TO THE       30610TH POWER

 PRESSURE MULTIPLIER, P=   1.419999E+00
 ITERATION NO.  0 MAXIMUM DISPLACEMENT=  8.5540E+00
 ITERATION NO.  1 MAXIMUM DISPLACEMENT=  8.5537E+00
 NUMBER OF CIRCUMFERENTIAL WAVES =      2      2      2      2
 VALUE OF STABILITY DETERMINANT = -4.9473E+07
 TIMES TEN TO THE       30610TH POWER
 IDETCT,KTM,KROOTS=          1       385       384
```

(Skipped roots in the stability stiffness matrix, K1(n,load level), in which n is the number of circumferential waves, are detected between pressure, p = 1.399999 and p = 1.419999. A control index, IDETCT, is set equal to unity. The continuing BIGBOSOR4 output, somewhat abridged and edited here, follows.)

```
 BIFURCATION BUCKLING EIGENVALUE(S) DETECTED BETWEEN
 SECOND-TO-LAST AND LAST LOAD STEPS FOR N = 2 CIRCUMFER-
```

```
 ENTIAL WAVES.  ANALYSIS TYPE (INDIC) IS NOW BEING CHANGED
 FROM INDIC = -2  TO  INDIC = -1  .

 A SEARCH FOR THE MINIMUM BIFURCATION BUCKLING LOAD WILL NOW
 BE CONDUCTED IN THE RANGE NMINB = -10 TO NMAXB = 10
 IN INCREMENTS OF INCRB = 1 CIRCUMFERENTIAL WAVES.

 PRESSURE MULTIPLIER, P= 1.410722E+00
           (load factor at the 2nd-to-last load step after interpolation)

 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 0
 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 1
 NEWTON-RAPHSON ITERATIONS REQUIRED FOR CONVERGENCE=ITER=1

 PRESSURE MULTIPLIER, P= 1.419999E+00
                         (load factor at the last load step)

 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 0
 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 1
 NEWTON-RAPHSON ITERATIONS REQUIRED FOR CONVERGENCE=ITER=1

(Next, solve the eigenvalue problem:
 K1(n, 1.410722) - LAMBDA x K2[n,(1.42000-1.410722)] = 0.0
 in which

 K1 = stiffness matrix for n circumferential waves
      corresponding to the load factor 1.410722)
 K2 = load-geometric matrix for n circumferential waves
      corresponding to the load factor increment,
      (1.42000-1.410722)
 LAMBDA = the eigenvalue being sought

 and search over n for the minimum eigenvalue, EIGENVALUE.)

 NUMBER OF CIRC. WAVES, n = 2;  EIGENVALUE=  1.1194E+00 (See Table A7b)
 NUMBER OF CIRC. WAVES, n = 3;  EIGENVALUE=  8.2910E+02 (See Table A7b)
 NUMBER OF CIRC. WAVES, n = 1;  EIGENVALUE=  1.5212E+04 (See Table A7b)

Critical wavenumber, N = 2, and eigenvalue, RHOS = 1.1194E+00
(A minimum eigenvalue with respect to n has been found at n = 2)

(See Table A7b for more BIGBOSOR4 output generated by SUBROUTINE EBAND2
for each eigenvalue during the search over the number of circumferential
waves n for a minimum eigenvalue with respect to n.)

 PRESSURE MULTIPLIER, P= 1.421107E+00
                       = (1.42 – 1.410722)x1.11945 + 1.410722
```

```
 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 0
 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO. 1
 NEWTON-RAPHSON ITERATIONS REQUIRED FOR CONVERGENCE=ITER=1

 PRESSURE MULTIPLIER, P= 1.422529E+00
                       = 1.421107 + 1.421107/1000.0

 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO.  0
 FACTORING AND SOLVING COMPLETED FOR PRESTRESS ITERATION NO.  1
 NEWTON-RAPHSON ITERATIONS REQUIRED FOR CONVERGENCE=ITER=1

 Number of circ. waves, n = 2; EIGENVALUE= -4.3970E+00

(In view of the very small load increment, 1.421107/1000, the eigenvalue,
-4.3970, is small enough so that BIGBOSOR4 accepts the load factor,
1.422529, as the converged, final value.)

 PRESSURE MULTIPLIER = 1.422529E+00

In B4MAIN: EIGCRT=  1.422529E+00
  ENTERING BIGBOSOR4 POSTPROCESSOR...

 PRESSURE MULTIPLIER (LOAD SYSTEM "A") = 1.422529E+00

(1.423 is the “symsymgenbuck” nonlinear general buckling load factor
called “BUKSYM” that is listed as one of the “behaviors” in Table 2.)
===================================================================
```

Table A7b Output from BIGBOSOR4 generated during the determination in SUBROUTINE EBAND2 of each eigenvalue in the search over number of circumferential waves, n, for the minimum eigenvalue with respect to n (This list output is part of the BIGBOSOR4 output file, mich8.OUT.)

```
=========================================================================
(The following 3 lines are taken from Table A7a)
 NUMBER OF CIRC. WAVES, n = 2;  EIGENVALUE=  1.1194E+00 (See Table A7b)
 NUMBER OF CIRC. WAVES, n = 3;  EIGENVALUE=  8.2910E+02 (See Table A7b)
 NUMBER OF CIRC. WAVES, n = 1;  EIGENVALUE=  1.5212E+04 (See Table A7b)

(The rest of this table lists output generated by SUBROUTINE EBAND2 of
BIGBOSOR4 during the determination of each of the eigenvalues just
listed.)
```

```
ENTER EBAND2 TO CALCULATE LOWEST 1 EIGENVALUE. WAVENUMBER,N= 2 CIRC. WAVES
  384 NEGATIVE ROOTS FOR SHIFT. AXT = -0.00000E+00
 NSHIFT=    1
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO  1, 2 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  0.00000E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.12474E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.11950E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.11945E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.11945E+00
 ITERATIONS HAVE CONVERGED FOR EIGENVALUE NO.  1
      EIGENVALUE =  1.11945E+00,       2 CIRCUMFERENTIAL WAVES
  384 NEGATIVE ROOTS FOR SHIFT. AXT = -1.11978E+00
 IDETCT,KTM,KROOTS=         1       384       384
 NUMBER OF CIRCUMFERENTIAL WAVES =  2  2  2  2 EIGENVALUE= 1.11945E+00
```

[COMMENT: Inverse power iterations for the eigenvalue (buckling load factor) for n = 2 circumferential waves converge easily because the stability determinant corresponding to n = 2 changes sign between pressure multiplier, P= 1.40 and P= 1.42. (See the top part of Table A7a.) As written at the top part of Table A7a, the eigenvalue problem for n = 2 is:
K1(n, 1.410722) - LAMBDA x K2[n,(1.42000-1.410722)] = 0.0
which means that we are searching for the smallest eigenvalue in the neighborhood of pressure multiplier, P= 1.410722. With the pressure multiplier, P = 1.410722 the smallest eigenvalue in the neighborhood of pressure multiplier, P= 1.410722 is much smaller than the second-smallest eigenvalue in that neighborhood, resulting in a rapid convergence of the inverse power iterations for n = 2 circumferential waves.]

[Next, we search for the smallest eigenvalue corresponding to a POSITIVE pressure multiplier, P for n = 3 circumferential waves, followed by a search for the smallest eigenvalue corresponding to a POSITIVE pressure multiplier. P for n = 1 circumferential wave. We do this in order to determine if the eigenvalue corresponding to n = 2 is a minimum with respect to n. Typically, the POSITIVE general buckling load factors (positive eigenvalues) for n = 3 and especially for n = 1 are much higher than that for n = 2. (See the list of general buckling load factors for n = 1, 2 and 3 given in Item 4 of Section 9.) Therefore, the eigenvalue shift, 1.410722, appropriate for n = 2, is not at all close to the POSITIVE general buckling load factors for n = 3 and especially for n = 1. Also, typically for "michelin" configurations, a uniformly laterally pressurized circumferentially corrugated shell of revolution can buckle under INTERNAL pressure at lower load factors than under EXTERNAL pressure. (See Figs. 44 and 45, for example.) This means that the closest eigenvalues for n = 3 and especially for n = 1 (Figs. 44 and 45) are usually negative. Therefore, for each value of n (first for n = 3 and then for n = 1) SUBROUTINE EBAND2 has to try to shift away from a prominent negative root (eigenvalue). Convergence to the lowest POSITIVE eigenvalue is therefore a much longer process for n = 3 and n = 1 than it was for n =

2, for which, during the INDIC = -2 process in BIGBOSOR4, we have previously already determined (by a load-stepping process) that the lowest positive eigenvalue lies between pressure multiplier, P=1.40 and 1.42.]

```
ENTER EBAND2 TO CALCULATE LOWEST 1 EIGENVALUE. WAVENUMBER,N= 3 CIRC. WAVES
  384 NEGATIVE ROOTS FOR SHIFT. AXT = -0.00000E+00
 NSHIFT=    1
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  0.00000E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -3.82958E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.95030E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.75441E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.64014E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.58575E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.55481E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.53743E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.52653E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.51911E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.51350E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.50887E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.50478E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.50100E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.49742E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.49397E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.49064E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.48741E+02

  384 NEGATIVE ROOTS FOR SHIFT. AXT = -3.73112E+02
 NSHIFT=    2
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  6.14442E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -6.19744E+03
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  5.79580E+03
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.67400E+03
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.09758E+03
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  9.82066E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.90889E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.74110E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.50398E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.47183E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.39947E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.39129E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.36676E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.36327E+02

  384 NEGATIVE ROOTS FOR SHIFT. AXT = -7.66845E+02
 NSHIFT=    3
```

```
BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.34590E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.33341E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.32428E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.31713E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.31163E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30751E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30448E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30230E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30074E+02

 385 NEGATIVE ROOTS FOR SHIFT. AXT = -8.29442E+02
NSHIFT=    4
********** WARNING  WARNING  WARNING **********
IT IS POSSIBLE FOR THIS WAVENUMBER THAT EIGENVALUES
MAY BE CALCULATED OUT OF ORDER OR THAT EIGENVALUES MAY BE
SKIPPED.
 Number of eigenvalues accepted so far              =    0
 Number of eigenvalues skipped                      =    1
 IFLAG,AXR2,AX1                            =    1  8.2944E+02  0.0000E+00
 Shifting downward to try to capture lo,wer eigenvalues.
 If, after this warning message, the following lines appear
 everything is okay:
  FINISH FORMING B - AXT*C AND START FACTORING.
M  NEGATIVE ROOTS FOR SHIFT, AXT =   -YYYYYYY
THERE ARE    0  EIGENVALUES BETWEEN 0.0000 AND YYYYYYY
 The thing to look for is that "0  EIGENVALUES BETWEEN..."
******** END WARNING    END WARNING    END WARNING *******

 384 NEGATIVE ROOTS FOR SHIFT. AXT = -5.80609E+02
NSHIFT=    5
BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  9.15999E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.29870E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.82091E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.49256E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.42801E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.40205E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.38554E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.37500E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.36729E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.36138E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.35649E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.35225E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.34844E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.34493E+02

 384 NEGATIVE ROOTS FOR SHIFT. AXT = -7.96410E+02
```

```
 NSHIFT=    6
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.33392E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.31979E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.31127E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30651E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30395E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30259E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30184E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30140E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30111E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30090E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30072E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30056E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30040E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.30024E+02

  384 NEGATIVE ROOTS FOR SHIFT. AXT = -8.24982E+02
 NSHIFT=    7
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 3 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29957E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29816E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29661E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29512E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29386E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29289E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29221E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29175E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29146E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29128E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29117E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29110E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29105E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  8.29103E+02

 ITERATIONS HAVE CONVERGED FOR EIGENVALUE NO.  1
      EIGENVALUE =  8.29103E+02,       3 CIRCUMFERENTIAL WAVES
  385 NEGATIVE ROOTS FOR SHIFT. AXT = -8.29351E+02
 NUMBER OF CIRCUMFERENTIAL WAVES =  3  3  3  3 EIGENVALUE= 8.2910E+02
```

[COMMENT: Finally, convergence to the smallest eigenvalue corresponding to a POSITIVE pressure multiplier, P has been achieved for n = 3. The process in SUBROUTINE EBAND2 is much longer for n= 3 circumferential waves than for n = 2 circumferential waves because the initial “eigenvalue shift”, 1.410722, is not close to the smallest eigenvalue corresponding to a POSTIVE pressure multiplier, P for n = 3. It has been found that this smallest eigenvalue for n = 3 is larger than that for n = 2. Therefore, SUBROUTINE EBAND2 next tries to find the smallest eigenvalue corresponding

to a POSITIVE pressure multiplier, P for n = 1 in order to ascertain that n = 2 corresponds to the critical general buckling load factor corresponding to POSITIVE pressure multiplier, P, that is, the lowest general buckling eigenvalue with respect to number n of circumferential waves for the EXTERNALLY laterally pressurized shell.]

[Next, SUBROUTINE EBAND2 attempts to find the lowest POSITIVE pressure multiplier, P for n = 1 circumferential wave. For n = 1 the smallest NEGATIVE root (eigenvalue) is more prominent, that is, SUBROUTINE EBAND2 has a harder time shifting away from it in order to determine the smallest POSITIVE pressure multiplier, P.]

```
ENTER EBAND2 TO CALCULATE LOWEST 1 EIGENVALUES. WAVENUMBER,N= 1 CIRC.WAVES
  385 NEGATIVE ROOTS FOR SHIFT. AXT = -0.00000E+00
 NSHIFT=    1
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO  1, 1 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  0.00000E+00
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.31054E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.14724E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.08775E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.05924E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.04417E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.03571E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.03080E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02788E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02611E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02503E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02436E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02395E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.02368E+02

  385 NEGATIVE ROOTS FOR SHIFT. AXT = -3.03553E+02
 NSHIFT=    2
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC. WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  3.14738E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.38153E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.17570E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.13086E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.10272E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.08399E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.07070E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.06087E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.05338E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.04757E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.04300E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.03936E+02
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.03646E+02
```

```
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.03412E+02

 385 NEGATIVE ROOTS FOR SHIFT. AXT = -1.06400E+03
NSHIFT=    3
BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC.WAVES.
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  9.22911E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -9.68318E+01
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.47549E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.61658E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.71061E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.77327E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.81863E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.85288E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.87961E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.90098E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.91840E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.93281E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.94488E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.95508E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.96376E+02

 385 NEGATIVE ROOTS FOR SHIFT. AXT = -2.95456E+03
NSHIFT=    4
BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC.WAVES.
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  2.91960E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -9.14917E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.05539E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.78169E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.50631E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.47287E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.41965E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.38615E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.35680E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.33228E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.31075E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.29172E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.27467E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.25930E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.24535E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.23264E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.22100E+02
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.21030E+02

 385 NEGATIVE ROOTS FOR SHIFT. AXT = -7.71795E+03
NSHIFT=    5
BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC.WAVES.
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  7.48904E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -1.15928E+04
```

```
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  2.71566E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -3.14583E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.51927E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.48709E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.46687E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.62319E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.59954E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -2.92194E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.77580E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -3.30267E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.97356E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -3.76113E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  2.18832E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -4.30951E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  2.41865E+03
EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -4.96838E+03

 399 NEGATIVE ROOTS FOR SHIFT. AXT = -2.67474E+04
 398 NEGATIVE ROOTS FOR SHIFT. AXT = -2.54101E+04
 397 NEGATIVE ROOTS FOR SHIFT. AXT = -2.41396E+04
 396 NEGATIVE ROOTS FOR SHIFT. AXT = -2.29326E+04
 396 NEGATIVE ROOTS FOR SHIFT. AXT = -2.17860E+04
 394 NEGATIVE ROOTS FOR SHIFT. AXT = -2.06967E+04
 391 NEGATIVE ROOTS FOR SHIFT. AXT = -1.96618E+04
 388 NEGATIVE ROOTS FOR SHIFT. AXT = -1.86787E+04
 388 NEGATIVE ROOTS FOR SHIFT. AXT = -1.77448E+04
 388 NEGATIVE ROOTS FOR SHIFT. AXT = -1.68576E+04
 388 NEGATIVE ROOTS FOR SHIFT. AXT = -1.60147E+04
 386 NEGATIVE ROOTS FOR SHIFT. AXT = -1.52139E+04

********** WARNING  WARNING  WARNING **********
IT IS POSSIBLE FOR THIS WAVENUMBER THAT EIGENVALUES
MAY BE CALCULATED OUT OF ORDER OR THAT EIGENVALUES MAY BE
SKIPPED.
 Number of eigenvalues accepted so far               =    0
 Number of eigenvalues skipped                       =    1
 IFLAG,AXR2,AX1                         =    1  1.5214E+04  0.0000E+00
 Shifting downward to try to capture lo,wer eigenvalues.
 If, after this warning message, the following lines appear
 everything is okay:
  FINISH FORMING B - AXT*C AND START FACTORING.
M  NEGATIVE ROOTS FOR SHIFT, AXT =   -YYYYYYY
THERE ARE    0  EIGENVALUES BETWEEN 0.0000 AND YYYYYYY
 The thing to look for is that "0  EIGENVALUES BETWEEN..."
******** END WARNING    END WARNING    END WARNING *******

 385 NEGATIVE ROOTS FOR SHIFT. AXT = -1.06498E+04
NSHIFT=    7
```

```
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.04887E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)= -3.24211E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  7.75356E+03
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  3.20202E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.30780E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.68213E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.47277E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.54892E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.51380E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52746E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52112E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52340E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52214E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52243E+04

  385 NEGATIVE ROOTS FOR SHIFT. AXT = -1.49956E+04
 NSHIFT=    8
 BEGIN INVERSE POWER ITERATIONS FOR EIGENVALUE NO 1, 1 CIRC.WAVES.
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52146E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52123E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52117E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52116E+04
 EIGENVALUE (FACTOR TO BE MULT. BY LOAD STEP)=  1.52115E+04

 ITERATIONS HAVE CONVERGED FOR EIGENVALUE NO.   1
      EIGENVALUE =  1.52115E+04,        1 CIRCUMFERENTIAL WAVES
 FORMAT130:FINISH FORMING B - AXT*C AND START FACTORING.
  386 NEGATIVE ROOTS FOR SHIFT. AXT = -1.52161E+04
 NUMBER OF CIRCUMFERENTIAL WAVES =  1  1  1  1 EIGENVALUE= 1.5212E+04
```

[COMMENT: After many initial "eigenvalue shifts" to avoid convergence to a NEGATIVE pressure mulitplier, P for n = 1, SUBROUTINE EBAND2 finally manages to converge to the lowest POSITIVE pressure multiplierm P. As listed in Table A7a, BIGBOSOR4 has determined that the critical general buckling load corresponds to n = 2 circumferential waves. Computations in BIGBOSOR4 continue as listed in Table A7a.]

===

Table A8 Input file, mich8.bin, for the first and second nonlinear STAGS executions for general buckling of the "mich8" configuration previously nonlinearly optimized by GENOPT/BIGBOSOR4. (See Table 2.)

```
==================================================================
PART 1 (mich8.bin for the first nonlinear STAGS execution):
optimized imperfect shell, nonlinear theory (INDIC=3)
 3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
 1, $ IPOST=1 means save displacements every IPOSTth step
 0, $ ILIST =0 means normal batch-oriented output
 0, $ ICOR  =0 means projection in; 1 means not in.
 1, $ IMPTHE=index for imperfection theory.
 0, $ IOPTIM=0 means bandwith optimization will be performed
 0, $ IFLU  =0 means no fluid interaction.
 -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
 5.000E-02, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
 5.000E-02, $ STEP(1) = load factor increment, System A
 1.200E+00, $ FACM(1) = maximum load factor, System A
 0.000E+00, $ STLD(2) = starting load factor, System B
 0.000E+00, $ STEP(2) = load factor increment, System B
 0.000E+00, $ FACM(2) = maximum load factor, System B
 0  $ ITEMP =0 means no thermal loads. END C-1 rec.
   0, $ ISTART=restart from ISTARTth load step.   BEGIN D-1 rec.
 5000,$ NSEC= number of CPU seconds before run termination
 15,$ NCUT = number of times step size may be cut
  -20, $ NEWT = number of refactorings allowed
-1,$ NSTRAT=-1 means path length used as independent parameter
 0.00005,$ DELX=convergence tolerance
 0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
 0,  1, 0  $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin.  ET-1

 PART 2 (part of the mich8.bin for the second nonlinear STAGS execution):
 1.20000,   $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
 5.000E-02, $ STEP(1) = load factor increment, System A
 1.250E+00, $ FACM(1) = maximum load factor, System A
 0.000E+00, $ STLD(2) = starting load factor, System B
 0.000E+00, $ STEP(2) = load factor increment, System B
 0.000E+00, $ FACM(2) = maximum load factor, System B
 0  $ ITEMP =0 means no thermal loads. END C-1 rec.
  10, $ ISTART=restart from ISTARTth load step.   BEGIN D-1 rec.
====================================================================
```

NOTE: The mich8.bin records not listed in PART 2 are the same as those listed under PART 1. A second nonlinear STAGS execution is usually required in order to “close in” on the correct nonlinear buckling load. The critical nonlinear buckling load is exact only if the eigenvalue obtained from the last two steps the load-stepping process is zero.

Table A9 A run stream for the previously nonlinearly optimized "mich8" configuration (Table 2), including GENOPT/BIGBOSOR4 executions and STAGS executions. This runstream is appropriate if a nonlinearly optimized design has already been found by GENOPT/BIGBOSOR4, and this optimum design has been archived in the file called "mich8.istrat13.veryverylatest.chg". This run stream demonstrates how many of the figures in the paper are created.

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

mich8.runstream [for a previously nonlinearly optimized
                "mich8" shell]

[How to re-run a "mich8" case with the use of the nonlinear
(INDIC = -2) analysis branch for both local and general
buckling (ISTRAT = 13 in mich8.BEG)]:

[First run GENOPT/BIGBOSOR4 in a NONLINEAR mode]:

cd /home/progs/genoptcase [directory for GENOPT execution]
begin [use ISTRAT = 13 in mich8.BEG, that is,
       LENGTH = 13 (3rd record in mich8.BEG; See Table A2.)]
cp mich8.istrat13.veryverylatest.chg mich8.CHG  [See Table A3.]
change [restore the archived nonlinearly optimized design]
cp mich8.nonlinear.dec mich8.DEC   [See Table A4.]
decide [obtain upper,lower bounds, linking, inequalities]
mainsetup [establish strategies, type of analysis. See Table A5.]
optimize  [run "mich8" in fixed design mode]
vi mich8.OPM [inspect the output file, mich8.OPM (See Tables 2, A6)]
-----------------------------------------------------------

[Next run "stand-alone" BIGBOSOR4 several times]:

cd /home/progs/work4 [working directory for BIGBOSOR4 runs]
bigbosor4log [activate the set of commands for BIGBOSOR4]

[First, get the axisymmetric pre-buckling behavior}:

cp ../genoptcase/mich8.BEHX5 mich8.ALL [get the BIGBOSOR4
    input file for axisymmetric nonlinear pre-buckling
    deformation and maximum effective stress]
bigbosorall  [execute BIGBOSOR4 with INDIC = 0: mich8.ALL]
vi mich8.OUT [inspect the BIGBOSOR4 output file. Search
              for the string "STRMAX" (maximum eff. stress)]
bosorplot    [get a plot of the discretized BIGBOSOR4 model]
gv metafile.ps [view the discretized model on your screen]
```

```
bosorplot    [get a plot of the pre-buckling deformation]
gv metafile.ps [view the pre-buckling deformation (Fig. 10)]
'rm' * [remove all files from /home/progs/work4]
```

[Next, get the nonlinear LOCAL buckling behavior]:

```
cp ../genoptcase/mich8.BEHX1 mich8.ALL [get the BIGBOSOR4
    input file for nonlinear (INDIC=-2) LOCAL buckling
    of the "mich8" shell
bigbosorall  [execute BIGBOSOR4 with INDIC = -2: mich8.ALL]
vi mich8.OUT [inspect the BIGBOSOR4 output file. Search
              for the string "EIGENVALUE(", then look at
              the part of the file that follows that string.
              Or, simpler, go to the end of the file, then
              search backward for the string, "PRESSURE".
              Look for the local buckling load factor. See Table A7a.]
bosorplot    [get a plot of the nonlinear LOCAL buckling mode]
gv metafile.ps [view the LOCAL buckling mode on your screen
                (Fig. 11)]
'rm' * [remove all files from /home/progs/work4]
```

[Next, get the nonlinear "symsymgenbuck" GENERAL buckling]:

```
cp ../genoptcase/mich8.BEHX2 mich8.ALL [get the BIGBOSOR4
    input file for nonlinear (INDIC=-2) GENERAL "symsymgenbuck"
    buckling of the "mich8" shell]
bigbosorall  [execute BIGBOSOR4 with INDIC = -2: mich8.ALL]
vi mich8.OUT [inspect the BIGBOSOR4 output file. Search
              for the string "EIGENVALUE(", then look at
              the part of the file that follows that string.
              Or, simpler, go to the end of the file, then
              search backward for the string, "PRESSURE".
              Look for the "symsymgenbuck" GENERAL buckling
              load factor. See Table A7a.]
bosorplot    [get a plot of the nonlinear "symsymgenbuck"
              GENERAL buckling mode]
gv metafile.ps [view the "symsymgenbuck" GENERAL buckling mode
                on your screen (Fig. 13a)]
'rm' * [remove all files from /home/progs/work4]
```

[Next, get the nonlinear "symantigenbuck" GENERAL buckling]:

```
cp ../genoptcase/mich8.BEHX2 mich8.ALL [get the BIGBOSOR4
    input file for nonlinear (INDIC=-2) GENERAL "symantigenbuck"
    buckling of the "mich8" shell]
bigbosorall  [execute BIGBOSOR4 with INDIC = -2: mich8.ALL]
vi mich8.OUT [inspect the BIGBOSOR4 output file. Search
              for the string "EIGENVALUE(", then look at
```

```
              the part of the file that follows that string.
              Or, simpler, go to the end of the file, then
              search backward for the string, "PRESSURE".
              Look for the "symantigenbuck" GENERAL buckling
              load factor. See Table A7a.]
bosorplot    [get a plot of the nonlinear "symantigenbuck"
              GENERAL buckling mode]
gv metafile.ps [view the "symantigenbuck" GENERAL buckling mode
                on your screen (Fig. 13b)]
'rm' * [remove all files from /home/progs/work4]
```

[Next, get the nonlinear "antiantigenbuck" GENERAL buckling]:

```
cp ../genoptcase/mich8.BEHX2 mich8.ALL [get the BIGBOSOR4
    input file for nonlinear (INDIC=-2) GENERAL "antiantigenbuck"
    buckling of the "mich8" shell]
bigbosorall  [execute BIGBOSOR4 with INDIC = -2: mich8.ALL]
vi mich8.OUT [inspect the BIGBOSOR4 output file. Search
              for the string "EIGENVALUE(", then look at
              the part of the file that follows that string.
              Or, simpler, go to the end of the file, then
              search backward for the string, "PRESSURE".
              Look for the "antiantigenbuck" GENERAL buckling
              load factor. See Table A7a.]
bosorplot    [get a plot of the nonlinear "antiantigenbuck"
              GENERAL buckling mode]
gv metafile.ps [view the "antiantigenbuck" GENERAL buckling mode
                on your screen (Fig. 13c)]
'rm' * [remove all files from /home/progs/work4]
---------------------------------------------------------------
```

[Next, run STAGS for two cases: "symantigenbuck" nonlinear GENERAL buckling and "antiantigenbuck" nonlinear GENERAL buckling]:

```
cd /home/stags/stagsops [go to working directory for STAGS
                         executions]
source /home/stags/prc/initialize  [activate STAGS]
```

[First run STAGS for "symantigenbuck" GENERAL buckling]:

```
cp /home/progs/genoptcase/mich8.inp4 mich8.inp [get the
      STAGS *.inp file for "symantigenbuck" GENERAL buckling]
cp nonlinearbuck.bin mich8.bin   [get STAGS *.bin file (Table A8).
                      Edit the mich8.bin file, if necessary]
/home/stags/prc/stags -b mich8 [run STAGS]
[Inspect the STAGS output file, mich8.out2. First, look for the
 string "roots", then look for the string "CONV" to see the
```

```
 "symantigenbuck" nonlinear GENERAL buckling load factor
 predicted by STAGS.]
cp nonlinearbuck.pin mich8.pin  [*.pin file for plotting the
                                 buckling mode from STAGS]
[Edit the mich8.pin file for the correct load step]
stapl mich8     [execute the STAGS post-processor, STAPL]
acroread mich8.pdf  [see the "symantigenbuck" GENERAL buckling
                     mode from STAGS on your screen
                     (Fig. 14a)]
'rm' mich8*        [remove all the "mich8" files]
```

[Next run STAGS for "antiantigenbuck" GENERAL buckling]:

```
cp /home/progs/genoptcase/mich8.inp5 mich8.inp [get the
      STAGS *.inp file for "antiantigenbuck" GENERAL buckling]
cp nonlinearbuck.bin mich8.bin   [get STAGS *.bin file. Table A8
                      Edit the mich8.bin file, if necessary]
/home/stags/prc/stags -b mich8 [run STAGS]
[Inspect the STAGS output file, mich8.out2. First, look for the
 string "roots", then look for the string "CONV" to see the
 "antiantigenbuck" nonlinear GENERAL buckling load factor
 predicted by STAGS.]
cp nonlinearbuck.pin mich8.pin  [*.pin file for plotting the
                                 buckling mode from STAGS]
[Edit the mich8.pin file for the correct load step]
stapl mich8     [execute the STAGS post-processor, STAPL]
acroread mich8.pdf  [see the "antiantigenbuck" GENERAL
                     buckling mode from STAGS on your screen
                     (Fig. 14b)]
'rm' mich8*         [remove all the "mich8" files]
-------------------------------------------------------------
```

[**Next, run STAGS for nonlinear LOCAL buckling. This step is a bit "tricky"** because, in order to get the proper mich8.inp file for the prediction of local buckling by STAGS, we have to first run GENOPT/BIGBOSOR4 in a LINEAR mode so that the STAGS input file, mich8.inp2, gets created. This "tricky" business is required because of the lack of the inclusion of "smoothing" segments in the "mmm0.5" STAGS half-module models. (An example of a STAGS half-module model is shown in Fig. 1 of the paper. Erroneously, there are no "smoothing" segments in that STAGS model that should be there. These "smoothing" segments are absent because the author of this paper never re-programmed SUBROUTINE BEHX1 to include "smoothing" segments in a STAGS half-module model, that is, in a STAGS model of axial length equal to WIDTH/2.)]

[First run GENOPT/BIGBOSOR4 in a LINEAR mode]:

```
cd /home/progs/genoptcase [directory for GENOPT execution]
begin [use ISTRAT = 1 in mich8.BEG, that is,
       LENGTH = 1 (3rd record in mich8.BEG; See Table A2)]
cp mich8.linear.dec mich8.DEC  [See Table A4.)
decide [obtain upper,lower bounds, linking, inequalities]
mainsetup [establish strategies, type of analysis; see Table A5.]
optimize  [run "mich8" in fixed design mode]

cd /home/stags/stagsops [go to working directory for STAGS
                         executions]
source /home/stags/prc/initialize  [activate STAGS]
```

[Run STAGS for nonlinaer LOCAL buckling]:

```
cp /home/progs/genoptcase/mich8.inp2 mich8.inp [get the
      STAGS *.inp file for LOCAL buckling]
cp nonlinearbuck.bin mich8.bin   [get STAGS *.bin file. Table A8
                      Edit the mich8.bin file, if necessary]
/home/stags/prc/stags -b mich8 [run STAGS]
[Inspect the STAGS output file, mich8.out2. First, look for the
 string "roots", then look for the string "CONV" to see the
 nonlinear LOCAL buckling load factor predicted by STAGS.]
cp nonlinearbuck.pin mich8.pin  [*.pin file for plotting the
                                 buckling mode from STAGS]
[Edit the mich8.pin file for the correct load step]
stapl mich8     [execute the STAGS post-processor, STAPL]
acroread mich8.pdf  [see the nonlinear LOCAL buckling
                     mode from STAGS on your screen
                     (Fig. 12)]
'rm' mich8*        [remove all the "mich8" files]
==============================================================
```