Table 1 Glossary of the variables for the generic case, “balloon”. These variables and their definitions, roles, etc. are established by the GENOPT user during the interactive session, GENTEXT.

ARRAY ?	NUMBER OF (ROWS,COLS)	ROLE	PROMPT NUMBER (balloon.PRO)	NAME	DEFINITION OF VARIABLE	NEW INPUT
n	(0, 0)	2	10	LENGTH	=length of the cylindrical shell	
n	(0, 0)	2	15	RADIUS	=inner radius of the cylindrical balloon	
n	(0, 0)	2	20	NMODUL	=number of modules over 90 degrees	
n	(0, 0)	2	30	ISHAPE	=balloon shape index	(NEW)
n	(0, 0)	2	40	IWEBS	=radial (1) or truss-like (2) webs	(NEW)
n	(0, 0)	2	50	IEMOD1	=material number in EMOD1(IEMOD1)	
y	(10, 0)	2	55	EMOD1	=elastic modulus, meridional direction	
y	(10, 0)	2	60	EMOD2	=elastic modulus, circumferential direction	
y	(10, 0)	2	65	G12	=in-plane shear modulus	
y	(10, 0)	2	70	G13	=out-of-plane (s,z) shear modulus	
y	(10, 0)	2	75	G23	=out-of-plane (y,z) shear modulus	
y	(10, 0)	2	80	NU	=Poisson ratio	
y	(10, 0)	2	85	ALPHA1	=meridional coef. thermal expansion	
y	(10, 0)	2	90	ALPHA2	=circumf.coef.thermal expansion	
y	(10, 0)	2	95	TEMPER	=delta-T from fabrication temperature	
y	(10, 0)	2	100	DENSTY	=weight density of material	
n	(0, 0)	1	110	HEIGHT	=height from inner to outer membranes	
n	(0, 0)	1	115	RINNER	=radius of curvature of inner membrane	
n	(0, 0)	1	120	ROUTER	=radius of curvature of outer membrane	
n	(0, 0)	1	125	TINNER	=thickness of the inner curved membrane	
n	(0, 0)	1	130	TOUTER	=thickness of the outer curved membrane	
n	(0, 0)	1	135	TFINNR	=thickness of inner truss-core segment	
n	(0, 0)	1	140	TFOUTR	=thickness of the outer truss segment	
n	(0, 0)	1	145	TFWEBS	=thickness of each truss-core web	
n	(0, 0)	2	155	NCASES	=Number of load cases (number of environments)	
y	(20, 0)	3	160	PINNER	=pressure inside the inner membrane	
y	(20, 0)	3	165	PMIDDL	=pressure between inner and outer membranes	
y	(20, 0)	3	170	POUTER	=pressure outside the outer membrane	
y	(20, 0)	4	180	BUCKB4	=buckling load factor from BIGBOSOR4	(NEW NAME)
y	(20, 0)	5	185	BUCKB4A	=buckling from BIGBOSOR4 allowable	(NEW NAME)
y	(20, 0)	6	190	BUCKB4F	=buckling from BIGBOSOR4 factor of safety	(NEWNAME)
y	(20, 0)	4	200	TENLOS	=load factor for tension loss	(NEW)
y	(20, 0)	5	205	TENLOSA	=tension loss allowable (Use 1.0)	(NEW)
y	(20, 0)	6	210	TENLOSF	=tension loss factor of safety	(NEW)
n	(0, 0)	2	215	JSTRM1	=stress component number in STRM1(NCASES,JSTRM1)	
y	(20, 5)	4	220	STRM1	=stress component in material 1	
y	(20, 5)	5	225	STRM1A	=allowable stress in material 1	
y	(20, 5)	6	230	STRM1F	=factor of safety for stress in material 1	
y	(20, 5)	4	235	STRM2	=stress component in material 2	
y	(20, 5)	5	240	STRM2A	=allowable for stress in material 2	
y	(20, 5)	6	245	STRM2F	=factor of safety for stress in material 2	
y	(20, 5)	4	250	STRM3	=stress component in material 3	
y	(20, 5)	5	255	STRM3A	=allowable for stress in material 3	
y	(20, 5)	6	260	STRM3F	=factor of safety for stress in material 3	
n	(0, 0)	7	270	WEIGHT	=weight/length of the balloon	

Table 2 The prompting file, balloon.PRO, generated automatically by the GENTEXT processor. This file contains the one-line prompts and "help" paragraphs that are created by the GENOPT user and seen by the end user. Note the new items and re-wording since [1] was written.

```
=========================================================
   5.0
       This GENOPT case is for a cylindrical or spherical balloon
       the wall of which is a double-walled sandwich made of cloth.
       The case was brought to the attention of the author,
       David Bushnell, by Mike Mayo (650-354-5463) on September 21,
       1010. In this application, GENOPT works with BIGBOSOR4.
       The cylindrical or spherical "balloon" has inner pressure
       equal to PINNER, outer pressure equal to POUTER, and
       pressure inside the double-walled sandwich equal to PMIDDL.
       PINNER is the lowest pressure, PMIDDL is the highest
       pressure, and POUTER is higher than PINNER but lower than
       PMIDDL. PMIDDL must be high enough to provide enough
       tension in the membrane segments of the "balloon" to
       prevent buckling under the difference, POUTER - PINNER.
       Details of the model and results are presented in Ref.[1]:
       [1a] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain
       optimum designs of a double-walled inflatable cylindrical
       vacuum chamber", unpublished report dated November, 2010.
       [1b] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain
       optimum designs of a double-walled inflatable spherical
       vacuum chamber", unpublished report dated December, 2010.
       Although the BIGBOSOR4 computer program is intended for
       use with axisymmetric shell structures with "finite"
       bending stiffness, the results obtained from this study of
       a balloon that consists of "shell" segments that act like
       membranes with essentially zero bending stiffness seem to
       be reasonable. It is emphasized that the results presented
       in [1] should be verified via models of the optimized
       designs from one or more general-purpose finite element
       codes such as STAGS or ABAQUS or NASTRAN.

  10.1 length of the cylindrical shell: LENGTH
  10.2
       Use a value of about 6000 inches. It should not
       matter what value you use because buckling (or collapse)
       with N = zero circumferential waves around the circumference
       of the huge torus is expected to be critical as of this
       writing. N = 1 is used instead of N = 0 in order to
       avoid rigid body "buckling" possible with N = 0.
       Therefore, always use a very large value for LENGTH.

  15.1 inner radius of the balloon: RADIUS
  15.2
       This is the radius to the points on the INNER membranes
       where these "shell" segments are connected to each other.
```

See Figs. 1 and 4 of [1a] and Figs. 1 and 2 of [1b].

20.1 number of modules over 90 degrees: NMODUL
20.2
This is the number of triangular "trusses" with two points
on the inner membrane and one point on the outer membrane
over a 90-degree sector of the circumference of the
cylindrical balloon (Figs.2,5 of [1a]) or over 90 degrees
of the meridian of the spherical balloon (Fig. 2
of [1b]). The webs can be radial rather than truss-like.
In that case NMODUL is equal to the number of radial
webs over 90 degrees of the circumference of the
cylindrical balloon (Figs. 1 and 4 of [1a] or over
90 degrees of the meridian of the spherical balloon
(Fig. 1 of [1b]).

25.0
The balloon can be either cylindrical or spherical.
An index called "ISHAPE" is used to establish which shape
of balloon you want to design and analyze:
ISHAPE = 1 means "cylindrical balloon"
ISHAPE = 2 means "spherical balloon"
Choose ISHAPE = 1 or ISHAPE = 2.

30.1 balloon shape index: ISHAPE
30.2
ISHAPE = 1 means "cylindrical balloon"
ISHAPE = 2 means "spherical balloon"

35.0
Next, you will be asked for a control index called "IWEBS".
IWEBS = 1 means that the double-walled balloon has radial
webs. (See Figs. 1 and 4 of [1a], Fig.1 of [1b].)
IWEBS = 2 means that the double-walled balloon has truss-like
(slanted) webs. (See Figs. 2 and 5 of [1a], Fig.2 of [1b].)

40.1 radial (1) or truss-like (2) webs: IWEBS
40.2
Use IWEBS = 1 for radial webs.
Use IWEBS = 2 for truss-like (slanted) webs.

45.0
Next you will be asked to provide material properties.
Three different materials are allowed:
1. The material of the outer and inner curved membranes.
2. The material of the outer and inner "truss" members
that run in the circumferential direction.
3. The material out of which the "truss" (slanted, Fig.2)
or radial (Fig. 1) webs are fabricated.
The material is orthotropic with the following properties:
EMOD1 = modulus in the meridional direction, that is,

in the direction along the arc of each shell segment in
the plane of the cross section of the complex wall
of the balloon.
EMOD2 = modulus in the circumferential direction of the
huge torus, that is, the modulus along the axis of the
prismatic (cylindrical) balloon or the modulus in the
circumferential direction of the spherical balloon.
G12 = in-plane shear modulus, that is, in the plane of
the wall of a "shell" segment
G13 = out-of plane shear modulus (not used, input required)
G23 = out-of-plane shear mdoulus (not used, input required)
NU = Poisson ratio
ALPHA1 = coefficient of thermal expansion in the meridional
direction
ALPHA2 = coefficient of thermal expansion in the
circumferential direction (prismatic axial direction in
the case of the cylindrical balloon)
TEMPER = temperature difference from the temperature at
which the balloon was fabricated (not used, input required)
DENSTY = weight density of the material
(Aluminum = 0.1 lb/in^3)

50.1 Number IEMOD1 of rows in the array EMOD1: IEMOD1
55.1 elastic modulus, meridional direction: EMOD1
60.1 elastic modulus, circumferential direction: EMOD2
65.1 in-plane shear modulus: G12
70.1 out-of-plane (s,z) shear modulus: G13
75.1 out-of-plane (y,z) shear modulus: G23
80.1 Poisson ratio: NU
85.1 meridional coef. thermal expansion: ALPHA1
90.1 circumf.coef.thermal expansion: ALPHA2
95.1 delta-T from fabrication temperature: TEMPER
100.1 weight density of material: DENSTY

105.0
Next, you will be asked to supply the decision variable
candidates. These are as follows:
1. HEIGHT = radial difference between the inner radius, RADIUS,
and the outer radius where the various segments
of the "balloon" are joined together. (See Fig. 1 of [1a].)
2. RINNER = radius of curvature of the inner curved membrane,
the one that "bulges" inward. (See Fig. 1 of [1a].)
3. ROUTER = radius of curvature of the outer curved membrane,
the one that "bulges" outward. (See Fig. 1 of [1a].)
4. TINNER = thickness of the inner curved membrane
5. TOUTER = thickness of the outer curved membrane
6. TFINNR = thickness of outer triangular truss segment
7. TFOUTR = thickness of inner triagular truss segment
8, TFWEBS = thickness of the webs

110.1 height from inner to outer membranes: HEIGHT
110.2
This is the difference from inner to outer radii at the
points where the inner segments are joined to eachother

and the outer segments are joined to eachother, that is, the height between inner and outer walls of the "balloon" not including the inward "bulging" of the inner wall and the outward "bulging" of the outer wall (Fig.1, [1a]).

115.1 radius of curvature of inner membrane: RINNER
120.1 radius of curvature of outer membrane: ROUTER
125.1 thickness of the inner curved membrane: TINNER
130.1 thickness of the outer curved membrane: TOUTER
135.1 thickness of inner truss-core segment: TFINNR
135.2

The three straight segments that form each module of the truss core have different thicknesses as follows:
1. The outer truss-core member that is oriented in the circumferential direction has thickness, TFOUTR.
2. The inner truss-core member that is oriented in the circumferential direction has thickness, TFINNR.
3. The two truss-core webs each have thickness, TFWEBS, or if the webs are radial each web has thickness, TFWEBS.

140.1 thickness of the outer truss segment: TFOUTR
140.2

The three straight segments that form each module of the truss core have different thicknesses as follows:
1. The outer truss-core member that is oriented in the circumferential direction has thickness, TFOUTR.
2. The inner truss-core member that is oriented in the circumferential direction has thickness, TFINNR.
3. The two truss-core webs each have thickness, TFWEBS or if the webs are radial each web has thickness, TFWEBS.

145.1 thickness of each truss-core web: TFWEBS
145.2

The three straight segments that form each module of the truss core have different thicknesses as follows:
1. The outer truss-core member that is oriented in the circumferential direction has thickness, TFOUTR.
2. The inner truss-core member that is oriented in the circumferential direction has thickness, TFINNR.
3. The two truss-core webs each have thickness, TFWEBS or if the webs are radial each web has thickness, TFWEBS.

150.0

Next, you will be asked to provide three pressures, PINNER, PMIDDL, and POUTER, which are different from each other and which are uniform over the entire structure.
1. PINNER = pressure inside the inner membrane. This is the lowest of the three pressures.
2. PMIDDL = pressure between the inner curved membrane and outer curved membrane. This is the highest of the

three pressures.
3. POUTER = pressure outside the outer curved membrane.
This pressure is higher than PINNER and lower than
PMIDDL.
Use positive numbers for PINNER, PMIDDL, and POUTER.

155.1 Number NCASES of load cases (environments): NCASES
160.1 pressure inside the inner membrane: PINNER
165.1 pressure between inner and outer membranes: PMIDDL
170.1 pressure outside the outer membrane: POUTER

175.0

Next, you will be asked to provide the "behaviors" that
might affect the evolution of the design during optimization
cycles. The "behaviors" included here are:
1. buckling from BIGBOSOR4: BUCKB4, BUCKB4A, BUCKB4F
BUCKB4 = buckling load factor computed from BIGBOSOR4
BUCKB4A= buckling from BIGBOSOR4 allowable
BUCKB4F= buckling from BIGBOSOR4 factor of safety
NOTE: The "BUCKB4" mode shape may represent
local buckling or general buckling. In this generic
"balloon" case only the lowest buckling eigenvalue
is computed, whether it correspond to a general
buckling mode shape or whether it correspond to a
local buckling mode shape. Whichever buckling mode
happens to be represented by "BUCKB4" will correspond
to the lowest eigenvalue. The other type of buckling
(general buckling if the lowest eigenvalue corresponds
to local buckling and local buckling if the lowest
eigenvalue corresponds to general buckling) will be
higher than the eigenvalue used to generate the
buckling constraint condition.
2. loss of prebuckling tension, TENLOS, TENLOSA, TENLOSF,
in which TENLOS = load factor applied to POUTER that
that corresponds to the initial loss of tension in any
of the shell segments.
3. stresses: STRMi(j,k), STRMiA(j,k), STRMiF(j,k)
in which "i" is the material number, "j" is the load case
number (always 1 here), and "k" is the stress component.
STRMi(j,k) is the maximum stress.
STRMiA(j,k) is the stress allowable
STRMiF(j,k) is the stress factor of safety.
There are five stress components:
STRMi(j,1) = maximum tensile stress in the meridional direction
STRMi(j,2) = maximum compressive stress in the meridional direction
STRMi(j,3) = maxiamum tensile stress in the circumfer. direction
In the case of the cylindrical balloon, STRMi(j,3) is the
maximum tensile stress along the axis of the prismatic
shell, that is, in the circumferential direction of the
"huge torus" model of the cylindrical shell. The "huge torus"
model of a cylindrical shell is shown in Fig. 3 of [1a].
STRMi(j,4) = maximum compressive stress in the circumf.direction
The same comment applies to STRMi(j,4) as to STRMi(j,3).
STRMi(j,5) = maximum in-plane shear stress.

This is in the plane of each segment of the multi-segment
model of the cylindrical or spherical balloon.

180.0 buckling load factor from BIGBOSOR4: BUCKB4
185.1 buckling from BIGBOSOR4 allowable: BUCKB4A
185.2

Usually, you supply 1.0 for BUCKB4A because BUCKB4 is
a buckling load FACTOR, that is, a quantity that is
to be multiplied by the design loads in order to obtain
the buckling load.

190.1 buckling from BIGBOSOR4 factor of safety: BUCKB4F
190.2

For this problem, use a value that depends of POUTER.
For example, suppose you want to design the balloon for
an external pressure, POUTER = 15 psi. Corresponding to
POUTER = 15 psi you would use a factor of safety,
BUCKB4F = 1.0. However, because of the nonlinearity of
the pre-buckling equilibrium state of the balloon the
Newton iterations may fail to converge if you use
POUTER = 15 psi. You will probably want to use POUTER = 5
psi, or something like that. If you use POUTER = 5 psi,
you must correspondingly use a factor of safety of 3.0
instead of 1.0. Always maintain the correspondence:
(design pressure)/POUTER = BUCKB4F
This "rule" also applies to the factor of safety
associated with the constraint called "TENLOS",
to be called "TENLOSF" and to be asked for below.

195.0

Next, you will be asked to supply an allowable and a
factor of safety for the load factor, TENLOS, that
corresponds to the initial loss of tension in any of the
segments of the balloon subjected to the total load,
that is, to PINNER, PMIDDL, DELTAT (if any), and POUTER.
The allowable should always be 1.0. The factor of safety
depends on what you used for POUTER. If POUTER = the
design pressure,say, POUTER = 15 psi, then you should use
a factor of safety, TENLOSF = 1.0. If you use a smaller
value of POUTER, say, POUTER = 5 psi, then you must use
a correspondingly higher factor of safety, TENLOSF = 3.0
psi. The "rule" is the same as that governing BUCKB4F.

200.0 load factor for tension loss: TENLOS
200.2

This is the load factor to be applied to POUTER. What
value of POUTER will cause the first complete loss of
tension in any of the segments of the balloon? In the
case of the cylindrical balloon we are concerned only
with meridional tension, that is, tension in the plane
of the cross section of the double-wall. In the case of
the spherical balloon we are concerned with the initial
loss of either meridional tension or circumferential

tension.

205.1 tension loss allowable (Use 1.0): TENLOSA
210.1 tension loss factor of safety: TENLOSF
210.2
The factor of safety you use must be related to the value of POUTER that you used above. If POUTER = the design pressure, then use TENLOSF = 1.0. If POUTER is less than the design pressure, then use a correspondingly higher value for the factor of safety, TENLOSF. For example, if POUTER = 5 psi instead of the design pressure, POUTER = 15 psi, the use TENLOSF = 3.0 instead of 1.0. Maintain the correspondence, (design pressure)/POUTER = TENLOSF.

215.1 Number JSTRM1 of columns in the array, STRM1: JSTRM1
220.0 stress component in material 1: STRM1
220.2
For an orthotropic material there are 5 stress components for which stress constraints may be generated:
1. maximum tensile stess in the meridional direction
2. maximum compressive stress in the meridional direction
3. maximum tensile stress in the circumferential direction
4. maximum compressive stress in the circumferential direction
5. maximum in-plane shear stress

225.1 allowable stress in material 1: STRM1A
225.2
For an orthotropic material there are 5 stress components for which stress constraints are generated:
1. maximum tensile stress in the meridional direction:
STRM1A(i,1), in which "i" is the load set number
2. maximum compressive stress in the meridional direction:
STRM1A(i,2), in which "i" is the load set number
3. maximum tensile stress in the circumferential direction:
STRM1A(i,3), in which "i" is the load set number
4. maximum compressive stress in the circumferential direction:
STRM1A(i,4), in which "i" is the load set number
5. maximum in-plane shear stress
STRM1A(i,5), in which "i" is the load set number

230.1 factor of safety for stress in material 1: STRM1F
230.2
In this application use a factor of safety of 1.0

235.0 stress component in material 2: STRM2
240.1 allowable for stress in material 2: STRM2A
245.1 factor of safety for stress in material 2: STRM2F
250.0 stress component in material 3: STRM3
255.1 allowable for stress in material 3: STRM3A
260.1 factor of safety for stress in material 3: STRM3F

265.0
Next, you will be asked to provide an objective.
In this case the objective is the weight/(axial length)

```
       of the balloon.
       This definition, "weight/length of the balloon", is
       appropriate only for the cylindrical balloon. In spite
       of this fact, the same definition is also used for
       the WEIGHT of the spherical balloon. However, in the
       case of the spherical balloon, the variable, WEIGHT,
       is the total weight of the spherical balloon and is
       computed by BIGBOSOR4 as the BIGBOSOR4 variable called
       "TOTMAS". In the case of the cylindrical balloon the
       variable WEIGHT is computed in SUBROUTINE BOSDEC.

 270.0 weight/length of the balloon: WEIGHT
 270.2
       This definition, "weight/length of the balloon", is
       appropriate only for the cylindrical balloon. In spite
       of this fact, the same definition is also used for
       the WEIGHT of the spherical balloon. However, in the
       case of the spherical balloon, the variable, WEIGHT,
       is the total weight of the spherical balloon and is
       computed by BIGBOSOR4 as the BIGBOSOR4 variable called
       "TOTMAS". In the case of the cylindrical balloon the
       variable WEIGHT is computed in SUBROUTINE BOSDEC.

 999.0 DUMMY ENTRY TO MARK END OF FILE
=================================================================
```

Table 3 Input file, balloon.INP, for the GENTEXT processor. This file is generated during the interactive GENTEXT session conducted by the GENOPT user. This is where the GENOPT user provides the variable names, one-line definitions, and "help" paragraphs that appear in the balloon.PRO file (Table 2) and that are seen by the end user. Note the changes in wording and new items since [1] was written.

```
=================================================================
       5  $ starting prompt index in the file balloon.PRO
       5  $ increment for prompt index
       0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
 This GENOPT case is for a cylindrical or spherical balloon
 y         $ Are there more lines in the "help" paragraph?
 the wall of which is a double-walled sandwich made of cloth.
 y         $ Are there more lines in the "help" paragraph?
 The case was brought to the attention of the author,
 y         $ Are there more lines in the "help" paragraph?
 David Bushnell, by Mike Mayo (650-354-5463) on September 21,
 y         $ Are there more lines in the "help" paragraph?
 1010. In this application, GENOPT works with BIGBOSOR4.
 y         $ Are there more lines in the "help" paragraph?
 The cylindrical or spherical "balloon" has inner pressure
 y         $ Are there more lines in the "help" paragraph?
 equal to PINNER, outer pressure equal to POUTER, and
 y         $ Are there more lines in the "help" paragraph?
 pressure inside the double-walled sandwich equal to PMIDDL.
 y         $ Are there more lines in the "help" paragraph?
 PINNER is the lowest pressure, PMIDDL is the highest
 y         $ Are there more lines in the "help" paragraph?
 pressure, and POUTER is higher than PINNER but lower than
 y         $ Are there more lines in the "help" paragraph?
 PMIDDL. PMIDDL must be high enough to provide enough
 y         $ Are there more lines in the "help" paragraph?
 tension in the membrane segments of the "balloon" to
 y         $ Are there more lines in the "help" paragraph?
 prevent buckling under the difference, POUTER - PINNER.
 y         $ Are there more lines in the "help" paragraph?
 Details of the model and results are presented in Ref.[1]:
 y         $ Are there more lines in the "help" paragraph?
 [1a] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain
 y         $ Are there more lines in the "help" paragraph?
 optimum designs of a double-walled inflatable cylindrical
 y         $ Are there more lines in the "help" paragraph?
 vacuum chamber", unpublished report dated November, 2010.
 y         $ Are there more lines in the "help" paragraph?
 [1b] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain
 y         $ Are there more lines in the "help" paragraph?
 optimum designs of a double-walled inflatable spherical
 y         $ Are there more lines in the "help" paragraph?
```

```
vacuum chamber", unpublished report dated December, 2010.
y          $ Are there more lines in the "help" paragraph?
Although the BIGBOSOR4 computer program is intended for
y          $ Are there more lines in the "help" paragraph?
use with axisymmetric shell structures with "finite"
y          $ Are there more lines in the "help" paragraph?
bending stiffness, the results obtained from this study of
y          $ Are there more lines in the "help" paragraph?
a balloon that consists of "shell" segments that act like
y          $ Are there more lines in the "help" paragraph?
membranes with essentially zero bending stiffness seem to
y          $ Are there more lines in the "help" paragraph?
be reasonable. It is emphasized that the results presented
y          $ Are there more lines in the "help" paragraph?
in [1] should be verified via models of the optimized
y          $ Are there more lines in the "help" paragraph?
designs from one or more general-purpose finite element
y          $ Are there more lines in the "help" paragraph?
codes such as STAGS or ABAQUS or NASTRAN.
n          $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt

LENGTH    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
n          $ Is the variable  LENGTH  an array?
length of the cylindrical shell
y          $ Do you want to include a "help" paragraph?
Use a value of about 6000 inches. It should not
y          $ Any more lines in the "help" paragraph?
matter what value you use because buckling (or collapse)
y          $ Any more lines in the "help" paragraph?
with N = zero circumferential waves around the circumference
y          $ Any more lines in the "help" paragraph?
of the huge torus is expected to be critical as of this
y          $ Any more lines in the "help" paragraph?
writing. N = 1 is used instead of N = 0 in order to
y          $ Any more lines in the "help" paragraph?
avoid rigid body "buckling" possible with N = 0.
y          $ Any more lines in the "help" paragraph?
Therefore, always use a very large value for LENGTH.
n          $ Any more lines in the "help" paragraph?
y          $ Any more variables for role types  1  or  2   ?    $10
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
RADIUS    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
n          $ Is the variable  RADIUS  an array?
inner radius of the balloon
y          $ Do you want to include a "help" paragraph?
This is the radius to the points on the INNER membranes
y          $ Any more lines in the "help" paragraph?
where these "shell" segments are connected to each other.
y          $ Any more lines in the "help" paragraph?
```

```
See Figs. 1 and 4 of [1a] and Figs. 1 and 2 of [1b].
n          $ Any more lines in the "help" paragraph?
y          $ Any more variables for role types  1  or  2   ?    $15
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
NMODUL     $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      1  $ type of variable:  1 =integer,  2 =floating point
n          $ Is the variable  NMODUL  an array?
number of modules over 90 degrees
y          $ Do you want to include a "help" paragraph?
This is the number of triangular "trusses" with two points
y          $ Any more lines in the "help" paragraph?
on the inner membrane and one point on the outer membrane
y          $ Any more lines in the "help" paragraph?
over a 90-degree sector of the circumference of the
y          $ Any more lines in the "help" paragraph?
cylindrical balloon (Figs.2,5 of [1a]) or over 90 degrees
y          $ Any more lines in the "help" paragraph?
of the meridian of the spherical balloon (Fig. 2
y          $ Any more lines in the "help" paragraph?
of [1b]). The webs can be radial rather than truss-like.
y          $ Any more lines in the "help" paragraph?
In that case NMODUL is equal to the number of radial
y          $ Any more lines in the "help" paragraph?
webs over 90 degrees of the circumference of the
y          $ Any more lines in the "help" paragraph?
cylindrical balloon (Figs. 1 and 4 of [1a] or over
y          $ Any more lines in the "help" paragraph?
90 degrees of the meridian of the spherical balloon
y          $ Any more lines in the "help" paragraph?
(Fig. 1 of [1b]).
n          $ Any more lines in the "help" paragraph?
y          $ Any more variables for role types  1  or  2   ?    $20
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
The balloon can be either cylindrical or spherical.
y          $ Are there more lines in the "help" paragraph?
An index called "ISHAPE" is used to establish which shape
y          $ Are there more lines in the "help" paragraph?
of balloon you want to design and analyze:
y          $ Are there more lines in the "help" paragraph?
ISHAPE = 1 means "cylindrical balloon"
y          $ Are there more lines in the "help" paragraph?
ISHAPE = 2 means "spherical balloon"
y          $ Are there more lines in the "help" paragraph?
Choose ISHAPE = 1 or ISHAPE = 2.
n          $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
ISHAPE     $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      1  $ type of variable:  1 =integer,  2 =floating point
n          $ Is the variable  ISHAPE  an array?
balloon shape index
y          $ Do you want to include a "help" paragraph?
ISHAPE = 1 means "cylindrical balloon"
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y         $ Any more lines in the "help" paragraph?
ISHAPE = 2 means "spherical balloon"
n         $ Any more lines in the "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?   $30
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked for a control index called "IWEBS".
y         $ Are there more lines in the "help" paragraph?
IWEBS = 1 means that the double-walled balloon has radial
y         $ Are there more lines in the "help" paragraph?
webs. (See Figs. 1 and 4 of [1a], Fig.1 of [1b].)
y         $ Are there more lines in the "help" paragraph?
IWEBS = 2 means that the double-walled balloon has truss-like
y         $ Are there more lines in the "help" paragraph?
(slanted) webs. (See Figs. 2 and 5 of [1a], Fig.2 of [1b].)
n         $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
IWEBS     $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      1  $ type of variable:  1 =integer,  2 =floating point
n         $ Is the variable  IWEBS  an array?
radial (1) or truss-like (2) webs
y         $ Do you want to include a "help" paragraph?
Use IWEBS = 1 for radial webs.
y         $ Any more lines in the "help" paragraph?
Use IWEBS = 2 for truss-like (slanted) webs.
n         $ Any more lines in the "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?   $40
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next you will be asked to provide material properties.
y         $ Are there more lines in the "help" paragraph?
Three different materials are allowed:
y         $ Are there more lines in the "help" paragraph?
1. The material of the outer and inner curved membranes.
y         $ Are there more lines in the "help" paragraph?
2. The material of the outer and inner "truss" members
y         $ Are there more lines in the "help" paragraph?
that run in the circumferential direction.
y         $ Are there more lines in the "help" paragraph?
3. The material out of which the "truss" (slanted, Fig.2)
y         $ Are there more lines in the "help" paragraph?
or radial (Fig. 1) webs are fabricated.
y         $ Are there more lines in the "help" paragraph?
The material is orthotropic with the following properties:
y         $ Are there more lines in the "help" paragraph?
EMOD1 = modulus in the meridional direction, that is,
y         $ Are there more lines in the "help" paragraph?
in the direction along the arc of each shell segment in
y         $ Are there more lines in the "help" paragraph?
the plane of the cross section of the complex wall
y         $ Are there more lines in the "help" paragraph?
of the balloon.
y         $ Are there more lines in the "help" paragraph?
EMOD2 = modulus in the circumferential direction of the
y         $ Are there more lines in the "help" paragraph?
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huge torus, that is, the modulus along the axis of the
y         $ Are there more lines in the "help" paragraph?
prismatic (cylindrical) balloon or the modulus in the
y         $ Are there more lines in the "help" paragraph?
circumferential direction of the spherical balloon.
y         $ Are there more lines in the "help" paragraph?
G12 = in-plane shear modulus, that is, in the plane of
y         $ Are there more lines in the "help" paragraph?
the wall of a "shell" segment
y         $ Are there more lines in the "help" paragraph?
G13 = out-of plane shear modulus (not used, input required)
y         $ Are there more lines in the "help" paragraph?
G23 = out-of-plane shear mdoulus (not used, input required)
y         $ Are there more lines in the "help" paragraph?
NU = Poisson ratio
y         $ Are there more lines in the "help" paragraph?
ALPHA1 = coefficient of thermal expansion in the meridional
y         $ Are there more lines in the "help" paragraph?
direction
y         $ Are there more lines in the "help" paragraph?
ALPHA2 = coefficient of thermal expansion in the
y         $ Are there more lines in the "help" paragraph?
circumferential direction (prismatic axial direction in
y         $ Are there more lines in the "help" paragraph?
the case of the cylindrical balloon)
y         $ Are there more lines in the "help" paragraph?
TEMPER = temperature difference from the temperature at
y         $ Are there more lines in the "help" paragraph?
which the balloon was fabricated (not used, input required)
y         $ Are there more lines in the "help" paragraph?
DENSTY = weight density of the material
y         $ Are there more lines in the "help" paragraph?
(Aluminum = 0.1 lb/in^3)
n         $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
EMOD1     $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  EMOD1  an array?
y         $ Do you want to establish new dimensions for EMOD1 ?
      1  $ Number of dimensions in the array,  EMOD1
material number
     10  $ Max. allowable number of rows NROWS in the array, EMOD1
elastic modulus, meridional direction
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $55
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
EMOD2     $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  EMOD2  an array?
n         $ Do you want to establish new dimensions for EMOD2 ?
elastic modulus, circumferential direction
n         $ Do you want to include a "help" paragraph?
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y         $ Any more variables for role types  1  or  2   ?    $60
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
G12       $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  G12  an array?
n         $ Do you want to establish new dimensions for G12 ?
in-plane shear modulus
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $65
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
G13       $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  G13  an array?
n         $ Do you want to establish new dimensions for G13 ?
out-of-plane (s,z) shear modulus
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $70
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
G23       $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  G23  an array?
n         $ Do you want to establish new dimensions for G23 ?
out-of-plane (y,z) shear modulus
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $75
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
NU        $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  NU  an array?
n         $ Do you want to establish new dimensions for NU ?
Poisson ratio
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $80
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
ALPHA1    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  ALPHA1  an array?
n         $ Do you want to establish new dimensions for ALPHA1 ?
meridional coef. thermal expansion
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $85
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
ALPHA2    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  ALPHA2  an array?
n         $ Do you want to establish new dimensions for ALPHA2 ?
circumf.coef.thermal expansion
n         $ Do you want to include a "help" paragraph?
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y         $ Any more variables for role types  1  or  2   ?    $90
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TEMPER    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  TEMPER  an array?
n         $ Do you want to establish new dimensions for TEMPER ?
delta-T from fabrication temperature
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $95
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
DENSTY    $ Name of a variable in the users program (defined below)
      2  $ Role of the variable in the users program
      2  $ type of variable:  1 =integer,  2 =floating point
y         $ Is the variable  DENSTY  an array?
n         $ Do you want to establish new dimensions for DENSTY ?
weight density of material
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $100
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked to supply the decision variable
y         $ Are there more lines in the "help" paragraph?
candidates. These are as follows:
y         $ Are there more lines in the "help" paragraph?
1. HEIGHT = radial difference between the inner radius, RADIUS,
y         $ Are there more lines in the "help" paragraph?
and the outer radius where the various segments
y         $ Are there more lines in the "help" paragraph?
of the "balloon" are joined together. (See Fig. 1 of [1a].)
y         $ Are there more lines in the "help" paragraph?
2. RINNER = radius of curvature of the inner curved membrane,
y         $ Are there more lines in the "help" paragraph?
the one that "bulges" inward. (See Fig. 1 of [1a].)
y         $ Are there more lines in the "help" paragraph?
3. ROUTER = radius of curvature of the outer curved membrane,
y         $ Are there more lines in the "help" paragraph?
the one that "bulges" outward. (See Fig. 1 of [1a].)
y         $ Are there more lines in the "help" paragraph?
4. TINNER = thickness of the inner curved membrane
y         $ Are there more lines in the "help" paragraph?
5. TOUTER = thickness of the outer curved membrane
y         $ Are there more lines in the "help" paragraph?
6. TFINNR = thickness of outer triangular truss segment
y         $ Are there more lines in the "help" paragraph?
7. TFOUTR = thickness of inner triagular truss segment
y         $ Are there more lines in the "help" paragraph?
8, TFWEBS = thickness of the webs
n         $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
HEIGHT    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  HEIGHT  an array?
height from inner to outer membranes
y         $ Do you want to include a "help" paragraph?
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This is the difference from inner to outer radii at the
y         $ Any more lines in the "help" paragraph?
points where the inner segments are joined to eachother
y         $ Any more lines in the "help" paragraph?
and the outer segments are joined to eachother, that is,
y         $ Any more lines in the "help" paragraph?
the height between inner and outer walls of the "balloon"
y         $ Any more lines in the "help" paragraph?
not including the inward "bulging" of the inner wall and
y         $ Any more lines in the "help" paragraph?
the outward "bulging" of the outer wall (Fig.1, [1a]).
n         $ Any more lines in the "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $110
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
RINNER    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  RINNER  an array?
radius of curvature of inner membrane
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $115
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
ROUTER    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  ROUTER  an array?
radius of curvature of outer membrane
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $120
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TINNER    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  TINNER  an array?
thickness of the inner curved membrane
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $125
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TOUTER    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  TOUTER  an array?
thickness of the outer curved membrane
n         $ Do you want to include a "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?    $130
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TFINNR    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  TFINNR  an array?
thickness of inner truss-core segment
y         $ Do you want to include a "help" paragraph?
The three straight segments that form each module of the
y         $ Any more lines in the "help" paragraph?
truss core have different thicknesses as follows:
y         $ Any more lines in the "help" paragraph?
1. The outer truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFOUTR.
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y         $ Any more lines in the "help" paragraph?
2. The inner truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFINNR.
y         $ Any more lines in the "help" paragraph?
3. The two truss-core webs each have thickness, TFWEBS,
y         $ Any more lines in the "help" paragraph?
or if the webs are radial each web has thickness,
y         $ Any more lines in the "help" paragraph?
TFWEBS.
n         $ Any more lines in the "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?   $135
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TFOUTR    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  TFOUTR  an array?
thickness of the outer truss segment
y         $ Do you want to include a "help" paragraph?
The three straight segments that form each module of the
y         $ Any more lines in the "help" paragraph?
truss core have different thicknesses as follows:
y         $ Any more lines in the "help" paragraph?
1. The outer truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFOUTR.
y         $ Any more lines in the "help" paragraph?
2. The inner truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFINNR.
y         $ Any more lines in the "help" paragraph?
3. The two truss-core webs each have thickness, TFWEBS
y         $ Any more lines in the "help" paragraph?
or if the webs are radial each web has thickness,
y         $ Any more lines in the "help" paragraph?
TFWEBS.
n         $ Any more lines in the "help" paragraph?
y         $ Any more variables for role types  1  or  2   ?   $140
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TFWEBS    $ Name of a variable in the users program (defined below)
      1  $ Role of the variable in the users program
n         $ Is the variable  TFWEBS  an array?
thickness of each truss-core web
y         $ Do you want to include a "help" paragraph?
The three straight segments that form each module of the
y         $ Any more lines in the "help" paragraph?
truss core have different thicknesses as follows:
y         $ Any more lines in the "help" paragraph?
1. The outer truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFOUTR.
y         $ Any more lines in the "help" paragraph?
2. The inner truss-core member that is oriented in the
y         $ Any more lines in the "help" paragraph?
circumferential direction has thickness, TFINNR.
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y          $ Any more lines in the "help" paragraph?
3. The two truss-core webs each have thickness, TFWEBS
y          $ Any more lines in the "help" paragraph?
or if the webs are radial each web has thickness,
y          $ Any more lines in the "help" paragraph?
TFWEBS.
n          $ Any more lines in the "help" paragraph?
n          $ Any more variables for role types  1  or  2   ?    $
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked to provide three pressures,
y          $ Are there more lines in the "help" paragraph?
PINNER, PMIDDL, and POUTER, which are different from
y          $ Are there more lines in the "help" paragraph?
each other and which are uniform over the entire structure.
y          $ Are there more lines in the "help" paragraph?
1. PINNER = pressure inside the inner membrane. This is
y          $ Are there more lines in the "help" paragraph?
the lowest of the three pressures.
y          $ Are there more lines in the "help" paragraph?
2. PMIDDL = pressure between the inner curved membrane
y          $ Are there more lines in the "help" paragraph?
and outer curved membrane. This is the highest of the
y          $ Are there more lines in the "help" paragraph?
three pressures.
y          $ Are there more lines in the "help" paragraph?
3. POUTER = pressure outside the outer curved membrane.
y          $ Are there more lines in the "help" paragraph?
This pressure is higher than PINNER and lower than
y          $ Are there more lines in the "help" paragraph?
PMIDDL.
y          $ Are there more lines in the "help" paragraph?
Use positive numbers for PINNER, PMIDDL, and POUTER.
n          $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
PINNER    $ Name of a variable in the users program (defined below)
      3  $ Role of the variable in the users program
pressure inside the inner membrane
n          $ Do you want to include a "help" paragraph?
y          $ Any more variables for role type  3 ?            $160
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
PMIDDL    $ Name of a variable in the users program (defined below)
      3  $ Role of the variable in the users program
pressure between inner and outer membranes
n          $ Do you want to include a "help" paragraph?
y          $ Any more variables for role type  3 ?            $165
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
POUTER    $ Name of a variable in the users program (defined below)
      3  $ Role of the variable in the users program
pressure outside the outer membrane
n          $ Do you want to include a "help" paragraph?
n          $ Any more variables for role type  3 ?            $
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked to provide the "behaviors" that
y          $ Are there more lines in the "help" paragraph?
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might affect the evolution of the design during optimization
y         $ Are there more lines in the "help" paragraph?
cycles. The "behaviors" included here are:
y         $ Are there more lines in the "help" paragraph?
1. buckling from BIGBOSOR4: BUCKB4, BUCKB4A, BUCKB4F
y         $ Are there more lines in the "help" paragraph?
BUCKB4 = buckling load factor computed from BIGBOSOR4
y         $ Are there more lines in the "help" paragraph?
BUCKB4A= buckling from BIGBOSOR4 allowable
y         $ Are there more lines in the "help" paragraph?
BUCKB4F= buckling from BIGBOSOR4 factor of safety
y         $ Are there more lines in the "help" paragraph?
NOTE: The "BUCKB4" mode shape may represent
y         $ Are there more lines in the "help" paragraph?
local buckling or general buckling. In this generic
y         $ Are there more lines in the "help" paragraph?
"balloon" case only the lowest buckling eigenvalue
y         $ Are there more lines in the "help" paragraph?
is computed, whether it correspond to a general
y         $ Are there more lines in the "help" paragraph?
buckling mode shape or whether it correspond to a
y         $ Are there more lines in the "help" paragraph?
local buckling mode shape. Whichever buckling mode
y         $ Are there more lines in the "help" paragraph?
happens to be represented by "BUCKB4" will correspond
y         $ Are there more lines in the "help" paragraph?
to the lowest eigenvalue. The other type of buckling
y         $ Are there more lines in the "help" paragraph?
(general buckling if the lowest eigenvalue corresponds
y         $ Are there more lines in the "help" paragraph?
to local buckling and local buckling if the lowest
y         $ Are there more lines in the "help" paragraph?
eigenvalue corresponds to general buckling) will be
y         $ Are there more lines in the "help" paragraph?
higher than the eigenvalue used to generate the
y         $ Are there more lines in the "help" paragraph?
buckling constraint condition.
y         $ Are there more lines in the "help" paragraph?
2. loss of prebuckling tension, TENLOS, TENLOSA, TENLOSF,
y         $ Are there more lines in the "help" paragraph?
in which TENLOS = load factor applied to POUTER that
y         $ Are there more lines in the "help" paragraph?
that corresponds to the initial loss of tension in any
y         $ Are there more lines in the "help" paragraph?
of the shell segments.
y         $ Are there more lines in the "help" paragraph?
3. stresses: STRMi(j,k), STRMiA(j,k), STRMiF(j,k)
y         $ Are there more lines in the "help" paragraph?
in which "i" is the material number, "j" is the load case
y         $ Are there more lines in the "help" paragraph?
number (always 1 here), and "k" is the stress component.
y         $ Are there more lines in the "help" paragraph?
STRMi(j,k) is the maximum stress.
y         $ Are there more lines in the "help" paragraph?
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STRMiA(j,k) is the stress allowable
y         $ Are there more lines in the "help" paragraph?
STRMiF(j,k) is the stress factor of safety.
y         $ Are there more lines in the "help" paragraph?
There are five stress components:
y         $ Are there more lines in the "help" paragraph?
STRMi(j,1) = maximum tensile stress in the meridional direction
y         $ Are there more lines in the "help" paragraph?
STRMi(j,2) = maximum compressive stress in the meridional direction
y         $ Are there more lines in the "help" paragraph?
STRMi(j,3) = maxiamum tensile stress in the circumfer. direction
y         $ Are there more lines in the "help" paragraph?
In the case of the cylindrical balloon, STRMi(j,3) is the
y         $ Are there more lines in the "help" paragraph?
maximum tensile stress along the axis of the prismatic
y         $ Are there more lines in the "help" paragraph?
shell, that is, in the circumferential direction of the
y         $ Are there more lines in the "help" paragraph?
"huge torus" model of the cylindrical shell. The "huge torus"
y         $ Are there more lines in the "help" paragraph?
model of a cylindrical shell is shown in Fig. 3 of [1a].
y         $ Are there more lines in the "help" paragraph?
STRMi(j,4) = maximum compressive stress in the circumf.direction
y         $ Are there more lines in the "help" paragraph?
The same comment applies to STRMi(j,4) as to STRMi(j,3).
y         $ Are there more lines in the "help" paragraph?
STRMi(j,5) = maximum in-plane shear stress.
y         $ Are there more lines in the "help" paragraph?
This is in the plane of each segment of the multi-segment
y         $ Are there more lines in the "help" paragraph?
model of the cylindrical or spherical balloon.
n         $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
BUCKB4    $ Name of a variable in the users program (defined below)
      4  $ Role of the variable in the users program
n         $ Do you want to reset the number of columns in BUCKB4 ?
buckling load factor from BIGBOSOR4
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
BUCKB4A   $ Name of a variable in the users program (defined below)
      5  $ Role of the variable in the users program
buckling from BIGBOSOR4 allowable
y         $ Do you want to include a "help" paragraph?
Usually, you supply 1.0 for BUCKB4A because BUCKB4 is
y         $ Any more lines in the "help" paragraph?
a buckling load FACTOR, that is, a quantity that is
y         $ Any more lines in the "help" paragraph?
to be multiplied by the design loads in order to obtain
y         $ Any more lines in the "help" paragraph?
the buckling load.
n         $ Any more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
BUCKB4F   $ Name of a variable in the users program (defined below)
      6  $ Role of the variable in the users program
```

```
buckling from BIGBOSOR4 factor of safety
y         $ Do you want to include a "help" paragraph?
For this problem, use a value that depends of POUTER.
y         $ Any more lines in the "help" paragraph?
For example, suppose you want to design the balloon for
y         $ Any more lines in the "help" paragraph?
an external pressure, POUTER = 15 psi. Corresponding to
y         $ Any more lines in the "help" paragraph?
POUTER = 15 psi you would use a factor of safety,
y         $ Any more lines in the "help" paragraph?
BUCKB4F = 1.0. However, because of the nonlinearity of
y         $ Any more lines in the "help" paragraph?
the pre-buckling equilibrium state of the balloon the
y         $ Any more lines in the "help" paragraph?
Newton iterations may fail to converge if you use
y         $ Any more lines in the "help" paragraph?
POUTER = 15 psi. You will probably want to use POUTER = 5
y         $ Any more lines in the "help" paragraph?
psi, or something like that. If you use POUTER = 5 psi,
y         $ Any more lines in the "help" paragraph?
you must correspondingly use a factor of safety of 3.0
y         $ Any more lines in the "help" paragraph?
instead of 1.0. Always maintain the correspondence:
y         $ Any more lines in the "help" paragraph?
(design pressure)/POUTER = BUCKB4F
y         $ Any more lines in the "help" paragraph?
This "rule" also applies to the factor of safety
y         $ Any more lines in the "help" paragraph?
associated with the constraint called "TENLOS",
y         $ Any more lines in the "help" paragraph?
to be called "TENLOSF" and to be asked for below.
n         $ Any more lines in the "help" paragraph?
      2  $ Indicator (1 or 2 or 3) for type of constraint
y         $ Any more variables for role type  4 ?             $190
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked to supply an allowable and a
y         $ Are there more lines in the "help" paragraph?
factor of safety for the load factor, TENLOS, that
y         $ Are there more lines in the "help" paragraph?
corresponds to the initial loss of tension in any of the
y         $ Are there more lines in the "help" paragraph?
segments of the balloon subjected to the total load,
y         $ Are there more lines in the "help" paragraph?
that is, to PINNER, PMIDDL, DELTAT (if any), and POUTER.
y         $ Are there more lines in the "help" paragraph?
The allowable should always be 1.0. The factor of safety
y         $ Are there more lines in the "help" paragraph?
depends on what you used for POUTER. If POUTER = the
y         $ Are there more lines in the "help" paragraph?
design pressure,say, POUTER = 15 psi, then you should use
y         $ Are there more lines in the "help" paragraph?
a factor of safety, TENLOSF = 1.0. If you use a smaller
y         $ Are there more lines in the "help" paragraph?
value of POUTER, say, POUTER = 5 psi, then you must use
```

```
y         $ Are there more lines in the "help" paragraph?
a correspondingly higher factor of safety, TENLOSF = 3.0
y         $ Are there more lines in the "help" paragraph?
psi. The "rule" is the same as that governing BUCKB4F.
n         $ Are there more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TENLOS    $ Name of a variable in the users program (defined below)
      4  $ Role of the variable in the users program
n         $ Do you want to reset the number of columns in TENLOS ?
load factor for tension loss
y         $ Do you want to include a "help" paragraph?
This is the load factor to be applied to POUTER. What
y         $ Any more lines in the "help" paragraph?
value of POUTER will cause the first complete loss of
y         $ Any more lines in the "help" paragraph?
tension in any of the segments of the balloon? In the
y         $ Any more lines in the "help" paragraph?
case of the cylindrical balloon we are concerned only
y         $ Any more lines in the "help" paragraph?
with meridional tension, that is, tension in the plane
y         $ Any more lines in the "help" paragraph?
of the cross section of the double-wall. In the case of
y         $ Any more lines in the "help" paragraph?
the spherical balloon we are concerned with the initial
y         $ Any more lines in the "help" paragraph?
loss of either meridional tension or circumferential
y         $ Any more lines in the "help" paragraph?
tension.
n         $ Any more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TENLOSA   $ Name of a variable in the users program (defined below)
      5  $ Role of the variable in the users program
tension loss allowable (Use 1.0)
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
TENLOSF   $ Name of a variable in the users program (defined below)
      6  $ Role of the variable in the users program
tension loss factor of safety
y         $ Do you want to include a "help" paragraph?
The factor of safety you use must be related to the
y         $ Any more lines in the "help" paragraph?
value of POUTER that you used above. If POUTER = the
y         $ Any more lines in the "help" paragraph?
design pressure, then use TENLOSF = 1.0. If POUTER is
y         $ Any more lines in the "help" paragraph?
less than the design pressure, then use a correspondingly
y         $ Any more lines in the "help" paragraph?
higher value for the factor of safety, TENLOSF. For example,
y         $ Any more lines in the "help" paragraph?
if POUTER = 5 psi instead of the design pressure, POUTER =
y         $ Any more lines in the "help" paragraph?
15 psi, the use TENLOSF = 3.0 instead of 1.0. Maintain
y         $ Any more lines in the "help" paragraph?
the correspondence, (design pressure)/POUTER = TENLOSF.
```

```
n         $ Any more lines in the "help" paragraph?
      2  $ Indicator (1 or 2 or 3) for type of constraint
y         $ Any more variables for role type  4 ?            $210
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM1     $ Name of a variable in the users program (defined below)
      4  $ Role of the variable in the users program
y         $ Do you want to reset the number of columns in STRM1 ?
      2  $ Number of dimensions in the array,  STRM1
stress component number
      5  $ Max. allowable number of columns NCOLS in the array, STRM1
stress component in material 1
y         $ Do you want to include a "help" paragraph?
For an orthotropic material there are 5 stress components
y         $ Any more lines in the "help" paragraph?
for which stress constraints may be generated:
y         $ Any more lines in the "help" paragraph?
1. maximum tensile stess in the meridional direction
y         $ Any more lines in the "help" paragraph?
2. maximum compressive stress in the meridional direction
y         $ Any more lines in the "help" paragraph?
3. maximum tensile stress in the circumferential direction
y         $ Any more lines in the "help" paragraph?
4. maximum compressive stress in the circumferential direction
y         $ Any more lines in the "help" paragraph?
5. maximum in-plane shear stress
n         $ Any more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM1A    $ Name of a variable in the users program (defined below)
      5  $ Role of the variable in the users program
allowable stress in material 1
y         $ Do you want to include a "help" paragraph?
For an orthotropic material there are 5 stress components
y         $ Any more lines in the "help" paragraph?
for which stress constraints are generated:
y         $ Any more lines in the "help" paragraph?
1. maximum tensile stress in the meridional direction:
y         $ Any more lines in the "help" paragraph?
STRM1A(i,1), in which "i" is the load set number
y         $ Any more lines in the "help" paragraph?
2. maximum compressive stress in the meridional direction:
y         $ Any more lines in the "help" paragraph?
STRM1A(i,2), in which "i" is the load set number
y         $ Any more lines in the "help" paragraph?
3. maximum tensile stress in the circumferential direction:
y         $ Any more lines in the "help" paragraph?
STRM1A(i,3), in which "i" is the load set number
y         $ Any more lines in the "help" paragraph?
4. maximum compressive stress in the circumferential direction:
y         $ Any more lines in the "help" paragraph?
STRM1A(i,4), in which "i" is the load set number
y         $ Any more lines in the "help" paragraph?
5. maximum in-plane shear stress
y         $ Any more lines in the "help" paragraph?
STRM1A(i,5), in which "i" is the load set number
```

```
n         $ Any more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM1F    $ Name of a variable in the users program (defined below)
      6  $ Role of the variable in the users program
factor of safety for stress in material 1
y         $ Do you want to include a "help" paragraph?
In this application use a factor of safety of 1.0
n         $ Any more lines in the "help" paragraph?
      3  $ Indicator (1 or 2 or 3) for type of constraint
y         $ Any more variables for role type  4 ?             $230
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM2     $ Name of a variable in the users program (defined below)
      4  $ Role of the variable in the users program
n         $ Do you want to reset the number of columns in STRM2 ?
stress component in material 2
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM2A    $ Name of a variable in the users program (defined below)
      5  $ Role of the variable in the users program
allowable for stress in material 2
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM2F    $ Name of a variable in the users program (defined below)
      6  $ Role of the variable in the users program
factor of safety for stress in material 2
n         $ Do you want to include a "help" paragraph?
      3  $ Indicator (1 or 2 or 3) for type of constraint
y         $ Any more variables for role type  4 ?             $245
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM3     $ Name of a variable in the users program (defined below)
      4  $ Role of the variable in the users program
n         $ Do you want to reset the number of columns in STRM3 ?
stress component in material 3
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM3A    $ Name of a variable in the users program (defined below)
      5  $ Role of the variable in the users program
allowable for stress in material 3
n         $ Do you want to include a "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
STRM3F    $ Name of a variable in the users program (defined below)
      6  $ Role of the variable in the users program
factor of safety for stress in material 3
n         $ Do you want to include a "help" paragraph?
      3  $ Indicator (1 or 2 or 3) for type of constraint
n         $ Any more variables for role type  4 ?             $
      0  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
Next, you will be asked to provide an objective.
y         $ Are there more lines in the "help" paragraph?
In this case the objective is the weight/(axial length)
y         $ Are there more lines in the "help" paragraph?
of the balloon.
y         $ Are there more lines in the "help" paragraph?
This definition, "weight/length of the balloon", is
```

```
y         $ Any more lines in the "help" paragraph?
appropriate only for the cylindrical balloon. In spite
y         $ Any more lines in the "help" paragraph?
of this fact, the same definition is also used for
y         $ Any more lines in the "help" paragraph?
the WEIGHT of the spherical balloon. However, in the
y         $ Any more lines in the "help" paragraph?
case of the spherical balloon, the variable, WEIGHT,
y         $ Any more lines in the "help" paragraph?
is the total weight of the spherical balloon and is
y         $ Any more lines in the "help" paragraph?
computed by BIGBOSOR4 as the BIGBOSOR4 variable called
y         $ Any more lines in the "help" paragraph?
"TOTMAS". In the case of the cylindrical balloon the
y         $ Any more lines in the "help" paragraph?
variable WEIGHT is computed in SUBROUTINE BOSDEC.
n         $ Any more lines in the "help" paragraph?
      1  $ Type of prompt: 0="help" paragraph, 1=one-line prompt
WEIGHT    $ Name of a variable in the users program (defined below)
      7  $ Role of the variable in the users program
weight/length of the balloon
y         $ Do you want to include a "help" paragraph?
This definition, "weight/length of the balloon", is
y         $ Any more lines in the "help" paragraph?
appropriate only for the cylindrical balloon. In spite
y         $ Any more lines in the "help" paragraph?
of this fact, the same definition is also used for
y         $ Any more lines in the "help" paragraph?
the WEIGHT of the spherical balloon. However, in the
y         $ Any more lines in the "help" paragraph?
case of the spherical balloon, the variable, WEIGHT,
y         $ Any more lines in the "help" paragraph?
is the total weight of the spherical balloon and is
y         $ Any more lines in the "help" paragraph?
computed by BIGBOSOR4 as the BIGBOSOR4 variable called
y         $ Any more lines in the "help" paragraph?
"TOTMAS". In the case of the cylindrical balloon the
y         $ Any more lines in the "help" paragraph?
variable WEIGHT is computed in SUBROUTINE BOSDEC.
n         $ Any more lines in the "help" paragraph?
========================================================
```

Table 4 A detailed list of a typical GENOPT/BIGBOSOR4 run stream

==

balloon.sphere.runstream

November 24-30, December 16, 2010

Please read the paper,
/home/progs/genopt/case/balloon/balloon.paper/balloon.pdf:

[1] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain optimum designs of double-walled inflatable cylindrical vacuum chambers", unpublished report, November, 2010.

The figures associated with the text, balloon.pdf, are in the file:
/home/progs/genopt/case/balloon/balloon.paper/balloonfigs.pdf
and the tables associated with the text are in the file:
/home/progs/genopt/case/balloon/balloon.paper/balloontables.pdf

In particular inspect Table 4 in balloontables.pdf.

NOTE: It is assumed here that the home directory is "/home/progs".

This "balloon.sphere.runstream" file (**Table 4**) applies to the determination of an optimum design of a spherical balloon with eight modules and with truss-like (slanted) webs. The main purpose of this file is to emphasize that, with respect to determination of the nonlinear prebuckling equilibrium state, the spherical balloon is a lot more "cranky" (nonlinear) than holds for the cylindrical balloon. The name of the generic case is "balloon" and the name of the specific case is "try4".

Commands typed by the end user are in **bold face**.

***************** IMPORTANT NOTE ****************************
This "run stream" file was composed before certain modifications were made to the file called "behavior.balloon" (**Table 5**). These modifications, made on November 28 and 29, 2010, are designed greatly to reduce or even eliminate unintended terminations ("bombs") of optimization runs via SUPEROPT caused by failure of convergence of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations.

Now, instead of "CALL ERREX" to terminate execution in the event of failure of convergence of the Newton iterations for solution of the pre-buckling equilibrium equations, SUBROUTINE BEHX1 sets WEIGHT and TOTMAS to a very large number and keeps on executing. In a particular specific case (a spherical balloon with 12 modules and radial webs) the following typical entries now exist in the *.OPP file following an execution of SUPEROPT:

```
 ------------------------------------------------------OPTIMIZE
```

```
  215         5.8165E+03         FEASIBLE          3
  216         5.6096E+03     MILDLY UNFEASIB       4
  217         5.3223E+03     MILDLY UNFEASIB       4
  218         5.7909E+03     ALMOST FEASIBLE       4
  219         5.7172E+03     ALMOST FEASIBLE       4
  220         5.7791E+03     ALMOST FEASIBLE       4
 ----------------------------------------------------AUTOCHANGE
 ------------------------------------------------------OPTIMIZE
  221         1.0000E+21         FEASIBLE          0
 ------------------------------------------------------OPTIMIZE
  222         1.0000E+21         FEASIBLE          0
 ------------------------------------------------------OPTIMIZE
  223         1.0000E+21         FEASIBLE          0
 ------------------------------------------------------OPTIMIZE
  224         1.0000E+21         FEASIBLE          0
 ------------------------------------------------------OPTIMIZE
  225         1.0000E+21         FEASIBLE          0
 ----------------------------------------------------AUTOCHANGE
 ------------------------------------------------------OPTIMIZE
  226         9.8328E+03      NOT FEASIBLE         3
  227         1.0274E+04      NOT FEASIBLE         3
  228         1.0879E+04     MORE UNFEASIBLE       2
  229         1.1307E+04     MORE UNFEASIBLE       2
  230         1.1601E+04     MILDLY UNFEASIB       2
  231         1.1822E+04     ALMOST FEASIBLE       2
 ------------------------------------------------------OPTIMIZE
```

The large numbers, 1.0000E+21, for the objective signify that failure of convergence of the Newton iterations for the solution of the nonlinear pre-buckling equilibrium equations has occurred in design iterations 221 - 225. These large numbers affect the *.PL5 file, which is produced by the GENOPT processor called "CHOOSEPLOT" and which contains a "plot" of the objective versus design iterations. If the user wants meaningful plots of objective versus design iterations, he or she will have to eliminate any "large-number" entries in the *.PL5 file. The part of the unedited *.PL5 file that corresponds to the above list involving design iterations 215 - 231 follows:

```
 0.21500E+03 0.56096E+04
 0.21600E+03 0.53223E+04
 0.21700E+03 0.57909E+04
 0.21800E+03 0.57172E+04
 0.21900E+03 0.57791E+04
 0.22000E+03 0.10000E+22 <--- remove this entry before plotting
 0.22100E+03 0.10000E+22 <--- remove this entry before plotting
 0.22200E+03 0.10000E+22 <--- remove this entry before plotting
 0.22300E+03 0.10000E+22 <--- remove this entry before plotting
 0.22400E+03 0.10000E+22 <--- remove this entry before plotting
 0.22500E+03 0.98328E+04
 0.22600E+03 0.10274E+05
 0.22700E+03 0.10879E+05
 0.22800E+03 0.11307E+05
 0.22900E+03 0.11601E+05
 0.23000E+03 0.11822E+05
 0.23100E+03 0.11822E+05
```

For another case with 15 modules and truss-like (slanted) webs, **Figure 21** shows the plot of objective versus design iterations before an editing of the *.PL5 file to remove all the "high-number" entries. **Figure 22** shows the same plot after removal of all the "high-number" entries in the *.PL5 file.

In these cases the plots are obtained via the following commands:

diplot (the input file is try4.PL5)
gv try4.5.ps (obtain plot of objective versus design iterations)

The following "pre-modification" run stream is retained because it provides some useful instruction to potential users of the generic "balloon" software concerning runs that may require more than one execution of SUPEROPT.
****

Executions of SUPEROPT used to bomb before the completion of 470 design iterations because the Newton iterations used for the solution of the nonlinear pre-buckling equilibrium equations corresponding either to Load Step 1 or to Load Step 2 fail to converge. Load Step 1 corresponds to application of only the "fixed" loads, PINNER and PMIDDL. Load Step 2 corresponds to application of the total loads, PINNER, PMIDDL, and POUTER. (There is no temperature change, DELTAT, in the case of the spherical balloon as exists in the case of the cylindrical balloon.)

The run stream listed here only covers commands given by the end user. The part of the run stream executed by the GENOPT user is listed in Table 4 of [1]. The final versions of the "balloon" software, behavior.balloon, struct.balloon, and bosdec.balloon, are listed in **Tables 5, 6, and 7**, respectively, of the present paper on optimization of spherical balloons. This "balloon" software now applies to both spherical and cylindrical balloons with either radial or truss-like webs. There no longer exists any "bosdec.balloon2" file.

************** IMPORTANT NOTE ***************************
Tables 5, 6, and 7 of [1] are now out-of-date and no longer applicable to the generic "balloon" case. Use only the versions of the balloon sofware, behavior.balloon, struct.balloon, and bosdec.balloon that are stored in the following files:

/home/progs/genopt/case/balloon/behavior.balloon
/home/progs/genopt/case/balloon/struct.balloon
/home/progs/genopt/case/balloon/bosdec.balloon

These versions of the generic "balloon" software are always kept up to date.
****

*********** ANOTHER IMPORTANT NOTE ************************
NOTE: A bug was found in SUBROUTINE BEHX5 (maximum stress in Material Type 3, the material out of which the webs are fabricated) after this table was generated. Therefore, the exact results listed below can no longer be reproduced. The main purpose of this table is to demonstrate how to proceed in a

case when SUPEROPT executions bomb because of failure of convergence of the Newton iterations to solve the nonlinear pre-buckling equilibrium equations. Here it is not the results that are important; it is the process. (However, please read the previous "IMPORTANT NOTE" in which it is stated that with the latest version of SUBROUTINE BEHX1 bombs of SUPEROPT executions are now much less likely to occur than was the case before November 28 and 29, 2010, when the following was written.)
****

************ YET ANOTHER IMPORTANT NOTE **********************
After this file was created the objective in the case of the spherical balloon was doubled from TOTMAS to 2.0*TOTMAS because the BIGBOSOR4 variable, TOTMAS, corresponds to only 90 degrees of the meridian of the spherical shell (the "northern" hemisphere). Therefore, the variable, WEIGHT, listed in this file is half the value of WEIGHT in the current version of the "balloon" software applicable to spherical balloons.
****

COMMAND MEANING OF COMMAND

begin (provide control indices, the starting design, material properties, loading, allowables, factors of safety. In this particular case the spherical balloon has truss-like (slanted) webs. The input file, try4.BEG = try41.8mod.sphere.beg, follows:)

```
      n         $ Do you want a tutorial session and tutorial output?
   6000.000     $ length of the cylindrical shell: LENGTH
   120.0000     $ inner radius of the cylindrical balloon: RADIUS
        8       $ number of modules over 90 degrees: NMODUL
        2       $ balloon shape index: ISHAPE
        2       $ radial (1) or truss-like (2) webs: IWEBS
        3       $ Number IEMOD1  of rows in the array  EMOD1: IEMOD1
   435100.0     $ elastic modulus, meridional direction: EMOD1(  1)
   435100.0     $ elastic modulus, meridional direction: EMOD1(  2)
   435100.0     $ elastic modulus, meridional direction: EMOD1(  3)
   435100.0     $ elastic modulus, circumferential direction: EMOD2(  1)
   435100.0     $ elastic modulus, circumferential direction: EMOD2(  2)
   435100.0     $ elastic modulus, circumferential direction: EMOD2(  3)
   167346.0     $ in-plane shear modulus: G12(  1)
   167346.0     $ in-plane shear modulus: G12(  2)
   167346.0     $ in-plane shear modulus: G12(  3)
   167346.0     $ out-of-plane (s,z) shear modulus: G13(  1)
   167346.0     $ out-of-plane (s,z) shear modulus: G13(  2)
   167346.0     $ out-of-plane (s,z) shear modulus: G13(  3)
   167346.0     $ out-of-plane (y,z) shear modulus: G23(  1)
   167346.0     $ out-of-plane (y,z) shear modulus: G23(  2)
   167346.0     $ out-of-plane (y,z) shear modulus: G23(  3)
  0.3000000     $ Poisson ratio: NU(  1)
  0.3000000     $ Poisson ratio: NU(  2)
  0.3000000     $ Poisson ratio: NU(  3)
  0.1000000E-09 $ meridional coef. thermal expansion: ALPHA1(  1)
  0.1000000E-09 $ meridional coef. thermal expansion: ALPHA1(  2)
  0.1000000E-09 $ meridional coef. thermal expansion: ALPHA1(  3)
  0.1000000E-03 $ circumf.coef.thermal expansion: ALPHA2(  1)
  0.1000000E-03 $ circumf.coef.thermal expansion: ALPHA2(  2)
```

```
  0.1000000E-03 $ circumf.coef.thermal expansion: ALPHA2(  3)
   0.000000     $ delta-T from fabrication temperature: TEMPER(  1)
   0.000000     $ delta-T from fabrication temperature: TEMPER(  2)
   0.000000     $ delta-T from fabrication temperature: TEMPER(  3)
  0.1000000     $ weight density of material: DENSTY(  1)
  0.1000000     $ weight density of material: DENSTY(  2)
  0.1000000     $ weight density of material: DENSTY(  3)
   90.00000     $ height from inner to outer membranes: HEIGHT
   16.00000     $ radius of curvature of inner membrane: RINNER
   30.00000     $ radius of curvature of outer membrane: ROUTER
  0.1000000     $ thickness of the inner curved membrane: TINNER
  0.1000000     $ thickness of the outer curved membrane: TOUTER
  0.1000000     $ thickness of inner truss-core segment: TFINNR
  0.1000000     $ thickness of the outer truss segment: TFOUTR
  0.1000000     $ thickness of each truss-core web: TFWEBS
        1       $ Number NCASES  of load cases (environments): NCASES
   0.000000     $ pressure inside the inner membrane: PINNER(  1)
   60.00000     $ pressure between inner and outer membranes: PMIDDL(  1)
   5.000000     $ pressure outside the outer membrane: POUTER(  1)
   1.000000     $ allowable for buckling load factor from BIGBOSOR4: BUCKB4A(  1)
   3.000000     $ buckling from BIGBOSOR4 factor of safety: BUCKB4F(  1)
   1.000000     $ tension loss allowable (Use 1.0): TENLOSA(  1)
   3.000000     $ tension loss factor of safety: TENLOSF(  1)
        5       $ Number JSTRM1  of columns in the array, STRM1: JSTRM1
   10000.00     $ allowable stress in material 1: STRM1A(  1,  1)
   10000.00     $ allowable stress in material 1: STRM1A(  1,  2)
   10000.00     $ allowable stress in material 1: STRM1A(  1,  3)
   10000.00     $ allowable stress in material 1: STRM1A(  1,  4)
   10000.00     $ allowable stress in material 1: STRM1A(  1,  5)
   1.000000     $ factor of safety for stress in material 1: STRM1F(  1,  1)
   1.000000     $ factor of safety for stress in material 1: STRM1F(  1,  2)
   1.000000     $ factor of safety for stress in material 1: STRM1F(  1,  3)
   1.000000     $ factor of safety for stress in material 1: STRM1F(  1,  4)
   1.000000     $ factor of safety for stress in material 1: STRM1F(  1,  5)
   10000.00     $ allowable for stress in material 2: STRM2A(  1,  1)
   10000.00     $ allowable for stress in material 2: STRM2A(  1,  2)
   10000.00     $ allowable for stress in material 2: STRM2A(  1,  3)
   10000.00     $ allowable for stress in material 2: STRM2A(  1,  4)
   10000.00     $ allowable for stress in material 2: STRM2A(  1,  5)
   1.000000     $ factor of safety for stress in material 2: STRM2F(  1,  1)
   1.000000     $ factor of safety for stress in material 2: STRM2F(  1,  2)
   1.000000     $ factor of safety for stress in material 2: STRM2F(  1,  3)
   1.000000     $ factor of safety for stress in material 2: STRM2F(  1,  4)
   1.000000     $ factor of safety for stress in material 2: STRM2F(  1,  5)
   10000.00     $ allowable for stress in material 3: STRM3A(  1,  1)
   10000.00     $ allowable for stress in material 3: STRM3A(  1,  2)
   10000.00     $ allowable for stress in material 3: STRM3A(  1,  3)
   10000.00     $ allowable for stress in material 3: STRM3A(  1,  4)
   10000.00     $ allowable for stress in material 3: STRM3A(  1,  5)
   1.000000     $ factor of safety for stress in material 3: STRM3F(  1,  1)
   1.000000     $ factor of safety for stress in material 3: STRM3F(  1,  2)
   1.000000     $ factor of safety for stress in material 3: STRM3F(  1,  3)
   1.000000     $ factor of safety for stress in material 3: STRM3F(  1,  4)
   1.000000     $ factor of safety for stress in material 3: STRM3F(  1,  5)
```

COMMAND   MEANING OF COMMAND

decide   (provide decision variables, lower and upper bounds,

```
                linking constraints, inequality constraints. In
                this particular case there are no linking constraints
                or inequality constraints. The input file,
                try4.DEC = try41.8mod.sphere.dec, follows:)

     n         $ Do you want a tutorial session and tutorial output?
        1      $ Choose a decision variable (1,2,3,...)
  20.00000     $ Lower bound of variable no.(  1)
 120.00000     $ Upper bound of variable no.(  1)
     n         $ Do you want especially to restrict variable no.(  1)
     y         $ Any more decision variables (Y or N) ?
        4      $ Choose a decision variable (1,2,3,...)
 0.0300000     $ Lower bound of variable no.(  4)
 0.3000000     $ Upper bound of variable no.(  4)
     n         $ Do you want especially to restrict variable no.(  4)
     y         $ Any more decision variables (Y or N) ?
        5      $ Choose a decision variable (1,2,3,...)
 0.0300000     $ Lower bound of variable no.(  5)
 0.3000000     $ Upper bound of variable no.(  5)
     n         $ Do you want especially to restrict variable no.(  5)
     y         $ Any more decision variables (Y or N) ?
        6      $ Choose a decision variable (1,2,3,...)
 0.0300000     $ Lower bound of variable no.(  6)
 0.3000000     $ Upper bound of variable no.(  6)
     n         $ Do you want especially to restrict variable no.(  6)
     y         $ Any more decision variables (Y or N) ?
        7      $ Choose a decision variable (1,2,3,...)
 0.0300000     $ Lower bound of variable no.(  7)
 0.3000000     $ Upper bound of variable no.(  7)
     n         $ Do you want especially to restrict variable no.(  7)
     y         $ Any more decision variables (Y or N) ?
        8      $ Choose a decision variable (1,2,3,...)
 0.0300000     $ Lower bound of variable no.(  8)
 0.3000000     $ Upper bound of variable no.(  8)
     n         $ Do you want especially to restrict variable no.(  8)
     n         $ Any more decision variables (Y or N) ?
     n         $ Any linked variables (Y or N) ?
     n         $ Any inequality relations among variables? (type H)
     y         $ Any escape variables (Y or N) ?
     y         $ Want to have escape variables chosen by default?
```

COMMAND MEANING OF COMMAND

mainsetup (provide analysis type, strategy, etc. for an optimization analysis. Input file, try4.OPT, follows:)

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

```
        1      $ Choose IAUTOF= 1 or 2 or 3 or 4 or 5 or 6 to change X(i)
```

superopt (launch the "global" optimizer. Use 5 OPTIMIZEs per AUTOCHANGE.)

SUPEROPT went to over 470 design iterations, a successful execution.
The GENOPT processor,

Next, execute CHOOSEPLOT to obtain plots of the objective vs design iterations (try4.5.ps) and the design margins vs desgn iterations (try4,3.ps).

chooseplot (choose what variables to plot versus design iterations. The input file, try4.CPL = try41.8mod.sphere.superopt1.cpl, follows:)

```
      n        $ Do you want a tutorial session and tutorial output?
      n        $ Any design variables to be plotted v. iterations (Y or N)?
      y        $ Any design margins to be plotted v. iterations (Y or N)?
        1      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
        2      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
        3      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
        5      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
        8      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
       10      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
       13      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y        $ Any more margins to be plotted (Y or N) ?
       15      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      n        $ Any more margins to be plotted (Y or N) ?
        1      $ Give maximum value (positive) to be included in plot frame.
      n        $ Do you want to get more plots before your next "SUPEROPT"?
```

COMMAND MEANING OF COMMAND

diplot (generate the Postscript files, try4.3.ps and try4.5.ps that contain, respectively, plots of the design margins and a plot of the objective function versus design iterations during the SUPEROPT execution.)

change (Save the optimized design. In this case the input for CHANGE is in the file, try4.CHG =try41.8mod.sphere.superopt1.chg, which follows:)

```
      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, . .)
   62.0000     $ New value of the parameter
      y        $ Want to change any other parameters in this set?
        2      $ Number of parameter to change (1, 2, 3, . .)
   16.00000    $ New value of the parameter
```

```
      y         $ Want to change any other parameters in this set?
         3      $ Number of parameter to change (1, 2, 3, . .)
   30.0000      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         4      $ Number of parameter to change (1, 2, 3, . .)
  0.11730       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         5      $ Number of parameter to change (1, 2, 3, . .)
  0.21299       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         6      $ Number of parameter to change (1, 2, 3, . .)
  0.072667      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         7      $ Number of parameter to change (1, 2, 3, . .)
  0.031669      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
  0.10558       $ 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?
```

COMMAND   MEANING OF COMMAND

mainsetup   (provide analysis type, strategy, etc. for the "fixed" locally optimum design. Input, try4.OPT, follows:)

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

optimize   (perform an analysis of the "fixed", locally optimized, design. The output file is try4.OPM = try41.8mod.sphere.superopt1.opm, part of which follows:)

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E+01 6.2000E+01  1.20E+02  height
from inner to outer membranes: HEIGHT
   2   N     N     N      0    0.00E+00  0.00E+00 1.6000E+01  0.00E+00  radius of
curvature of inner membrane: RINNER
   3   N     N     N      0    0.00E+00  0.00E+00 3.0000E+01  0.00E+00  radius of
curvature of outer membrane: ROUTER
```

```
   4   Y     N     N      0    0.00E+00  3.00E-02 1.1730E-01  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  3.00E-02 2.1299E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  3.00E-02 7.2667E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  3.00E-02 3.1669E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  3.00E-02 1.0558E-01  3.00E-01  thickness
of each truss-core web: TFWEBS

    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.431E+04  weight/length of the balloon: WEIGHT (Actually TOTMAS from
BIGBOSOR4)
```

We must do more optimization because up to now the decision variable candidates, RINNER and ROUTER, have not been decision variables. We next use the GENOPT processor, DECIDE, to establish RINNER and ROUTER as decision variables and to set a couple of new lower and upper bounds based on the preliminary optimum design just listed.

COMMAND   MEANING OF COMMAND

decide   (provide decision variables, lower and upper bounds,
                      linking constraints, inequality constraints.
                      Input, try4.DEC= try41.8mod.sphere.superopt1.dec)
                      The input file follows:)

```
      n          $ Do you want a tutorial session and tutorial output?
         1       $ Choose a decision variable (1,2,3,...)
   30.00000      $ Lower bound of variable no.(  1)
   65.00000      $ Upper bound of variable no.(  1)
      y          $ Do you want especially to restrict variable no.(  1)
   0.500000      $ Maximum permitted change in variable no.(  1)
      y          $ Any more decision variables (Y or N) ?
         2       $ Choose a decision variable (1,2,3,...)
   12.00000      $ Lower bound of variable no.(  2)
        25       $ Upper bound of variable no.(  2)
      y          $ Do you want especially to restrict variable no.(  2)
  0.2000000      $ Maximum permitted change in variable no.(  2)
      y          $ Any more decision variables (Y or N) ?
         3       $ Choose a decision variable (1,2,3,...)
   20.00000      $ Lower bound of variable no.(  3)
        40       $ Upper bound of variable no.(  3)
      y          $ Do you want especially to restrict variable no.(  3)
  0.2000000      $ Maximum permitted change in variable no.(  3)
      y          $ Any more decision variables (Y or N) ?
         4       $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  4)
  0.3000000      $ Upper bound of variable no.(  4)
      n          $ Do you want especially to restrict variable no.(  4)
      y          $ Any more decision variables (Y or N) ?
         5       $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  5)
```

```
  0.3000000     $ Upper bound of variable no.(  5)
      n         $ Do you want especially to restrict variable no.(  5)
      y         $ Any more decision variables (Y or N) ?
         6      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  6)
  0.3000000     $ Upper bound of variable no.(  6)
      n         $ Do you want especially to restrict variable no.(  6)
      y         $ Any more decision variables (Y or N) ?
         7      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.(  7)
  0.3000000     $ Upper bound of variable no.(  7)
      n         $ Do you want especially to restrict variable no.(  7)
      y         $ Any more decision variables (Y or N) ?
         8      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  8)
  0.3000000     $ Upper bound of variable no.(  8)
      n         $ Do you want especially to restrict variable no.(  8)
      n         $ Any more decision variables (Y or N) ?
      n         $ Any linked variables (Y or N) ?
      n         $ Any inequality relations among variables? (type H)
      y         $ Any escape variables (Y or N) ?
      y         $ Want to have escape variables chosen by default?
```

Next, continue by executing SUPEROPT again. Do the following:

COMMAND   MEANING OF COMMAND

mainsetup   (provide analysis type, strategy, etc. for optimization
 The input file, try4.OPT, follows:)

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

superopt   (launch the "global" optimizer. Use 5 OPTIMIZEs per
 AUTOCHANGE.)

SUPEROPT bombs after 90 iterations with the following message at the end of the try4.OPM file:

```
 ********* ABORT **********
 THIS IS THE INDIC=1 BUCKLING ANALYSIS
 SHELL COLLAPSES AXISYMMETRICALLY
 Run is now aborting: IMODX= 0
 Look near the end of the *.OPP file for the "FEASIBLE" or for
```

the "ALMOST FEASIBLE" design. Choose whichever of those you prefer, and use CHANGE to save that design. Then, if you want to continue with SUPEROPT, execute SUPEROPT again. Bushnell has found that this execution of SUPEROPT may run for many iterations before bombing again, or it may run to completion (a total of about 470 design iterations).
****

This message is provided when the "bomb" occurs because of failure of convergence of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to application of the loads in Load Step 2: PINNER, PMIDDL, POUTER.

********************* NOTE ****************************
This is unlikely to happen now because of the November, 2010 modifications to SUBROUTINE BEHX1 described above and in ITEM 7d of the file, balloon.sphere.readme (**Table 8**).
****

Inspect the *.OPP (try4.OPP) file. Look near the end of that file for the "FEASIBLE" or "ALMOST FEASIBLE" design. Choose one of those designs and use the GENOPT processor, CHANGE, to establish that design as a new "starting" design.

COMMAND   MEANING OF COMMAND

change   (establish a new "starting" design. In this case the input for CHANGE is in the file: try4.CHG = try41.8mod.sphere.superopt2.chg, which follows:)

```
     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, . .)
   43.2900     $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        2      $ Number of parameter to change (1, 2, 3, . .)
   12.00000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        3      $ Number of parameter to change (1, 2, 3, . .)
   20.0000     $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        4      $ Number of parameter to change (1, 2, 3, . .)
  0.08869      $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        5      $ Number of parameter to change (1, 2, 3, . .)
  0.1477       $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        6      $ Number of parameter to change (1, 2, 3, . .)
  0.08486      $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        7      $ Number of parameter to change (1, 2, 3, . .)
  0.03222      $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        8      $ Number of parameter to change (1, 2, 3, . .)
  0.09393      $ 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?
```

COMMAND   MEANING OF COMMAND

mainsetup   (provide analysis type, strategy, etc. for the "fixed" locally optimum design. Input, try4.OPT, follows:)

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

optimize   (perform an analysis of the "fixed", locally optimized, design. The output file is try4.OPM = try41.8mod.sphere.superopt2.opm, part of which follows:)

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  3.00E+01 4.3290E+01  5.00E+01  height
from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01  radius of
curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  1.70E+01 2.0000E+01  3.00E+01  radius of
curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  3.00E-02 8.8690E-02  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  3.00E-02 1.4770E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  3.00E-02 8.4860E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  2.00E-02 3.2220E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  3.00E-02 9.3930E-02  3.00E-01  thickness
of each truss-core web: TFWEBS

    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    9.557E+03  weight/length of the balloon: WEIGHT  (Actually TOTMAS from
BIGBOSOR4)
```

Next, we want to do more optimization with SUPEROPT. First, we modify the input for DECIDE again.

```
COMMAND                    MEANING OF COMMAND

decide           (provide decision variables, lower and upper bounds,
                  linking constraints, inequality constraints.
                  Input, try4.DEC= try41.8mod.sphere.superopt2.dec)

     n           $ Do you want a tutorial session and tutorial output?
        1        $ Choose a decision variable (1,2,3,...)
   30.00000      $ Lower bound of variable no.(  1)
   50.00000      $ Upper bound of variable no.(  1)
     y           $ Do you want especially to restrict variable no.(  1)
   0.500000      $ Maximum permitted change in variable no.(  1)
     y           $ Any more decision variables (Y or N) ?
        2        $ Choose a decision variable (1,2,3,...)
   12.00000      $ Lower bound of variable no.(  2)
       20        $ Upper bound of variable no.(  2)
     y           $ Do you want especially to restrict variable no.(  2)
  0.2000000      $ Maximum permitted change in variable no.(  2)
     y           $ Any more decision variables (Y or N) ?
        3        $ Choose a decision variable (1,2,3,...)
   17.00000      $ Lower bound of variable no.(  3)
       30        $ Upper bound of variable no.(  3)
     y           $ Do you want especially to restrict variable no.(  3)
  0.2000000      $ Maximum permitted change in variable no.(  3)
     y           $ Any more decision variables (Y or N) ?
        4        $ Choose a decision variable (1,2,3,...)
  0.3000000E-01  $ Lower bound of variable no.(  4)
  0.3000000      $ Upper bound of variable no.(  4)
     n           $ Do you want especially to restrict variable no.(  4)
     y           $ Any more decision variables (Y or N) ?
        5        $ Choose a decision variable (1,2,3,...)
  0.3000000E-01  $ Lower bound of variable no.(  5)
  0.3000000      $ Upper bound of variable no.(  5)
     n           $ Do you want especially to restrict variable no.(  5)
     y           $ Any more decision variables (Y or N) ?
        6        $ Choose a decision variable (1,2,3,...)
  0.3000000E-01  $ Lower bound of variable no.(  6)
  0.3000000      $ Upper bound of variable no.(  6)
     n           $ Do you want especially to restrict variable no.(  6)
     y           $ Any more decision variables (Y or N) ?
        7        $ Choose a decision variable (1,2,3,...)
  0.2000000E-01  $ Lower bound of variable no.(  7)
  0.3000000      $ Upper bound of variable no.(  7)
     n           $ Do you want especially to restrict variable no.(  7)
     y           $ Any more decision variables (Y or N) ?
        8        $ Choose a decision variable (1,2,3,...)
  0.3000000E-01  $ Lower bound of variable no.(  8)
  0.3000000      $ Upper bound of variable no.(  8)
     n           $ Do you want especially to restrict variable no.(  8)
     n           $ Any more decision variables (Y or N) ?
     n           $ Any linked variables (Y or N) ?
     n           $ Any inequality relations among variables? (type H)
     y           $ Any escape variables (Y or N) ?
     y           $ Want to have escape variables chosen by default?
```

Next, continue by executing SUPEROPT again. Do the following:

```
COMMAND                  MEANING OF COMMAND

mainsetup       (provide analysis type, strategy, etc. for optimization
                 Input, try4.OPT, follows:)

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

superopt        (launch the "global" optimizer. Use 5 OPTIMIZEs per
                 AUTOCHANGE.)

SUPEROPT bombs after 94 additional iterations (a total of 184 iterations
since the beginning of the case) with the following information listed
at the end of the try4.OPM file:

 Decision variable candidates, HEIGHT,RINNER,ROUTER,TINNER,TOUTER=
  2.458114E+01  1.200000E+01  3.000000E+01  2.795527E-01  1.168092E-01
 TFINNR,TFOUTR,TFWEBS=  8.7636E-02  2.9031E-02  3.0000E-01

 ****** CHANGE FROM 10 TO 1 LOAD STEPS ******
 INITIAL LOADS TOO HIGH FOR THIS STRUCT
 Changing from 10 to 1 steps: IMODX= 0
 ********************************
 Decision variable candidates, HEIGHT,RINNER,ROUTER,TINNER,TOUTER=
  2.458114E+01  1.200000E+01  3.000000E+01  2.795527E-01  1.168092E-01
 TFINNR,TFOUTR,TFWEBS=  8.7636E-02  2.9031E-02  3.0000E-01

 ****** CHANGE FROM 1 TO 50 LOAD STEPS ******
 INITIAL LOADS TOO HIGH FOR THIS STRUCT
 Changing from 1 to 50 steps: IMODX= 0
 ********************************
 Decision variable candidates, HEIGHT,RINNER,ROUTER,TINNER,TOUTER=
  2.458114E+01  1.200000E+01  3.000000E+01  2.795527E-01  1.168092E-01
 TFINNR,TFOUTR,TFWEBS=  8.7636E-02  2.9031E-02  3.0000E-01

 ************* ABORT **********
 INITIAL LOADS TOO HIGH FOR THIS STRUCT
 This is an unrecoverable error because we have already
 tried and failed to obtain nonlinear pre-buckling convergence
 by changing from a nonlinear solution with 10 load steps to
 a nonlinear solution with 1 load step and then changing from
 1 load step to 50 load steps:three tries. That strategy just
 failed. You may well have performed enough design iterations
 to have a good optimum design now. Look near the end of the
 *.OPP file at the "FEASIBLE" and "ALMOST FEASIBLE" designs.
 If you are not satisfied that you have performed enough
```

design iterations, then use the GENOPT processor to reset
the values of the decision variables to those of the already
accepted "FEASIBLE" or "ALMOST FEASIBLE" design and then
launch SUPEROPT again. This has worked for Bushnell.
You may also which to tighten the lower and upper bounds
of one or more of the decision variables, especially the
lower bounds of HEIGHT and ROUTER, and possibly one or more
of the thicknesses of segments that are becoming very thin.
The run is now aborting: IMODX= 0
****

This message is provided when the "bomb" occurs because of failure of convergence of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to application of the loads in Load Step 1: PINNER, PMIDDL.

********************** NOTE ****************************
This is unlikely to happen now because of the November, 2010 modifications to SUBROUTINE BEHX1 described above and in ITEM 7d of the file, balloon.sphere.readme (**Table 8**).
****

Inspect the *.OPP (try4.OPP) file. Look near the end of that file for the "FEASIBLE" or "ALMOST FEASIBLE" design. Choose one of those designs and use the GENOPT processor, CHANGE, to establish that design as a new "starting" design.

COMMAND	MEANING OF COMMAND
change	(establish a new "starting" design. In this case the input for CHANGE is in the file, try4.CHG = try41.8mod.sphere.superopt3.chg, which follows:)

```
     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, . .)
   38.1700     $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        2      $ Number of parameter to change (1, 2, 3, . .)
   12.00000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        3      $ Number of parameter to change (1, 2, 3, . .)
   17.0000     $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        4      $ Number of parameter to change (1, 2, 3, . .)
  0.08854      $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        5      $ Number of parameter to change (1, 2, 3, . .)
  0.1167       $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        6      $ Number of parameter to change (1, 2, 3, . .)
  0.08943      $ New value of the parameter
     y         $ Want to change any other parameters in this set?
        7      $ Number of parameter to change (1, 2, 3, . .)
```

```
  0.02628       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
  0.08950       $ 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?
```

COMMAND MEANING OF COMMAND

mainsetup (provide analysis type, strategy, etc. for the "fixed" locally optimum design. Input, try4.OPT, follows:)

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

optimize (perform an analysis of the "fixed", locally optimized, design. The output file is try4.OPM = try41.8mod.sphere.superopt3.opm, part of which follows:)

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  3.00E+01 3.8170E+01  5.00E+01  height
from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01  radius of
curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  1.70E+01 1.7000E+01  3.00E+01  radius of
curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  3.00E-02 8.8540E-02  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  3.00E-02 1.1670E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  3.00E-02 8.9430E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-02 2.6280E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  3.00E-02 8.9500E-02  3.00E-01  thickness
of each truss-core web: TFWEBS

    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE             DEFINITION
```

```
  1    8.231E+03  weight/length of the balloon: WEIGHT  (Actually TOTMAS from
BIGBOSOR4)
```

Next, we want to do more optimization with SUPEROPT. First, we modify the input for DECIDE again.

```
COMMAND                      MEANING OF COMMAND

decide          (provide decision variables, lower and upper bounds,
                 linking constraints, inequality constraints.
                 Input, try4.DEC= try41.8mod.sphere.superopt3.dec)

      n         $ Do you want a tutorial session and tutorial output?
         1      $ Choose a decision variable (1,2,3,...)
   30.00000     $ Lower bound of variable no.(  1)
   40.00000     $ Upper bound of variable no.(  1)
      y         $ Do you want especially to restrict variable no.(  1)
   0.500000     $ Maximum permitted change in variable no.(  1)
      y         $ Any more decision variables (Y or N) ?
         2      $ Choose a decision variable (1,2,3,...)
   12.00000     $ Lower bound of variable no.(  2)
        20      $ Upper bound of variable no.(  2)
      y         $ Do you want especially to restrict variable no.(  2)
  0.2000000     $ Maximum permitted change in variable no.(  2)
      y         $ Any more decision variables (Y or N) ?
         3      $ Choose a decision variable (1,2,3,...)
   16.00000     $ Lower bound of variable no.(  3)
        30      $ Upper bound of variable no.(  3)
      y         $ Do you want especially to restrict variable no.(  3)
  0.2000000     $ Maximum permitted change in variable no.(  3)
      y         $ Any more decision variables (Y or N) ?
         4      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  4)
  0.3000000     $ Upper bound of variable no.(  4)
      n         $ Do you want especially to restrict variable no.(  4)
      y         $ Any more decision variables (Y or N) ?
         5      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  5)
  0.3000000     $ Upper bound of variable no.(  5)
      n         $ Do you want especially to restrict variable no.(  5)
      y         $ Any more decision variables (Y or N) ?
         6      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  6)
  0.3000000     $ Upper bound of variable no.(  6)
      n         $ Do you want especially to restrict variable no.(  6)
      y         $ Any more decision variables (Y or N) ?
         7      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.(  7)
  0.3000000     $ Upper bound of variable no.(  7)
      n         $ Do you want especially to restrict variable no.(  7)
      y         $ Any more decision variables (Y or N) ?
         8      $ Choose a decision variable (1,2,3,...)
  0.3000000E-01 $ Lower bound of variable no.(  8)
  0.3000000     $ Upper bound of variable no.(  8)
      n         $ Do you want especially to restrict variable no.(  8)
      n         $ Any more decision variables (Y or N) ?
      n         $ Any linked variables (Y or N) ?
```

```
      n          $ Any inequality relations among variables? (type H)
      y          $ Any escape variables (Y or N) ?
      y          $ Want to have escape variables chosen by default?
```

Next, continue by executing SUPEROPT again. Do the following:

COMMAND   MEANING OF COMMAND

mainsetup   (provide analysis type, strategy, etc. for optimization Input, try4.OPT, follows:)

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

superopt   (launch the "global" optimizer. Use 5 OPTIMIZEs per AUTOCHANGE.)

SUPEROPT bombs after 60 additional iterations (a total of 244 iterations since the beginning of the case) with the following message at the end of the try4.OPM file:

```
 ********* ABORT **********
 THIS IS THE INDIC=1 BUCKLING ANALYSIS
 SHELL COLLAPSES AXISYMMETRICALLY
 Run is now aborting: IMODX= 0
 Look near the end of the *.OPP file for the "FEASIBLE" or for
 the "ALMOST FEASIBLE" design. Choose whichever of those you
 prefer, and use CHANGE to save that design. Then, if you want
 to continue with SUPEROPT, execute SUPEROPT again. Bushnell
 has found that this execution of SUPEROPT may run for many
 iterations before bombing again, or it may run to completion
 (a total of about 470 design iterations).
 ********************************
```

This message is provided when the "bomb" occurs because of failure of convergence of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to application of the loads in Load Step 2: PINNER, PMIDDL, POUTER.

********************* NOTE ****************************
This is unlikely to happen now because of the November, 2010 modifications to SUBROUTINE BEHX1 described above and in ITEM 7d of the file, balloon.sphere.readme (**Table 8**).
****

Inspect the *.OPP (try4.OPP) file. Look near the end of that file for the "FEASIBLE" or "ALMOST FEASIBLE" design. It turns out in this particular case that the best design at the end of the fourth execution of SUPEROPT is the same as the best design at the end of the third execution of SUPEROPT. Therefore, we will stop trying to find a better "global" optimum design and settle for the following design as the final optimum design:

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  3.00E+01 3.8170E+01  5.00E+01  height
from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01  radius of
curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  1.70E+01 1.7000E+01  3.00E+01  radius of
curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  3.00E-02 8.8540E-02  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  3.00E-02 1.1670E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  3.00E-02 8.9430E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-02 2.6280E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  3.00E-02 8.9500E-02  3.00E-01  thickness
of each truss-core web: TFWEBS

    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    8.231E+03  weight/length of the balloon: WEIGHT  (Actually TOTMAS from
BIGBOSOR4)
```

We next do the following:

COMMAND   MEANING OF COMMAND

chooseplot (choose what to plot versus design iterations.
Input file, try4.CPL = try41.8mod.sphere.superopt1.cpl,
which follows:

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

```
      y          $ Any more margins to be plotted (Y or N) ?
        13       $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y          $ Any more margins to be plotted (Y or N) ?
        15       $ Choose a margin to be plotted v. iterations (1,2,3,..)
      n          $ Any more margins to be plotted (Y or N) ?
         1       $ Give maximum value (positive) to be included in plot frame.
      n          $ Do you want to get more plots before your next "SUPEROPT"?
```

COMMAND   MEANING OF COMMAND

diplot   (try4.3.ps and try4.5.ps files are generated.)

gv try4.3.ps   (margins versus design iterations from 2nd, 3rd, and 4th executions of SUPEROPT.)

gv try4.5.ps   (objective versus design iterations from 2nd, 3rd, and 4th executions of SUPEROPT.)

try4.3.ps = try41.8mod.sphere.superopt4.margins.ps
try4.5.ps = try41.8mod.sphere.superopt4.objective.ps

Next, we wish to plot some of the prebuckled states from Load Step 1 ["fixed" (non-eigenvalue) loads, PINNER, PMIDDL]. We do this by executing BIGBOSOR4 independently of the GENOPT context, as follows:

COMMAND   MEANING OF COMMAND

change   (re-establish the final optimum design. In this case the input for CHANGE is in the input, try4.CHG =try41.8mod.sphere.superopt3.chg, which follows:)

```
      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, . .)
   38.1700       $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         2       $ Number of parameter to change (1, 2, 3, . .)
   12.00000      $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         3       $ Number of parameter to change (1, 2, 3, . .)
   17.0000       $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         4       $ Number of parameter to change (1, 2, 3, . .)
  0.08854        $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         5       $ Number of parameter to change (1, 2, 3, . .)
  0.1167         $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         6       $ Number of parameter to change (1, 2, 3, . .)
  0.08943        $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         7       $ Number of parameter to change (1, 2, 3, . .)
  0.02628        $ New value of the parameter
      y          $ Want to change any other parameters in this set?
         8       $ Number of parameter to change (1, 2, 3, . .)
```

```
  0.08950       $ 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?
```

COMMAND MEANING OF COMMAND

mainsetup (provide analysis type, strategy, etc. for the "fixed" locally optimum design. Input, try4.OPT, follows:)

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

optimize (perform an analysis of the "fixed", locally optimized, design. The output file is try4.OPM = try41.8mod.sphere.superopt3.opm, part of which follows:)

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  3.00E+01 3.8170E+01  5.00E+01  height
from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01  radius of
curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  1.70E+01 1.7000E+01  3.00E+01  radius of
curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  3.00E-02 8.8540E-02  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  3.00E-02 1.1670E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  3.00E-02 8.9430E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-02 2.6280E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  3.00E-02 8.9500E-02  3.00E-01  thickness
of each truss-core web: TFWEBS

    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    8.231E+03  weight/length of the balloon: WEIGHT  (Actually TOTMAS from
BIGBOSOR4)
```

Next, get plots from BIGBOSOR4 of the pre-buckling equilibrium state corresponding to the loads in Load Set B (loads in Load Step 1: PINNER and PMIDDL:

COMMAND	MEANING OF COMMAND
cd /home/progs/work6	(go to a working space, "work6")
bigbosor4log	(activate the BIGBOSOR4 set of commands)
cp /home/progs/genoptcase/try4.LOADB try4.ALL	(get BIGBOSOR4 input file)
bigbosorall	(execute BIGBOSOR4: input file = try4.ALL . NOTE: valid input files for bigbosor4 always have the suffix, ".ALL")

Inspect the try4.OUT file. Search for the string, "LOAD STEP".

Next, you want to plot the axisymmetric prebuckled state. Do the following:

COMMAND	MEANING OF COMMAND
bosorplot	(choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)
gv metafile.ps	(get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the pre-buckled state corresponding to Load Step 11, for which PINNER = 0 and P = 1.002 x PMIDDL. The plot is generated from the Postscript file:
try41.8mod.sphere.superopt4.loadb.step11.ps (**Figure 6**)

COMMAND	MEANING OF COMMAND
bosorplot	(choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)
gv metafile.ps	(get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the pre-buckled state corresponding to Load Step 1, for which PINNER = 0 and P = 0.002 x PMIDDL. The plot is generated from the Postscript file:
try41.8mod.sphere.superopt4.loadb.step1.ps (**Figure 5**)

cleanup	(Clean up the files generated by BIGBOSOR4)

Next, get plots from BIGBOSOR4 of one of the buckling modes.

COMMAND MEANING OF COMMAND

cp /home/progs/genoptcase/try4.PLT2 . (get BOSORPLOT input file)

bosorplot (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the buckling mode corresponding to N = 0 circumferential waves. The plot is generated from the Postscript file: try41.8mod.sphere.superopt4.locbuck.n0.ps (**Figure 10a**)

COMMAND MEANING OF COMMAND

bosorplot (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the buckling mode corresponding to N = 64 circumferential waves. The plot is generated from the Postscript try41.8mod.sphere.superopt4.locbuck.n64.ps (**Figure 10i**)

The plots displayed in Figs. 10a – 10k are all obtained in an analogous fashion.

The following was added to this "run stream" file after a bug was found and corrected in SUBROUTINE BEHX5 and after a limited re-optimization was performed:

******************** IMPORTANT NOTE *************************
NOTE: A bug was found in SUBROUTINE BEHX5 (maximum stress in Material Type 3, the material out of which the webs are fabricated) after this table was generated. Therefore, the exact results listed below cannot be reproduced. The main purpose of this table is to demonstrate how to proceed in a case when SUPEROPT executions bomb because of failure of convergence of the Newton iterations to solve the nonlinear pre-buckling equilibrium equations. Here it is not the results that are important; it is the process.
****

In order to obtain a new optimum design after the bug was corrected, the old optimum design was used as a starting design, a new input file for MAINSETUP was established, and the GENOPT command, OPTIMIZE, was given three times in succession.

The following run stream was executed:

```
COMMAND                  MEANING OF COMMAND

cleanspec  (clean up the specific "try4" files.)
cd /home/bush/Documents    (go to the directory where files are archived)
cp try41.8mod.sphere.beg /home/progs/genoptcase/try4.BEG
cp try41.8mod.sphere.superopt3.dec /home/progs/genoptcase/try4.DEC
cp try41.8mod.sphere.superopt3.chg /home/progs/genoptcase/try4.CHG
begin      (try4.BEG is the input file)
change          (try4.CHG is the input file)
decide          (try4.DEC is the input file)
mainsetup  (The input file, try4.OPT, follows:)

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

Next, perform limited re-optimization by executing OPTIMIZE three times:

```
COMMAND                  MEANING OF COMMAND

optimize   (first  execution of OPTIMIZE with ITYPE=1)
optimize        (second execution of OPTIMIZE with ITYPE=1)
optimize        (third  execution of OPTIMIZE with ITYPE=1)
```

After the three executions of "optimize", the last part of the try4.OPP file contains the following information:

```
 ITERATION                                       NUMBER OF
  NUMBER      OBJECTIVE     THE DESIGN IS...   CRITICAL MARGINS
 -------------------------------------------------------------
 -----------------------------------------------------OPTIMIZE
     1         8.2315E+03     MORE UNFEASIBLE         5
     2         8.2063E+03     MILDLY UNFEASIB         5
     3         8.3797E+03     MILDLY UNFEASIB         5
     4         8.4871E+03     MILDLY UNFEASIB         5
     5         8.6173E+03     MILDLY UNFEASIB         5
     6         8.7322E+03     MILDLY UNFEASIB         5
 -----------------------------------------------------OPTIMIZE
     7         8.7322E+03     MILDLY UNFEASIB         5
```

```
    8         8.9950E+03     MILDLY UNFEASIB        5
    9         9.0619E+03     ALMOST FEASIBLE        4
   10         9.1675E+03         FEASIBLE           5
   11         9.0480E+03         FEASIBLE           5
   12         8.9767E+03     ALMOST FEASIBLE        5
------------------------------------------------------OPTIMIZE
   13         8.9767E+03     ALMOST FEASIBLE        5
   14         8.7681E+03     MILDLY UNFEASIB        5
   15         8.8871E+03     ALMOST FEASIBLE        5
   16         8.7555E+03     ALMOST FEASIBLE        5
   17         8.8281E+03     ALMOST FEASIBLE        5
   18         8.9161E+03         FEASIBLE           5

 VALUES OF DESIGN VARIABLES CORRESPONDING TO ALMOST FEASIBLE DESI
VAR.   CURRENT
NO.     VALUE           DEFINITION
 1    3.850E+01  height from inner to outer membranes: HEIGHT
 2    1.200E+01  radius of curvature of inner membrane: RINNER
 3    1.714E+01  radius of curvature of outer membrane: ROUTER
 4    8.844E-02  thickness of the inner curved membrane: TINNER
 5    1.224E-01  thickness of the outer curved membrane: TOUTER
 6    8.914E-02  thickness of inner truss-core segment: TFINNR
 7    2.772E-02  thickness of the outer truss segment: TFOUTR
 8    9.891E-02  thickness of each truss-core web: TFWEBS
MARGINS CORRESPONDING TO THE DESIGN (F.S.= FACTOR OF SAFETY)
MAR.   CURRENT
NO.     VALUE           DEFINITION
 1    1.346E-01  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
 2    4.354E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
 3    2.954E-03  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
 4    1.000E+14  (STRM1A(1 ,2 )/STRM1(1 ,2 )) / STRM1F(1 ,2 )-1; F.S.=  1.00
 5    5.646E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
 6    1.000E+14  (STRM1A(1 ,4 )/STRM1(1 ,4 )) / STRM1F(1 ,4 )-1; F.S.=  1.00
 7    1.000E+14  (STRM1A(1 ,5 )/STRM1(1 ,5 )) / STRM1F(1 ,5 )-1; F.S.=  1.00
 8    7.838E-03  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
 9    1.000E+14  (STRM2A(1 ,2 )/STRM2(1 ,2 )) / STRM2F(1 ,2 )-1; F.S.=  1.00
10    3.961E-02  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
11    1.000E+14  (STRM2A(1 ,4 )/STRM2(1 ,4 )) / STRM2F(1 ,4 )-1; F.S.=  1.00
12    1.000E+14  (STRM2A(1 ,5 )/STRM2(1 ,5 )) / STRM2F(1 ,5 )-1; F.S.=  1.00
13   -4.244E-02  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
14    1.000E+14  (STRM3A(1 ,2 )/STRM3(1 ,2 )) / STRM3F(1 ,2 )-1; F.S.=  1.00
15    9.967E-01  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00
16    1.000E+14  (STRM3A(1 ,4 )/STRM3(1 ,4 )) / STRM3F(1 ,4 )-1; F.S.=  1.00
17    1.000E+14  (STRM3A(1 ,5 )/STRM3(1 ,5 )) / STRM3F(1 ,5 )-1; F.S.=  1.00

******************* DESIGN OBJECTIVE ******************
*************                        ***********
 CORRESPONDING VALUE OF THE OBJECTIVE FUNCTION:
VAR.   CURRENT
NO.     VALUE           DEFINITION
 1    8.755E+03  weight/length of the balloon: WEIGHT
*************                        ************
******************* DESIGN OBJECTIVE ******************
```

New plots of the margins and objective versus the 24 design iterations that correspond to the three executions of OPTIMIZE are generated as follows:

```
COMMAND                     MEANING OF COMMAND
```

chooseplot (choose what to plot: margins. The input file, try4.CPL, follows:)

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

```
COMMAND                     MEANING OF COMMAND
```

diplot (DIPLOT generates try4.3.ps and try4.5.ps)
gv try4.3.ps (view the plot of margins v. design iterations on screen)
gv try4.5.ps (view the plot of objective v. design iterations on screen)

cd /home/bush/Documents (archive of results)

Put the two plot files, try4.3.ps (margins) and try4.5.ps (objective) in archive files, as follows:

cp /home/progs/genoptcase/try4.3.ps try41.8mod.sphere.corrected.margins.ps
cp /home/progs/genoptcase/try4.5.ps try41.8mod.sphere.corrected.objective.ps

Next, archive the re-optimized design via the GENOPT processor, CHANGE:

```
COMMAND                     MEANING OF COMMAND
```

change (save the re-optimized design. The input file is try4.CHG, which follows:)

```
      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, . .)
   38.5000      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         2      $ Number of parameter to change (1, 2, 3, . .)
   12.00000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         3      $ Number of parameter to change (1, 2, 3, . .)
```

```
   17.1400      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         4      $ Number of parameter to change (1, 2, 3, . .)
  0.08844       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         5      $ Number of parameter to change (1, 2, 3, . .)
  0.1224        $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         6      $ Number of parameter to change (1, 2, 3, . .)
  0.08914       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         7      $ Number of parameter to change (1, 2, 3, . .)
  0.02772       $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
  0.09891       $ 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?
```

Execute MAINSETUP and OPTIMIZE with ITYPE = 2 ("fixed" design):

COMMAND   MEANING OF COMMAND

mainsetup (The input file, try4.OPT, follows:)

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

COMMAND   MEANING OF COMMAND

optimize (generate the try4.OPM file that corresponds to the re-optimized design. The first part of the try4.OPM file follows:)

```
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  3.00E+01 3.8500E+01  4.00E+01  height
from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01  radius of
curvature of inner membrane: RINNER
```

```
   3   Y     N     N      0    0.00E+00  1.60E+01 1.7140E+01  3.00E+01  radius of
curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  3.00E-02 8.8440E-02  3.00E-01  thickness
of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  3.00E-02 1.2240E-01  3.00E-01  thickness
of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  3.00E-02 8.9140E-02  3.00E-01  thickness
of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  2.00E-02 2.7720E-02  3.00E-01  thickness
of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  3.00E-02 9.8910E-02  3.00E-01  thickness
of each truss-core web: TFWEBS

 ******************* DESIGN OBJECTIVE ******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    8.756E+03  weight/length of the balloon: WEIGHT
 ******************* DESIGN OBJECTIVE ******************
```

Next, get plots from BIGBOSOR4 of the pre-buckling equilibrium state corresponding to the loads in Load Set B (loads in Load Step 1: PINNER and PMIDDL:

COMMAND   MEANING OF COMMAND

cd /home/progs/work6   (go to a working space, "work6")
bigbosor4log   (activate the BIGBOSOR4 set of commands)
cp /home/progs/genoptcase/try4.LOADB try4.ALL   (get BIGBOSOR4 input file)
bigbosorall   (execute BIGBOSOR4: input file = try4.ALL .
NOTE: valid input files for bigbosor4 always have the suffix, ".ALL")

Inspect the try4.OUT file. Search for the string, "LOAD STEP".

Next, you want to plot the axisymmetric prebuckled state.
Do the following:

COMMAND   MEANING OF COMMAND

bosorplot   (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the pre-buckled state corresponding to Load Step 11, for which PINNER = 0 and P = 1.002 x PMIDDL. The plot is generated from the Postscript file:
try41.8mod.sphere.corrected.loadb.step11.ps

COMMAND   MEANING OF COMMAND

bosorplot (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the pre-buckled state corresponding to Load Step 1, for which PINNER = 0 and P = 0.002 x PMIDDL. The plot is generated from the Postscript file:
try41.8mod.sphere.corrected.loadb.step1.ps

cleanup (Clean up the files generated by BIGBOSOR4)

Next, get plots from BIGBOSOR4 of one of the buckling modes.

COMMAND MEANING OF COMMAND

cp /home/progs/genoptcase/try4.PLT2 . (get BOSORPLOT input file)

bosorplot (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the buckling mode corresponding to N = 0 circumferential waves. The plot is generated from the Postscript file:
try41.8mod.sphere.corrected.locbuck.n0.ps (**Figure 10a**)

COMMAND MEANING OF COMMAND

bosorplot (choose what to plot. Use "x" in response to prompt if you want plot on your screen. Use "p" in response to prompt if you want plot to be in the file called "metafile.ps".)

gv metafile.ps (get a plot on your screen via the "ghost view" utility, if "ghost view" is available on your workstation.)

Choose the buckling mode corresponding to N = 64 circumferential waves. The plot is generated from the Postscript
try41.8mod.sphere.corrected.locbuck.n64.ps (**Figure 10i**)

The plots displayed in Figs. 10a – 10k are all obtained in an analogous fashion.
==

Table 5 This is the file, behavior.balloon, which is the "fleshed out" version of the skeletal behavior.new that is automatically produced by GENTEXT. It is the duty of the GENOPT user to do the "fleshing out". The code supplied by the GENOPT user is in bold face. Note that this behavior.balloon file is somewhat different from the now out-of-date file with the same name in [1].

```
==============================================================================
C=DECK      BEHAVIOR.NEW
C  This library contains the skeletons of
C  subroutines called SUBROUTINE BEHXn, n = 1,
C  2, 3, . . . that will yield predictions
C  of behavioral responses of various systems
C  to environments (loads).
C
C  You may complete the subroutines by writing
C  algorithms that yield the responses,
C  each of which plays a part in constraining
C  the design to a feasible region. Examples
C  of responses are: stress, buckling, drag,
C  vibration, deformation, clearances, etc.
C
C  A skeleton routine called SUBROUTINE OBJECT
C  is also provided for any objective function
C  (e.g. weight, deformation, conductivity)
C  you may wish to create.
C
C  A skeleton routine called SUBROUTINE USRCON
C  is also provided for any user-written
C  constraint condition you may wish to write:
C  This is an INEQUALITY condition that
C  involves any program variables.  However,
C  note that this kind of thing is done
C  automatically in the program DECIDE, so
C  try DECIDE first to see if your particular
C  constraint conditions can be accommodated
C  more easily there.
C
C  Please note that you do not have to modify
C  BEHAVIOR.NEW in any way, but may instead
C  prefer to insert your subroutines into the
C  skeletal libraries ADDCODEn.NEW, n=1,2,...
C  and appropriate common blocks, dimension
C  and type statements and calls to these
C  subroutines in the library STRUCT.NEW.
C  This strategy is best if your FORTRAN
C  input to GENOPT contains quite a bit
C  of software previously written by
C  yourself or others, and/or the generation
C  of behavioral constraints is more easily
C  accomplished via another architecture
```

```
C  than that provided for in the
C  BEHAVIOR.NEW library. (See instructions
C  in the libraries ADDCODEn.NEW and
C  STRUCT.NEW for this procedure.)
C
C  The two test cases provided with GENOPT
C  provide examples of each method:
C   PLATE (test case 1): use of BEHAVIOR.NEW
C   PANEL (test case 2): use of ADDCODEn.NEW
C                        and STRUCT.NEW.
C
C   SEVEN ROLES THAT VARIABLES IN THIS SYSTEM OF PROGRAMS PLAY
C
C    A variable can have one of the following roles:
C
C    1 = a possible decision variable for optimization,
C        typically a dimension of a structure.
C    2 = a constant parameter (cannot vary as design evolves),
C        typically a control integer or material property,
C        but not a load, allowable, or factor of safety,
C        which are asked for later.
C    3 = a parameter characterizing the environment, such
C        as a load component or a temperature.
C    4 = a quantity that describes the response of the
C        structure, (e.g. stress, buckling load, frequency)
C    5 = an allowable, such as maximum allowable stress,
C        minimum allowable frequency, etc.
C    6 = a factor of safety
C    7 = the quantity that is to be minimized or maximized,
C        called the "objective function" (e.g. weight).
C ==========================================================
C
C  NAMES, DEFINITIONS, AND ROLES OF THE VARIABLES:

C YOU ARE USING WHAT I HAVE CALLED "GENOPT" TO GENERATE AN
C OPTIMIZATION PROGRAM FOR A PARTICULAR CLASS OF PROBLEMS.
C THE NAME YOU HAVE CHOSEN FOR THIS CLASS OF PROBLEMS IS: balloon

C "GENOPT" (GENeral OPTimization) was written during 1987-1988
C by Dr. David Bushnell, Dept. 93-30, Bldg. 251, (415)424-3237
C    Lockheed Missiles and Space Co., 3251 Hanover St.,
C    Palo Alto, California, USA  94304

C The optimizer used in GENOPT is called ADS, and was
C written by G. Vanderplaats [3]. It is based on the method
C of feasible directions [4].

C                       ABSTRACT

C "GENOPT" has the following purposes and properties:
C     1. Any relatively simple analysis is "automatically"
C        converted into an optimization of whatever system
C        can be analyzed with fixed properties. Please note
C        that GENOPT is not intended to be used for problems
```

```
C          that require elaborate data-base management systems
C          or large numbers of degrees of freedom.

C       2. The optimization problems need not be in fields nor
C          jargon familiar to me, the developer of GENOPT.
C          Although all of the example cases (See the cases
C          in the directories under genopt/case)
C          are in the field of structural analysis, GENOPT is
C          not limited to that field.


C       3. GENOPT is a program that writes other programs. These
C          programs, WHEN AUGMENTED BY USER-SUPPLIED CODING,
C          form a program system that should be user-friendly in
C          the GENOPT-user"s field. In this instance the user
C          of GENOPT must later supply FORTRAN coding that
C          calculates behavior in the problem class called "balloon".

C       4. Input data and textual material are elicited from
C          the user of GENOPT in a general enough way so that
C          he or she may employ whatever data, definitions, and
C          "help" paragraphs will make subsequent use of the
C          program system thus generated easy by those less
C          familiar with the class of problems "balloon" than
C          the GENOPT user.

C       5. The program system generated by GENOPT has the same
C          general architecture as previous programs written for
C          specific applications by the developer [7 - 16]. That
C          is, the command set is:

C             BEGIN     (User supplies starting design, loads,
C                        control integers, material properties,
C                        etc. in an interactive-help mode.)

C             DECIDE    (User chooses decision and linked
C                        variables and inequality constraints
C                        that are not based on behavior.)

C             MAINSETUP (User chooses output option, whether
C                        to perform analysis of a fixed design
C                        or to optimize, and number of design
C                        iterations.)

C             OPTIMIZE  (The program system performs, in a batch
C                        mode, the work specified in MAINSETUP.)

C             SUPEROPT  (Program tries to find the GLOBAL optimum
C                        design as described in Ref.[11] listed
C                        below (Many OPTIMIZEs in one run.)

C             CHANGE    (User changes certain parameters)

C             CHOOSEPLOT (User selects which quantities to plot
```

```
C                        vs. design iterations.)

C            DIPLOT    (User generates plots)

C            CLEANSPEC (User cleans out unwanted files.)

C      A typical runstream is:
C        GENOPTLOG   (activate command set)
C        BEGIN       (provide starting design, loads, etc.)
C        DECIDE      (choose decision variables and bounds)
C        MAINSETUP   (choose print option and analysis type)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        CHANGE      (change some variables for new starting pt)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        OPTIMIZE    (launch batch run for n design iterations)
C        CHOOSEPLOT  (choose which variables to plot)
C        DIPLOT      (plot variables v. iterations)
C        CHOOSEPLOT  (choose additional variables to plot)
C        DIPLOT      (plot more variables v design iterations)
C        CLEANSPEC   (delete extraneous files for specific case)

C   IMPORTANT:  YOU MUST ALWAYS GIVE THE COMMAND "OPTIMIZE"
C               SEVERAL TIMES IN SUCCESSION IN ORDER TO OBTAIN
C               CONVERGENCE! AN EXPLANATION OF WHY YOU MUST DO
C               THIS IS GIVEN ON P 580-582 OF THE PAPER "PANDA2,
C               PROGRAM FOR MINIMUM WEIGHT DESIGN OF STIFFENED,
C               COMPOSITE LOCALLY BUCKLED PANELS", Computers and
C               Structures, Vol. 25, No. 4, pp 469-605 (1987).

C Due to introduction of a "global" optimizer, SUPEROPT,
C described in Ref.[11], you can now use the runstream

C       BEGIN       (provide starting design, loads, etc.)
C       DECIDE      (choose decision variables and bounds)
C       MAINSETUP   (choose print option and analysis type)
C       SUPEROPT    (launch batch run for "global" optimization)
C       CHOOSEPLOT  (choose which variables to plot)
C       DIPLOT      (plot variables v. iterations)

C "Global" is in quotes because SUPEROPT does its best to find
C a true global optimum design. The user is strongly urged to
C execute SUPEROPT/CHOOSEPLOT several times in succession in
C order to determine an optimum that is essentially just as
C good as the theoretical true global optimum. Each execution
C of the series,
C       SUPEROPT
C       CHOOSEPLOT
```

```
C does the following:

C 1. SUPEROPT executes many sets of the two processors,
C    OPTIMIZE and AUTOCHANGE (AUTOCHANGE gets a new random
C    "starting" design), in which each set does the following:

C      OPTIMIZE          (perform k design iterations)
C      OPTIMIZE          (perform k design iterations)
C      OPTIMIZE          (perform k design iterations)
C      OPTIMIZE          (perform k design iterations)
C      OPTIMIZE          (perform k design iterations)
C      AUTOCHANGE        (get new starting design randomly)

C    SUPEROPT keeps repeating the above sequence until the
C    total number of design iterations reaches about 270.
C    The number of OPTIMIZEs per AUTOCHANGE is user-provided.

C 2. CHOOSEPLOT allows the user to plot stuff and resets the
C    total number of design iterations from SUPEROPT to zero.
C    After each execution of SUPEROPT the user MUST execute
C    CHOOSEPLOT: before the next execution of SUPEROPT the
C    total number of design iterations MUST be reset to zero.

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C===============================================================
C                TABLE 1      "GENOPT" COMMANDS
C===============================================================
C     HELPG        (get information on GENOPT.)
C     GENTEXT      (GENOPT user generate a prompt file, program
C                   fragments [see TABLE 5], programs [see
C                   TABLE 4]., and this and other files
C                   [see TABLE 5 and the rest of this file.])
C     GENPROGRAMS  (GENOPT user generate absolute elements:
C                   BEGIN.EXE, DECIDE.EXE, MAINSETUP.EXE,
C                   OPTIMIZE.EXE, CHANGE.EXE, STORE.EXE,
C                   CHOOSEPLOT.EXE, DIPLOT.EXE.)

C     BEGIN        (end user provide starting data.)
C     DECIDE       (end user choose decision variables, bounds,
C                   linked variables,inequality constraints.)
C     MAINSETUP    (end user set up strategy parameters.)
C     OPTIMIZE     (end user perform optimization, batch mode.)
C     SUPEROPT     (Program tries to find the GLOBAL optimum
C                   design as described in Ref.[11] listed
C                   above (Many OPTIMIZEs in one run.)

C     CHANGE       (end user change some parameters.)
C     CHOOSEPLOT   (end user choose which variables to plot v.
C                   design iterations.)
C     DIPLOT       (end user obtain plots.)
C     INSERT       (GENOPT user add parameters to the problem.)
C     CLEANGEN     (GENOPT user cleanup your GENeric files.)
C     CLEANSPEC    (end user cleanup your SPECific case files)

C   Please consult the following sources for more
C   information about GENOPT:
```

```
C        1.  GENOPT.STORY  and  HOWTO.RUN  and  GENOPT.NEWS
C        2.  Sample cases: (in the directory, genopt/case)
C        3.  NAME.DEF file, where NAME is the name chosen by
C            the GENOPT-user for a class of problems. (In this
C            case  NAME = balloon)
C        4.  GENOPT.HLP file    (type HELPG)
C==============================================================

C===============================================================
C   TABLE 2   GLOSSARY OF VARIABLES USED IN "balloon"
C===============================================================
C  ARRAY  NUMBER OF         PROMPT
C    ?   (ROWS,COLS)  ROLE  NUMBER   NAME                DEFINITION OF VARIABLE
C                         (balloon.PRO)
C=========================================================
C    n   (   0,   0)    2      10   LENGTH   = length of the cylindrical shell
C    n   (   0,   0)    2      15   RADIUS   = inner radius of the cylindrical b
C    n   (   0,   0)    2      20   NMODUL   = number of modules over 90 degrees
C    n   (   0,   0)    2      30   ISHAPE   = balloon shape index
C    n   (   0,   0)    2      40   IWEBS    = radial (1) or truss-like (2) webs
C    n   (   0,   0)    2      50   IEMOD1   = material number in EMOD1(IEMOD1)
C    y   (  10,   0)    2      55   EMOD1    = elastic modulus, meridional direc
C    y   (  10,   0)    2      60   EMOD2    = elastic modulus, circumferential
C    y   (  10,   0)    2      65   G12      = in-plane shear modulus
C    y   (  10,   0)    2      70   G13      = out-of-plane (s,z) shear modulus
C    y   (  10,   0)    2      75   G23      = out-of-plane (y,z) shear modulus
C    y   (  10,   0)    2      80   NU       = Poisson ratio
C    y   (  10,   0)    2      85   ALPHA1   = meridional coef. thermal expansio
C    y   (  10,   0)    2      90   ALPHA2   = circumf.coef.thermal expansion
C    y   (  10,   0)    2      95   TEMPER   = delta-T from fabrication temperat
C    y   (  10,   0)    2     100   DENSTY   = weight density of material
C    n   (   0,   0)    1     110   HEIGHT   = height from inner to outer membra
C    n   (   0,   0)    1     115   RINNER   = radius of curvature of inner memb
C    n   (   0,   0)    1     120   ROUTER   = radius of curvature of outer memb
C    n   (   0,   0)    1     125   TINNER   = thickness of the inner curved mem
C    n   (   0,   0)    1     130   TOUTER   = thickness of the outer curved mem
C    n   (   0,   0)    1     135   TFINNR   = thickness of inner truss-core seg
C    n   (   0,   0)    1     140   TFOUTR   = thickness of the outer truss segm
C    n   (   0,   0)    1     145   TFWEBS   = thickness of each truss-core web
C    n   (   0,   0)    2     155   NCASES   = Number of load cases (number of e
C    y   (  20,   0)    3     160   PINNER   = pressure inside the inner membran
C    y   (  20,   0)    3     165   PMIDDL   = pressure between inner and outer
C    y   (  20,   0)    3     170   POUTER   = pressure outside the outer membra
C    y   (  20,   0)    4     180   BUCKB4   = buckling load factor from BIGBOSO
C    y   (  20,   0)    5     185   BUCKB4A  = allowable for buckling load facto
C    y   (  20,   0)    6     190   BUCKB4F  = buckling from BIGBOSOR4 factor of
C    y   (  20,   0)    4     200   TENLOS   = load factor for tension loss
C    y   (  20,   0)    5     205   TENLOSA  = tension loss allowable (Use 1.0)
C    y   (  20,   0)    6     210   TENLOSF  = tension loss factor of safety
C    n   (   0,   0)    2     215   JSTRM1   = stress component number in STRM1(
C    y   (  20,   5)    4     220   STRM1    = stress component in material 1
C    y   (  20,   5)    5     225   STRM1A   = allowable stress in material 1
C    y   (  20,   5)    6     230   STRM1F   = factor of safety for stress in ma
C    y   (  20,   5)    4     235   STRM2    = stress component in material 2
C    y   (  20,   5)    5     240   STRM2A   = allowable for stress in material
C    y   (  20,   5)    6     245   STRM2F   = factor of safety for stress in ma
C    y   (  20,   5)    4     250   STRM3    = stress component in material 3
C    y   (  20,   5)    5     255   STRM3A   = allowable for stress in material
```

```
C    y   (  20,   5)    6     260   STRM3F   = factor of safety for stress in ma
C    n   (   0,   0)    7     270   WEIGHT   = weight/length of the balloon
C
C=DECK      BEHX1
      SUBROUTINE BEHX1
     1 (IFILE,NPRINX,IMODX,IFAST,ILOADX,PHRASE)
C
C   PURPOSE: OBTAIN buckling load factor from BIGBOSOR4
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE RESPONSE VARIABLE FOR
C   THE ith LOAD CASE, ILOADX:
C
C     BUCKB4(ILOADX)
C
C   AS OUTPUT. THE ith CASE REFERS
C   TO ith ENVIRONMENT (e.g. load com-
C   bination).
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
C
C     ILOADX = ith LOADING COMBINATION
C     PHRASE = buckling load factor from BIGBOSOR4
C
C   OUTPUT:
C
C     BUCKB4(ILOADX)
C
       CHARACTER*80 PHRASE
C  INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
```

```
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  INSERT SUBROUTINE STATEMENTS HERE.
C
C BEG NOV 2010
      COMMON/EIGMNX/EIGMIN
      COMMON/IABRTX/IABORT
      COMMON/ITRYX/ITRY,NSTEPS,KSEGS
      COMMON/TOTMAX/TOTMAS
      DIMENSION INODM1(10),INODM2(10),ISEGM1(10),ISEGM2(10)
      DIMENSION INODE1(10),INODE2(10),ISEGE1(10),ISEGE2(10)
      DIMENSION FN1MAX(10),FN2MAX(10),DIFF(10)
      DIMENSION EIG1MN(10),EIG2MN(10)
C END NOV 2010
      DOUBLE PRECISION FTOTX
      COMMON/FPREBX/FMAXST(200),FTOTX(20000)
      COMMON/IFPREB/IFTOTS
      COMMON/SEGS/NSEGB4,M2B4,I5B4(295),I2B4,I2GB4
      COMMON/IFRHX/IFBB4,RHFIX(198),
     1             KKKK,MNUMB,ISWTCH,KNTB4,IFTOT,INDSIG,IFIXB4
      COMMON/FLNFLO/FLINNR,FLOUTR
      COMMON/WRDCLX/WRDCOL
      CHARACTER*45 WRDCOL
      COMMON/ITERS/ITER
      COMMON/ITERS2/ITRSTP(200)
C BEG NOV 2010
      COMMON/CODWRX/CODWRD
      CHARACTER*20 CODWRD
      COMMON/MEMSTR/STRS1F(1,6),STRS2F(1,6),STRS1V(1,6),STRS2V(1,6)
      DIMENSION THK(6)
C END NOV 2010
      COMMON/ERROR/ERR
C BEG NOV 2010
      COMMON/N1N2FX/N1FIX(100,295),N2FIX(100,295)
      COMMON/N1N2VR/N1VAR(100,295),N2VAR(100,295)
      DIMENSION EIGEN1(100,295), EIGEN2(100,295)
C END NOV 2010
C BEG JAN 2011
      DIMENSION N1AVEF(10),N2AVEF(10),N1AVEV(10),N2AVEV(10)
      REAL N1AVEF,N2AVEF,N1AVEV,N2AVEV
```

```
C END JAN 2011
      REAL N1FIX,N2FIX,N1VAR,N2VAR
      COMMON/N2DIFX/N2DIFF(6)
      REAL N2DIFF
      COMMON/FINNER/C44FIN,DELTAT,DELT,NODSEG,MSEGS
      COMMON/NUMSEG/NSEGS
      COMMON/INSTAB/INDIC
      COMMON/EIGB4M/EIGCOM(200),EIGNEG(200),EIGCRN
      COMMON/WVEB4M/NWVCOM(200),NWVNEG(200),IWAVEB,NWVCRN
      COMMON/EIGBUK/EIGCRT
      COMMON/NWVBUK/NWVCRT
      COMMON/BUCKN/NOBX,NMINBX,NMAXBX,INCRBX
      COMMON/BUCKN0/NOB,NMAXB
      COMMON/RBEGX/RBIG0,RBIGL,RBIGG
      COMMON/PRMOUT/IFILE3,IFILE4,IFILE8,IFILE9,IFIL11
      COMMON/EIGALL/EIG0,EIG1,EIG2,EIG3,EIG4
      COMMON/WAVALL/NWAV0,NWAV1,NWAV2,NWAV3,NWAV4
      COMMON/NUMPAR/IPARX,IVARX,IALLOW,ICONSX,NDECX,NLINKX,NESCAP,ITYPEX
      common/caseblock/CASE
      CHARACTER*28 CASE
C BEG NOV 2010
      CHARACTER*35 CASA,CASA2,CASA3
C
C BEG DEC 2010
      IF (IMODX.EQ.0) THEN
         WRITE(IFILE,'(/,A,/,A,I2,/,A,I2,/,A,1P,E12.4)')
     1 ' ************** TYPE OF BALLOON AND WEBS ***************',
     1 ' ISHAPE =',ISHAPE,
     1 ' IWEBS  =',IWEBS,
     1 ' Inner radius, RADIUS =',RADIUS
         IF (ISHAPE.EQ.1) WRITE(IFILE,'(A)')
     1 ' The balloon is cylindrical.'
         IF (ISHAPE.EQ.2) WRITE(IFILE,'(A)')
     1 ' The balloon is spherical.'
         WRITE(IFILE,'(A,I3)') ' Number of modules,NMODUL=',NMODUL
         IF (IWEBS.EQ.1) WRITE(IFILE,'(A)')
     1 ' The balloon has radial webs (Fig. 1).'
         IF (IWEBS.EQ.2) WRITE(IFILE,'(A)')
     1 ' The balloon has truss-like (slanted) webs (Fig. 2).'
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' Pressures: PINNER,PMIDDL,POUTER=',
     1             PINNER(ILOADX),PMIDDL(ILOADX),POUTER(ILOADX)
         WRITE(IFILE,'(A,1P,2E12.4)')
     1 ' Factors of safety: BUCKB4F,TENLOSF=',
     1                     BUCKB4F(ILOADX),TENLOSF(ILOADX)
         WRITE(IFILE,'(A)')
     1 ' *******************************************************'
      ENDIF
C END DEC 2010
      IF (IWEBS.EQ.1) KSEGS = 5
      IF (IWEBS.EQ.2) KSEGS = 6
C END NOV 2010
C
      PI = 3.1415927
```

```
C
C BEG DEC 2010
C BEG JAN 2011
      IF (IWEBS.EQ.2) NMODMX = 45
      IF (IWEBS.EQ.1) NMODMX = 55
C     IF (NMODUL.GT.48) THEN
      IF (NMODUL.GT.NMODMX) THEN
C END JAN 2011
         I=INDEX(CASE,' ')
         NLET = I - 1
         IF (I.EQ.0) NLET = 28
C BEG JAN 2011
         WRITE(IFILE,'(/,A,/,A,I3,/,A,A,A,/,A)')
     1' ************* RUN ABORT *****************',
     1' Too many modules. NMODUL must be less than or equal to',
     1  NMODMX,
     1' Reduce NMODUL in the file, ',CASE(1:NLET),'.BEG.',
     1' *****************************************'
        CALL ERREX
      ENDIF
C END DEC 2010
C
      IF (IMODX.EQ.0) ERR = 0.
      IF (IMODX.EQ.1) ERR = 0.01
C
      RAVE = RADIUS/PI
      RBIGG = RAVE
C BEG NOV 2010
      IF (ISHAPE.EQ.2.AND.KSEGS.EQ.5) RBIGG = 0.0
C     IF (ISHAPE.EQ.2.AND.KSEGS.EQ.6) RBIGG = 0.0
      IF (ISHAPE.EQ.2.AND.KSEGS.EQ.6) RBIGG = 0.025*RAVE
C END NOV 2010
C
C   Obtain nonlinear equilibrium for Load Set B by itself.
C   Use 10 load steps to assure convergence.
C
      INDIC = 0
C BEG NOV 2010
      WRDCOL = '                                              '
      CODWRD = 'BALLOON                     '
C END NOV 2010
      IFTOTS = 0
      ITRY = 1
C BEG NOV 2010
      ITRYS = ITRY
C END NOV 2010
      NSTEPS = 11
      CALL MOVER(0.,0,FTOTX,1,40000)
      CALL BOSDEC(0,24,ILOADX,INDIC)
C
      IF (0.5*FLINNR.GT.RINNER) THEN
         WRITE(IFILE,'(/,A)') ' ************* ABORT **********'
         WRITE(IFILE,'(A)') ' 0.5 x FLINNR is greater than RINNER'
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
```

```
     1 ' 0.5 x FLINNR =',0.5*FLINNR,'; RINNER =',RINNER,'; IMODX=',IMODX
         WRITE(IFILE,'(A)') ' Put a higher lower bound on RINNER.'
         WRITE(IFILE,'(A)') ' The run is now aborting.'
         WRITE(IFILE,'(A)') ' ********************************'
         CALL ERREX
      ENDIF
C2345678901234567890123456789012345678901234567890123456789012345678901 2
C
      IF (0.5*FLOUTR.GT.ROUTER) THEN
         WRITE(IFILE,'(/,A)') ' ************* ABORT **********'
         WRITE(IFILE,'(A)') ' 0.5 x FLOUTR is greater than ROUTER'
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLOUTR =',0.5*FLOUTR,'; ROUTER =',ROUTER,'; IMODX=',IMODX
         WRITE(IFILE,'(A)') ' Put a higher lower bound on ROUTER.'
         WRITE(IFILE,'(A)') ' The run is now aborting.'
         WRITE(IFILE,'(A)') ' ********************************'
         CALL ERREX
      ENDIF
C
C BEG NOV 2010
C  creation of BIGBOSOR4 input file, CASE.LOADB, moved down.
C
      CALL B4READ
      CALL B4MAIN
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
      ILETW = INDEX(WRDCOL,'SHELL COLLAPSES AXISYMMETRICALLY')
      IF (ILETW.NE.0) THEN
         WRITE(IFILE,'(/,A)') ' ************* ABORT **********'
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
         WRITE(IFILE,'(A)') ' SHELL COLLAPSES AXISYMMETRICALLY'
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLINNR =',0.5*FLINNR,'; RINNER =',RINNER,'; IMODX=',IMODX
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLOUTR =',0.5*FLOUTR,'; ROUTER =',ROUTER,'; IMODX=',IMODX
         WRITE(IFILE,'(A)') ' Put a higher lower bound on RINNER or'
         WRITE(IFILE,'(A)') ' put a higher lower bound on ROUTER.'
         WRITE(IFILE,'(A)') ' The run is now aborting.'
         WRITE(IFILE,'(A)') ' ********************************'
         CALL ERREX
      ENDIF
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
      ILETW = INDEX(WRDCOL,'INITIAL LOADS TOO HIGH FOR THIS STRUCT')
      IF (ILETW.NE.0) THEN
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
```

```
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
         WRITE(IFILE,'(/,A)')
     1              ' ****** CHANGE FROM 10 TO 1 LOAD STEPS ******'
         WRITE(IFILE,'(A)') ' INITIAL LOADS TOO HIGH FOR THIS STRUCT'
         WRITE(IFILE,'(A,I2)') ' Changing from 10 to 1 steps: IMODX=',
     1    IMODX
         WRITE(IFILE,'(A)') ' ********************************'
         CALL GASP(DUM1,DUM2,-2,DUM3)
         WRDCOL = '                                              '
         INDIC = 0
         IFTOTS = 0
         ITRY = 2
C BEG NOV 2010
         ITRYS = ITRY
C END NOV 2010
         NSTEPS = 1
         CALL MOVER(0.,0,FTOTX,1,40000)
         CALL BOSDEC(0,24,ILOADX,INDIC)
         CALL B4READ
         CALL B4MAIN
         ITRY = 1
      ENDIF
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
      ILETW = INDEX(WRDCOL,'SHELL COLLAPSES AXISYMMETRICALLY')
      IF (ILETW.NE.0) THEN
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
         WRITE(IFILE,'(/,A)') ' ************* ABORT **********'
         WRITE(IFILE,'(A)') ' SHELL COLLAPSES AXISYMMETRICALLY'
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLINNR =',0.5*FLINNR,'; RINNER =',RINNER,'; IMODX=',IMODX
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLOUTR =',0.5*FLOUTR,'; ROUTER =',ROUTER,'; IMODX=',IMODX
         WRITE(IFILE,'(A)') ' Put a higher lower bound on RINNER or'
         WRITE(IFILE,'(A)') ' put a higher lower bound on ROUTER.'
         WRITE(IFILE,'(A)') ' The run is now aborting.'
         WRITE(IFILE,'(A)') ' ********************************'
         CALL ERREX
      ENDIF
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
      ILETW = INDEX(WRDCOL,'INITIAL LOADS TOO HIGH FOR THIS STRUCT')
      IF (ILETW.NE.0) THEN
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
```

```
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
         WRITE(IFILE,'(/,A)')
     1              ' ****** CHANGE FROM 1 TO 50 LOAD STEPS ******'
         WRITE(IFILE,'(A)') ' INITIAL LOADS TOO HIGH FOR THIS STRUCT'
         WRITE(IFILE,'(A,I2)') ' Changing from 1 to 50 steps: IMODX=',
     1    IMODX
         WRITE(IFILE,'(A)') ' ********************************'
         CALL GASP(DUM1,DUM2,-2,DUM3)
         WRDCOL = '                                              '
         INDIC = 0
         IFTOTS = 0
         ITRY = 3
C BEG NOV 2010
         ITRYS = ITRY
C END NOV 2010
         NSTEPS = 51
         CALL MOVER(0.,0,FTOTX,1,40000)
         CALL BOSDEC(0,24,ILOADX,INDIC)
         CALL B4READ
         CALL B4MAIN
         ITRY = 1
      ENDIF
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
      ILETW = INDEX(WRDCOL,'SHELL COLLAPSES AXISYMMETRICALLY')
      IF (ILETW.NE.0) THEN
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
         WRITE(IFILE,'(/,A)') ' ************* ABORT **********'
         WRITE(IFILE,'(A)') ' SHELL COLLAPSES AXISYMMETRICALLY'
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLINNR =',0.5*FLINNR,'; RINNER =',RINNER,'; IMODX=',IMODX
         WRITE(IFILE,'(A,1P,E12.4,A,1P,E12.4,A,I2)')
     1 ' 0.5 x FLOUTR =',0.5*FLOUTR,'; ROUTER =',ROUTER,'; IMODX=',IMODX
         WRITE(IFILE,'(A)') ' Put a higher lower bound on RINNER or'
         WRITE(IFILE,'(A)') ' put a higher lower bound on ROUTER.'
         WRITE(IFILE,'(A)') ' The run is now aborting.'
         WRITE(IFILE,'(A)') ' ********************************'
         CALL ERREX
      ENDIF
C
C     IF (ITYPEX.EQ.2.AND.IMODX.EQ.0)
C    1 WRITE(IFILE,'(/,A,A)') ' WRDCOL=',WRDCOL
C BEG NOV 2010
      IF (IMODX.EQ.0) IABORT = 0
```

```
      IF (IABORT.EQ.1) THEN
C BEG DEC 2010
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
C END DEC 2010
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         GO TO 1000
      ENDIF
C END NOV 2010
      ILETW = INDEX(WRDCOL,'INITIAL LOADS TOO HIGH FOR THIS STRUCT')
      IF (ILETW.NE.0) THEN
        WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
        WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
C BEG NOV 2010
        EIGMIN = 10.E+16
        IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(/,A)') ' ********* ABORT **********'
        IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(/,A)') ' ********* WARNING **********'
C END NOV 2010
        WRITE(IFILE,'(A)') ' INITIAL LOADS TOO HIGH FOR THIS STRUCT'
        WRITE(IFILE,'(A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' This is an unrecoverable error because we have already',
     1 ' tried and failed to obtain nonlinear pre-buckling convergence',
     1 ' by changing from a nonlinear solution with 10 load steps to',
     1 ' a nonlinear solution with 1 load step and then changing from',
     1 ' 1 load step to 50 load steps:three tries. That strategy just',
     1 ' failed. You may well have performed enough design iterations',
     1 ' to have a good optimum design now. Look near the end of the',
     1 ' *.OPP file at the "FEASIBLE" and "ALMOST FEASIBLE" designs.'
        WRITE(IFILE,'(A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' If you are not satisfied that you have performed enough',
     1 ' design iterations, then use the GENOPT processor to reset',
     1 ' the values of the decision variables to those of the already',
     1 ' accepted "FEASIBLE" or "ALMOST FEASIBLE" design and then',
     1 ' launch SUPEROPT again. This has worked for Bushnell.',
     1 ' You may also which to tighten the lower and upper bounds',
     1 ' of one or more of the decision variables, especially the',
     1 ' lower bounds of HEIGHT and ROUTER, and possibly one or more',
     1 ' of the thicknesses of segments that are becoming very thin.'
        IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(A,I2)') ' The run is now aborting: IMODX=',IMODX
C BEG NOV 2010
        IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(A,I2)') ' IABORT is now set to 1: IMODX=',IMODX
        IF (ITYPEX.NE.2) WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1 ' WEIGHT and TOTMAS and EIGMIN are being set equal to large',
     1 ' numbers. If you want a plot of the objective edit the *.PL5',
```

```
     1 ' file by removing all entries with very large numbers, then',
     1 ' execute DIPLOT.'
         WRITE(IFILE,'(A)') ' ********************************'
         IABORT = 1
C BEG DEC 2010
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
C END DEC 2010
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
C BEG DEC 2010
         GO TO 1000
C END DEC 2010
C END NOV 2010
      ENDIF
C
C BEG NOV 2010
      IF (ITYPEX.EQ.2) THEN
C       Get CASE.LOADB file for input for BIGBOSOR4...
C       CASE.LOADB is an input file for BIGBOSOR4 for axisym.load set B
C       pre-buckling state of the balloon under Load set B by itself.
         I=INDEX(CASE,' ')
         IF (I.NE.0) THEN
            CASA3=CASE(:I-1)//'.LOADB'
         ELSE
            CASA3=CASE//'.LOADB'
         ENDIF
         OPEN(UNIT=62,FILE=CASA3,STATUS='UNKNOWN')
         ITRY = ITRYS
         CALL BOSDEC(0,62,ILOADX,INDIC)
         ITRY = 1
         CLOSE(UNIT=62)
         WRITE(IFILE,'(/,/,A,A,/,A)')
     1 ' BIGBOSOR4 input file for:',
     1 ' pre-buckling state of the balloon, Load Set B',
     1   CASA3
      ENDIF
C
C BEG DEC 2010
      IF (ISHAPE.EQ.2) WRITE(IFILE,'(/,A,A,1P,E12.4)')
     1' Total weight of the spherical balloon from BIGBOSOR4,',
     1' 2 x  TOTMAS=', 2.0*TOTMAS
C END DEC 2010
C END NOV 2010
C
      IF (IMODX.EQ.0) THEN
         WRITE(IFILE,'(/,A,/,A,/,A,1P,E12.4,A,1P,E12.4,A,1P,E12.4,/,A)')
     1 ' Newton iterations required to solve the nonlinear',
     1 ' axisymmetric pre-buckling equilibrium state for the',
     1 ' "fixed" loads, PINNER=',PINNER(ILOADX),
     1 ', PMIDDL=',PMIDDL(ILOADX),', DELTAT=',DELTAT,
     1 ' LOAD STEP   Newton iterations  Maximum displacement'
```

```
C BEG NOV 2010
         DO 1 I = 1,NSTEPS
          WRITE(IFILE,'(I6,I15,1P,E25.6)') I,ITRSTP(I),FMAXST(I)
    1    CONTINUE
C END NOV 2010
      ENDIF
C
C BEG DEC 2010
      IABRTS = IABORT
      IF (IABRTS.EQ.0.AND.
     1           (FMAXST(1).EQ.0.0.OR.FMAXST(2).EQ.0.0)) THEN
C
         EIGMIN = 10.E+16
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(/,A)') ' ********* ABORT **********'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(/,A)') ' ********* WARNING **********'
C
         IF (ITYPEX.NE.2) WRITE(IFILE,'(A,A,I2)')
     1 ' IMODX=0 means current design, IMODX=1 means perturbed',
     1 ' design: IMODX=',IMODX
         WRITE(IFILE,'(A,A,/,1P,5E14.6)')
     1 ' Decision variable candidates,',
     1 ' HEIGHT,RINNER,ROUTER,TINNER,TOUTER=',
     1   HEIGHT,RINNER,ROUTER,TINNER,TOUTER
         WRITE(IFILE,'(A,1P,3E12.4)')
     1 ' TFINNR,TFOUTR,TFWEBS=',TFINNR,TFOUTR,TFWEBS
C
         WRITE(IFILE,'(/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Failed to find the pre-buckling "fixed" load B solution.',
     1 ' The maximum displacement in sub-step no. 1 or 2 is zero.',
     1 ' This is probably caused by a nearly singular matrix.',
     1 ' Raise the values of HEIGHT and the thicknesses, and',
     1 ' also raise the lower bounds of these quantities, and',
     1 ' try the run again.'
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(A,I2)') ' The run is now aborting: IMODX=',IMODX
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(A,I2)') ' IABORT is now set to 1: IMODX=',IMODX
         IF (ITYPEX.NE.2) WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1 ' WEIGHT and TOTMAS and EIGMIN are being set equal to large',
     1 ' numbers. If you want a plot of the objective edit the *.PL5',
     1 ' file by removing all entries with very large numbers, then',
     1 ' execute DIPLOT.'
         WRITE(IFILE,'(A)') ' ********************************'
         IABORT = 1
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
C BEG DEC 2010
         GO TO 1000
```

```
C END DEC 2010
      ENDIF
C END DEC 2010
      IF (ITYPEX.EQ.1)
     1 WRITE(IFILE,'(A,A,/,A,/,A,I2)') ' WRDCOL=',WRDCOL,
     1' IMODX=0 for current design,',
     1' IMODX=1 for perturbed design: IMODX=',IMODX
C
C23456789012345678901234567890123456789012345678901234567890123456789012
C     WRITE(IFILE,'(/,A,2I10)')' IFTOT, M2B4 =', IFTOT,M2B4
C BEG DEC 2010
C  Next, solve the bifurcation buckling equations
C  with use of the INDIC = 1 strategy in BIGBOSOR4.
C  The vector, FTOTX, contains the solution of the
C  pre-buckling equilibrium equations for the balloon
C  loaded by PINNER, PMIDDL, and DELTAT, that is, the
C  loads in Load Set B, the "fixed" (non-eigenvalue)
C  loads. This is the starting vector for the Newton
C  iterations for the solution of the nonlinear
C  pre-buckling equilibrium equations for the balloon
C  loaded by PINNER, PMIDDL, DELTAT, and POUTER, that is,
C  the TOTAL loads on the balloon. The eigenvalue
C  problem is:
C
C     [A] + eigenvalue x [B] = 0
C
C  in which [A] is the stiffness matrix of the balloon
C  as loaded by Load Set B only, and [B] is the load-
C  geometric matrix of the balloon as loaded by the
C  difference: (TOTAL load) - (Load Set B).
C
C  The input file, *.ALL, for BIGBOSOR4 is generated
C  by the statement below:
C
C     CALL BOSDEC(1,24,ILOADX,INDIC)
C
C  and the bifurcation buckling eigenvalue problem is
C  solved via the stementa below:
C
C     CALL B4READ
C     CALL B4MAIN
C
C  Bifurcation buckling mode shapes are produced via
C  the following statement below:
C
C     IF (ITYPEX.EQ.2) CALL B4POST
C
C  SUBROUTINE B4POST generates the file, *.PLT2, in
C  which "*" denotes the end-user-selected specific
C  name for the case (e.g. "try4"). Plots of the
C  bifurcation buckling mode shapes are obtained
C  as follows:
C
C  cd /home/progs/work6       (go to a working directory
```

```
C                                   for execution of BIGBOSOR4
C                                   processors)
C
C  cp ../genoptcase/try4.PLT2 .  (get the *.PLT2 file)
C
C  bigbosor4log                  (activate BIGBOSOR4 commands)
C
C  bosorplot                     (generate plots)
C
C END DEC 2010
      IFTOTS = IFTOT
      M22B4 = 2*M2B4
      CALL GASP(FTOTX,M22B4,3,IFTOT)
C     WRITE(IFILE,'(/,A,/,(1P,10E10.2))')
C    1' Nonlinear solution for Load Set B by itself, FTOTX=',
C    1 (FTOTX(I),I=1,M2B4)
      CALL GASP(DUM1,DUM2,-2,DUM3)
C
      INDIC = 1
C BEG NOV 2010
      IF (IMODX.EQ.0) IABORT = 0
      IF (ISHAPE.EQ.1) THEN
        NOB = 1
        NMAXB = 1
        INCRB = 1
      ELSE
        NOB = 0
        NMAXB = 0
        INCRB = 1
C BEG DEC 2010
C  Perhaps comment out the following block because of the possible
C  existence of spurious modes with very low spurious eigenvalues:
        IF (ITYPEX.EQ.2) THEN
          NMAXB = 10*NMODUL
          INCRB = NMAXB/10
          IF (INCRB.LT.1) INCRB = 1
        ENDIF
C END DEC 2010
      ENDIF
      IF (IABORT.EQ.1) THEN
C BEG DEC 2010
          CALL MOVER(0.,0,STRS1V,1,6)
          CALL MOVER(0.,0,STRS2V,1,6)
          EIGMIN = 10.E16
C END DEC 2010
          WEIGHT = 10.E20
          TOTMAS = 10.E20
          GO TO 1000
      ENDIF
C END NOV 2010
      WRDCOL = '                                              '
      CALL BOSDEC(1,24,ILOADX,INDIC)
C
      IF (ITYPEX.EQ.2) THEN
```

```
C      Get CASE.BEHX1 file for input for BIGBOSOR4...
C      CASE.BEHX1 is an input file for BIGBOSOR4 for behavior no. 1:
C      buckling load from BIGBSOSOR4
         I=INDEX(CASE,' ')
         IF(I.NE.0) THEN
            CASA=CASE(:I-1)//'.BEHX1'
         ELSE
            CASA=CASE//'.BEHX1'
         ENDIF
         OPEN(UNIT=61,FILE=CASA,STATUS='UNKNOWN')
         CALL BOSDEC(1,61,ILOADX,INDIC)
         CLOSE(UNIT=61)
         WRITE(IFILE,'(/,/,A,A,/,A)')
     1 ' BIGBOSOR4 input file for:',
     1 ' general buckling load',
     1   CASA
C BEG DEC 2010
C234567890123456789012345678901234567890123456789012345678901234567890l2
         IF (ISHAPE.EQ.2)
     1   WRITE(IFILE,'(A,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Ordinarily, the file called ',CASA,
     1 ' which contains valid input data for BIGBOSOR4,',
     1 ' would be used for an execution of BIGBOSOR4 independently',
     1 ' of the GENOPT environment. However, that BIGBOSOR4 execution',
     1 ' will probably fail in this case because of failure of the',
     1 ' Newton iterations for solution of the nonlinear pre-buckling',
     1 ' equilibrium equations corresponding to the application of the',
     1 ' "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and',
     1 ' PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not',
     1 ' presently have the capability to divide Load Set B into sub-',
     1 ' steps.'
C END DEC 2010
      ENDIF
C
      CALL B4READ
      IF (IMODX.EQ.0) THEN
         NOBX = NOB
         NMINBX = NOB
         NMAXBX = NMAXB
         INCRBX = INCRB
      ELSE
         NOBX = NWAV1
         NMINBX = NWAV1
         NMAXBX = NWAV1
         INCRBX = INCRB
      ENDIF
      REWIND IFILE9
      CALL STOCM1(IFILE9)
      CALL STOCM2(IFILE9)
      CALL B4MAIN
C BEG NOV 2010
      IF (ITYPEX.EQ.2) CALL B4POST
C END NOV 2010
      CALL GASP(DUM1,DUM2,-2,DUM3)
```

```
      IF (IMODX.EQ.0) THEN
C BEG NOV 2010
         EIG1 = EIGCRT
C END NOV 2010
         NWAV1= NWVCRT
      ENDIF
C BEG DEC 2010
C2345678901234567890123456789012345678901234567890123456789012345678901
      IF (EIGCRT.LE.0.0) THEN
        WRITE(IFILE,'(/,A,/,A,/,A,1P,E12.4,/,A)')
     1' ***************** NOTE NOTE NOTE ***************************',
     1' BIGBOSOR4 eigenvalue, EIGCRT, is less than or equal to zero:',
     1' Eigenvalue (buckling load factor), EIGCRT =',EIGCRT,
     1' A change of strategy or lower bound(s) is required.'
        WRITE(IFILE,
     1  '(/,A,/,A,/,A,I3,/,A,1P,E12.4,/,A,/,A,/,A,I3,/,A,1P,E12.4,/)')
     1' Newton iterations required to solve the nonlinear',
     1' axisymmetric pre-buckling equilibrium state for the',
     1' "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=',ITRSTP(1),
     1' Maximum displacement,                         FMAX=',FMAXST(1),
     1' Newton iterations required to solve the nonlinear',
     1' axisymmetric pre-buckling equilibrium state for the',
     1' total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=',ITRSTP(2),
     1' Maximum displacement,                         FMAX=',FMAXST(2)
        IF (FMAXST(2).EQ.0.0) THEN
           WRITE(IFILE,'(/,A,/,A,/,A,I3,/,A,/,A)')
     1    ' ************** RUN ABORT ************************',
     1    ' Pre-buckling convergence under the total loads failed.',
     1    ' Number of iterations under total loads, ITER=',ITRSTP(2),
     1    ' Try increasing HEIGHT and increase lower bound of HEIGHT',
     1    ' ************** RUN ABORT ************************'
           IF (ITYPEX.EQ.2) CALL ERREX
        ENDIF
C
         WRITE(IFILE,'(/,A,I2,A,/,A,I6,A,1P,E12.4,/,A)')
     1 ' IMODX =',IMODX,'; IMODX=0 for current, IMODX=1 for perturbed',
     1 ' Eigenvalue, EIGCRT, from BIGBOSOR4 for N=',NWVCRT,' =',EIGCRT,
     1 ' Use the "initial-loss-of-tension" load factor for EIGCRT.'
         IABORT = 1
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
         GO TO 1000
      ENDIF
C END DEC 2010
C
      ILETW = INDEX(WRDCOL,'SHELL COLLAPSES AXISYMMETRICALLY')
      IF (ILETW.NE.0) THEN
C BEG NOV 2010
         EIGMIN = 10.E+16
         IF (ITYPEX.EQ.2)
```

```
     1   WRITE(IFILE,'(/,A)') ' ********* ABORT **********'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(/,A)') ' ********* WARNING **********'
         WRITE(IFILE,'(A)') ' THIS IS THE INDIC=1 BUCKLING ANALYSIS'
         WRITE(IFILE,'(A)') ' SHELL COLLAPSES AXISYMMETRICALLY'
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(A,I2)') ' Run is now aborting: IMODX=',IMODX
         WRITE(IFILE,'(A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Look near the end of the *.OPP file for the "FEASIBLE" or for',
     1 ' the "ALMOST FEASIBLE" design. Choose whichever of those you',
     1 ' prefer, and use CHANGE to save that design. Then, if you want',
     1 ' to continue with SUPEROPT, execute SUPEROPT again. Bushnell',
     1 ' has found that this execution of SUPEROPT may run for many',
     1 ' iterations before bombing again, or it may run to completion',
     1 ' (a total of about 470 design iterations).'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(A,I2)') ' IABORT is now set to 1: IMODX=',IMODX
         IF (ITYPEX.NE.2) WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1 ' WEIGHT and TOTMAS and EIGMIN are being set equal to large',
     1 ' numbers. If you want a plot of the objective edit the *.PL5',
     1 ' file by removing all entries with very large numbers, then',
     1 ' execute DIPLOT.'
         WRITE(IFILE,'(A)') ' ********************************'
         IABORT = 1
C BEG DEC 2010
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
C END DEC 2010
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
C BEG DEC 2010
         GO TO 1000
C END DEC 2010
C23456789012345678901234567890123456789012345678901234567890123456789012
C END NOV 2010
      ENDIF
C
      ILETW = INDEX(WRDCOL,'INITIAL LOADS TOO HIGH FOR THIS STRUCT')
      IF (ILETW.NE.0) THEN
C BEG NOV 2010
         EIGMIN = 10.E+16
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(/,A)') ' ********* ABORT **********'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(/,A)') ' ********* WARNING **********'
         WRITE(IFILE,'(A)') ' THIS IS THE INDIC=1 BUCKLING ANALYSIS'
         WRITE(IFILE,'(A)') ' INITIAL LOADS TOO HIGH FOR THIS STRUCT'
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(A,I2)') ' Run is now aborting: IMODX=',IMODX
         WRITE(IFILE,'(A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Look near the end of the *.OPP file for the "FEASIBLE" or for',
     1 ' the "ALMOST FEASIBLE" design. Choose whichever of those you',
```

```
     1 ' prefer, and use CHANGE to save that design. Then, if you want',
     1 ' to continue with SUPEROPT, execute SUPEROPT again. Bushnell',
     1 ' has found that this execution of SUPEROPT may run for many',
     1 ' iterations before bombing again, or it may run to completion',
     1 ' (a total of about 470 design iterations).'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(A,I2)') ' IABORT is now set to 1: IMODX=',IMODX
         IF (ITYPEX.NE.2) WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1 ' WEIGHT and TOTMAS and EIGMIN are being set equal to large',
     1 ' numbers. If you want a plot of the objective edit the *.PL5',
     1 ' file by removing all entries with very large numbers, then',
     1 ' execute DIPLOT.'
         WRITE(IFILE,'(A)') ' ********************************'
         IABORT = 1
C BEG DEC 2010
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
C END DEC 2010
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
C BEG DEC 2010
         GO TO 1000
C END DEC 2010
C END NOV 2010
      ENDIF
C
C23456789012345678901234567890123456789012345678901234567890123456789012
C
C BEG DEC 2010 (comment out the following and move it down.
C1000 CONTINUE
C END DEC 2010
C
C   Compute the membrane stresses
      THK(1) = TFOUTR
      THK(2) = TOUTER
      THK(3) = TFINNR
      THK(4) = TINNER
      THK(5) = TFWEBS
C BEG NOV 2010
      THK(6) = TFWEBS
C END NOV 2010
C
C BEG NOV 2010
      EIGMIN = 10.E+16
      IF (ISHAPE.EQ.1) THEN
         DO 2 J = 1,KSEGS
          EIGEN1(1,J) = N1FIX(1,J)/(N1FIX(1,J) - N1VAR(1,J))
          EIGEN2(1,J) = N2FIX(1,J)/(N2FIX(1,J) - N2VAR(1,J))
          EIGMIN = MIN(EIGMIN,ABS(EIGEN1(1,J)))
          STRS1F(1,J) = N1FIX(1,J)/THK(J)
          STRS2F(1,J) = N2FIX(1,J)/THK(J)
          STRS1V(1,J) = N1VAR(1,J)/THK(J)
```

```
          STRS2V(1,J) = N2VAR(1,J)/THK(J)
    2    CONTINUE
         IF (KSEGS.EQ.5) THEN
           WRITE(IFILE,'(/,A,/,1P,5E12.4)')
     1   ' LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,5)=',
     1     (EIGEN1(1,ISEG),ISEG=1,KSEGS)
           WRITE(IFILE,'(/,A,/,1P,5E12.4)')
     1   ' LOSS OF CIRCUMFERENTIAL TENSION: (EIGEN2(1,ISEG),ISEG=1,5)=',
     1     (EIGEN2(1,ISEG),ISEG=1,KSEGS)
         ENDIF
C23456789012345678901234567890123456789012345678901234567890123456789012
         IF (KSEGS.EQ.6) THEN
           WRITE(IFILE,'(/,A,/,1P,6E12.4)')
     1   ' LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,6)=',
     1     (EIGEN1(1,ISEG),ISEG=1,KSEGS)
           WRITE(IFILE,'(/,A,/,1P,6E12.4)')
     1   ' LOSS OF CIRCUMFERENTIAL TENSION: (EIGEN2(1,ISEG),ISEG=1,6)=',
     1     (EIGEN2(1,ISEG),ISEG=1,KSEGS)
         ENDIF
      ELSE
C following is for spherical vacuum chamber...
C  first, find the maximum values of N1FIX and N2FIX:
C
         DO 5 ISEG = 1,KSEGS
          FN1MAX(ISEG) = 0.
          FN2MAX(ISEG) = 0.
          EIG1MN(ISEG) = 1.E+17
          EIG2MN(ISEG) = 1.E+17
C
          DO 4 IMODUL = 1,NMODUL
C BEG JAN 2011
C Introduce test for skipping modules near the pole
           IF (IMODUL.LT.NMODUL/10) GO TO 4
C END JAN 2011
           ISEGT = (IMODUL -1)*KSEGS +ISEG
           INODBG = 5
           INODED = NODSEG - 2
           IF (KSEGS.EQ.6.AND.IMODUL.EQ.1.AND.ISEG.LE.5)
     1        INODBG = NODSEG/2 +1
           DO 3 INOD = INODBG,INODED
C BEG JAN 2011
C  Take average at two neighboring nodal points to smooth out n1,n2
            INOD1 = INOD + 1
            FN1AVF = 0.5*(N1FIX(INOD,ISEGT) +N1FIX(INOD1,ISEGT))
            FN2AVF = 0.5*(N2FIX(INOD,ISEGT) +N2FIX(INOD1,ISEGT))
            FN1AVV = 0.5*(N1VAR(INOD,ISEGT) +N1VAR(INOD1,ISEGT))
            FN2AVV = 0.5*(N2VAR(INOD,ISEGT) +N2VAR(INOD1,ISEGT))
            FN1MAX(ISEG) = MAX(FN1MAX(ISEG),FN1AVF)
            FN2MAX(ISEG) = MAX(FN2MAX(ISEG),FN2AVF)
C
            EIGEN1(INOD,ISEGT) = FN1AVF/(FN1AVF - FN1AVV)
            IF (FN2AVF.GT.0.2*FN1AVF) THEN
              EIGEN2(INOD,ISEGT) = FN2AVF/(FN2AVF - FN2AVV)
C END JAN 2011
```

```
           ELSE
             EIGEN2(INOD,ISEGT) = 10.E+16
           ENDIF
           IF (EIGEN1(INOD,ISEGT).GE.0.0)
     1     EIG1MN(ISEG) = MIN(EIG1MN(ISEG),EIGEN1(INOD,ISEGT))
           IF (EIGEN2(INOD,ISEGT).GE.0.0)
     1     EIG2MN(ISEG) = MIN(EIG2MN(ISEG),EIGEN2(INOD,ISEGT))
           EIGMIN = MIN(EIGMIN,ABS(EIG1MN(ISEG)))
           EIGMIN = MIN(EIGMIN,ABS(EIG2MN(ISEG)))
C
    3     CONTINUE
    4    CONTINUE
    5   CONTINUE
C
        IF (KSEGS.EQ.5) THEN
          WRITE(IFILE,'(/,A,/,1P,5E12.4)')
     1  ' (FN1MAX(ISEG),ISEG=1,5)=',(FN1MAX(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(A,/,1P,5E12.4)')
     1  ' (FN2MAX(ISEG),ISEG=1,5)=',(FN2MAX(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(/,A,/,1P,5E12.4)')
     1  ' LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=',
     1    (EIG1MN(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(/,A,/,1P,5E12.4)')
     1  ' LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=',
     1    (EIG2MN(ISEG),ISEG=1,KSEGS)
        ENDIF
C
        IF (KSEGS.EQ.6) THEN
          WRITE(IFILE,'(/,A,/,1P,6E12.4)')
     1  ' (FN1MAX(ISEG),ISEG=1,6)=',(FN1MAX(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(A,/,1P,6E12.4)')
     1  ' (FN2MAX(ISEG),ISEG=1,6)=',(FN2MAX(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(/,A,/,1P,6E12.4)')
     1  ' LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,6)=',
     1    (EIG1MN(ISEG),ISEG=1,KSEGS)
          WRITE(IFILE,'(/,A,/,1P,6E12.4)')
     1  ' LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,6)=',
     1    (EIG2MN(ISEG),ISEG=1,KSEGS)
        ENDIF
C
C  next, find which shell segments and nodal points have the max. values:
        DO 8 ISEG = 1,KSEGS
         DO 7 IMODUL = 1,NMODUL
C BEG JAN 2011
C Introduce test for skipping modules near the pole
          IF (IMODUL.LT.NMODUL/10) GO TO 7
C END JAN 2011
          INODBG = 5
          INODED = NODSEG - 2
          IF (KSEGS.EQ.6.AND.IMODUL.EQ.1.AND.ISEG.LE.5)
     1       INODBG = NODSEG/2 +1
          ISEGT = (IMODUL -1)*KSEGS +ISEG
          DO 6 INOD = INODBG,INODED
C BEG JAN 2011
```

```
C  Take average at two neighboring nodal points to smooth out n1,n2
            INOD1 = INOD + 1
            FN1AVF = 0.5*(N1FIX(INOD,ISEGT) +N1FIX(INOD1,ISEGT))
            FN1AVV = 0.5*(N1VAR(INOD,ISEGT) +N1VAR(INOD1,ISEGT))
            DIFF(ISEG) = ABS((FN1MAX(ISEG)-FN1AVF)/FN1MAX(ISEG))
C END JAN 2011
            IF (DIFF(ISEG).LE.0.0001) THEN
C BEG JAN 2011
             N1AVEF(ISEG) = FN1AVF
             N1AVEV(ISEG) = FN1AVV
C END JAN 2011
             INODM1(ISEG) = INOD
             ISEGM1(ISEG) = ISEGT
             GO TO 8
            ENDIF
    6      CONTINUE
    7     CONTINUE
    8    CONTINUE
C234567890123456789012345678901234567890123456789012345678901234567890012
         DO 11 ISEG = 1,KSEGS
          DO 10 IMODUL = 1,NMODUL
C BEG JAN 2011
C Introduce test for skipping modules near the pole
           IF (IMODUL.LT.NMODUL/10) GO TO 10
C END JAN 2011
           INODBG = 5
           INODED = NODSEG - 2
           IF (KSEGS.EQ.6.AND.IMODUL.EQ.1.AND.ISEG.LE.5)
     1        INODBG = NODSEG/2 +1
           ISEGT = (IMODUL -1)*KSEGS +ISEG
C BEG JAN 2011
           DO 9 INOD = INODBG,INODED
C  Take average at two neighboring nodal points to smooth out n1,n2
            INOD1 = INOD + 1
            FN2AVF = 0.5*(N2FIX(INOD,ISEGT) +N2FIX(INOD1,ISEGT))
            FN2AVV = 0.5*(N2VAR(INOD,ISEGT) +N2VAR(INOD1,ISEGT))
            DIFF(ISEG) = ABS((FN2MAX(ISEG)-FN2AVF)/FN2MAX(ISEG))
C END JAN 2011
            IF (DIFF(ISEG).LE.0.0001) THEN
C BEG JAN 2011
             N2AVEF(ISEG) = FN2AVF
             N2AVEV(ISEG) = FN2AVV
C END JAN 2011
             INODM2(ISEG) = INOD
             ISEGM2(ISEG) = ISEGT
             GO TO 11
            ENDIF
    9      CONTINUE
   10     CONTINUE
   11    CONTINUE
C
         DO 12 J = 1,KSEGS
C BEG JAN 2011
C         IARG1 = INODM1(J)
```

```
C          JARG1 = ISEGM1(J)
C          IARG2 = INODM2(J)
C          JARG2 = ISEGM2(J)
           STRS1F(1,J) = N1AVEF(J)/THK(J)
           STRS2F(1,J) = N2AVEF(J)/THK(J)
           STRS1V(1,J) = N1AVEV(J)/THK(J)
           STRS2V(1,J) = N2AVEV(J)/THK(J)
C END JAN 2011
   12    CONTINUE
C
C  next, find which shell segments and nodal points have the min. values:
         DO 15 ISEG = 1,KSEGS
          DO 14 IMODUL = 1,NMODUL
C BEG JAN 2011
C Introduce test for skipping modules near the pole
           IF (IMODUL.LT.NMODUL/10) GO TO 14
C END JAN 2011
           INODBG = 5
           INODED = NODSEG - 2
           IF (KSEGS.EQ.6.AND.IMODUL.EQ.1.AND.ISEG.LE.5)
     1        INODBG = NODSEG/2 +1
           ISEGT = (IMODUL -1)*KSEGS +ISEG
           DO 13 INOD = INODBG,INODED
            DIFF(ISEG) =
     1        ABS((EIG1MN(ISEG)-EIGEN1(INOD,ISEGT))/EIG1MN(ISEG))
            IF (DIFF(ISEG).LE.0.0001) THEN
             INODE1(ISEG) = INOD
             ISEGE1(ISEG) = ISEGT
             GO TO 15
            ENDIF
   13      CONTINUE
   14     CONTINUE
   15    CONTINUE
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
         DO 18 ISEG = 1,KSEGS
          DO 17 IMODUL = 1,NMODUL
C BEG JAN 2011
C Introduce test for skipping modules near the pole
           IF (IMODUL.LT.NMODUL/10) GO TO 17
C END JAN 2011
           INODBG = 5
           INODED = NODSEG - 2
           IF (KSEGS.EQ.6.AND.IMODUL.EQ.1.AND.ISEG.LE.5)
     1        INODBG = NODSEG/2 +1
           ISEGT = (IMODUL -1)*KSEGS +ISEG
           DO 16 INOD = INODBG,INODED
            DIFF(ISEG) =
     1        ABS((EIG2MN(ISEG)-EIGEN2(INOD,ISEGT))/EIG2MN(ISEG))
            IF (DIFF(ISEG).LE.0.0001) THEN
             INODE2(ISEG) = INOD
             ISEGE2(ISEG) = ISEGT
             GO TO 18
            ENDIF
   16      CONTINUE
```

```
   17     CONTINUE
   18    CONTINUE
C
C     End of ISHAPE=2 alternative.
      ENDIF
C     End of IF (ISHAPE....) condition
C
      IF (ISHAPE.EQ.1) WRITE(IFILE,'(/,A,/,A,1P,E12.4)')
     1' Buckling load factor corresponding to the initial loss of',
     1' meridional tension, EIGMIN=',EIGMIN
C
      IF (ISHAPE.EQ.2) WRITE(IFILE,'(/,A,/,A,1P,E12.4)')
     1' Buckling load factor corresponding to the initial loss of',
     1' either meridional or circumferential tension, EIGMIN=',EIGMIN
C END NOV 2010
C
      IF (IMODX.EQ.0) THEN
C23456789012345678901234567890123456789012345678901234567890123456789012
C BEG NOV 2010
        IF (ISHAPE.EQ.1) THEN
C END NOV 2010
        WRITE(IFILE,'(/,A,/,A,/,A,/,A,/,A,1P,E12.4,A,/,A,/,A,1P,E12.4)')
     1' Changes in temperature required to create 2 total axial loads:',
     1'  ',
     1'  1. Change in temperature required to create the axial thermal',
     1'     strain that generates the axial tension due to closing the',
     1'     two ends of the pressurized volume (PMIDDL=',
     1  PMIDDL(ILOADX),')',
     1'     between the inner and outer walls of the balloon in',
     1'     Load Step No. 1:                                DELTAT=',
     1  DELTAT
        WRITE(IFILE,'(/,A,/,A,/,A,1P,1E12.4,A,1P,E12.4,/,/)')
     1'  2. Change in temperature required to simulate the Poisson',
     1'     axial expansion caused by the application of the outer',
     1'     pressure, POUTER =',
     1  POUTER(ILOADX),' in Load Step No. 2:  DELT=',
     1  DELT
C BEG NOV 2010
        ENDIF
        IF (IABORT.EQ.0) THEN
           WRITE(IFILE,'(/,A)')
     1   ' BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)'
           DO 20 I = 1,IWAVEB
            WRITE(IFILE,'(A,1P,E12.4,A,I6,A)')
     1     '       ',EIGCOM(I),'(',NWVCOM(I),')'
   20      CONTINUE
        ELSE
           WRITE(IFILE,'(/,A,A)')
     1   ' BUCKLING LOAD FACTORS AND MODES FROM THE INITIAL LOSS OF',
     1   ' MERIDIONAL TENSION'
           EIGCRT = EIGMIN
           IF (ISHAPE.EQ.1) NWVCRT = 1
           IF (ISHAPE.EQ.2) NWVCRT = 0
           WRITE(IFILE,'(A,1P,E12.4,A,I3)')
```

```
     1      ' Loss-of-meridional-tension "eigenvalue", EIGMIN=',
     1        EIGMIN,', wave number=',NWVCRT
        ENDIF
        WRITE(IFILE,'(A,1P,E12.4)')
     1' Critical buckling load factor, BUCKB4=',EIGCRT
        IF (ISHAPE.EQ.1) WRITE(IFILE,'(A,I5)')
     1' Critical number of axial half-waves, NWVCRT=',NWVCRT
        IF (ISHAPE.EQ.2) WRITE(IFILE,'(A,I5)')
     1' Critical number of circumferential full-waves, NWVCRT=',NWVCRT
C
        IF (ISHAPE.EQ.1) THEN
         DO 30 J = 1,6
         DO 25 I = 1,1
          N2DIFF(J) = N2VAR(I,J) - N2FIX(I,J)
   25    CONTINUE
   30    CONTINUE
         WRITE(IFILE,'(/,A,/,A,/,A,/,A,1P,6E12.4,/,A,/,A,/,A,/,A,/,A)')
     1 ' Differences in the resultants along the axis of the prismatic',
     1 ' balloon for each segment, J, of the first module:',
     1' [N2VAR(J) for the total load] - [N2FIX(J) for the fixed load]=',
     1 ' N2DIFF(J),J=1,6)=',(N2DIFF(J),J=1,6),
     1' N2VAR(J) (total load) are the resultants from Load Step No. 2.',
     1' N2FIX(J) (fixed load) are the resultants from Load Step No. 1.',
     1 ' NOTE: The stresses used as behavioral constraints are',
     1 '       computed from N2VAR(J)/thickness(J). These stresses are',
     1 '       lower than those computed from N2FIX(J)/thickness(J).'
C23456789012345678901234567890123456789012345678901234567890123456789012
        ENDIF
C END NOV 2010
C
        IF (NPRINX.GE.2) THEN
C BEG NOV 2010
         IF (ISHAPE.EQ.1) THEN
            WRITE(IFILE,'(/,A,/,A,A,/,A,A)')
     1     ' PREBUCKLING STRESS RESULTANTS IN THE FIRST MODULE',
     1     '           "fixed" from Load Step No. 1',
     1     ' total from Load Step No. 2',
     1     ' Seg.J  Node I  N1FIX(I,J)   N2FIX(I,J)',
     1     '   N1VAR(I,J)   N2VAR(I,J)'
            DO 50 J = 1,KSEGS
            DO 40 I = 1,1
              WRITE(IFILE,'(I5,I7,1P,4E13.4)')
     1        J,I,N1FIX(I,J),N2FIX(I,J),N1VAR(I,J),N2VAR(I,J)
   40       CONTINUE
   50       CONTINUE
         ELSE
            WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1     ' MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS ',
     1     '                 "fixed"       "total"',
     1     '               Load Step 1   Load Step 2',
     1     ' Seg.J  Node I  N1FIX(I,J)    N1VAR(I,J)'
C
            DO 60 J = 1,KSEGS
              IARG1 = INODM1(J)
```

```
           JARG1 = ISEGM1(J)
C BEG JAN 2011
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
           IARG11 = IARG1 + 1
           FN1AVF = 0.5*(N1FIX(IARG1,JARG1) +N1FIX(IARG11,JARG1))
           FN1AVV = 0.5*(N1VAR(IARG1,JARG1) +N1VAR(IARG11,JARG1))
           WRITE(IFILE,'(I5,I7,1P,2E14.5)')
     1     JARG1,IARG1,FN1AVF,FN1AVV
C END JAN 2011
   60    CONTINUE
C
         WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1   ' MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS ',
     1   '                "fixed"       "total"',
     1   '              Load Step 1   Load Step 2',
     1   ' Seg.J  Node I  N2FIX(I,J)    N2VAR(I,J)'
C
         DO 70 J = 1,KSEGS
           IARG2 = INODM2(J)
           JARG2 = ISEGM2(J)
C BEG JAN 2011
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
           IARG21 = IARG2 + 1
           FN2AVF = 0.5*(N2FIX(IARG2,JARG2) +N2FIX(IARG21,JARG2))
           FN2AVV = 0.5*(N2VAR(IARG2,JARG2) +N2VAR(IARG21,JARG2))
           WRITE(IFILE,'(I5,I7,1P,2E14.5)')
     1     JARG2,IARG2,FN2AVF,FN2AVV
C END JAN 2011
   70    CONTINUE
C
         WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1   ' MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION ',
     1   '                              "fixed"       "total"',
     1   '                            Load Step 1   Load Step 2',
     1   ' Seg.J  Node I  EIGEN1(I,J)    N1FIX(I,J)    N1VAR(I,J)'
C
         DO 75 J = 1,KSEGS
           IARG1 = INODE1(J)
           JARG1 = ISEGE1(J)
C BEG JAN 2011
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
           IARG11 = IARG1 + 1
           FN1AVF = 0.5*(N1FIX(IARG1,JARG1) +N1FIX(IARG11,JARG1))
           FN1AVV = 0.5*(N1VAR(IARG1,JARG1) +N1VAR(IARG11,JARG1))
           WRITE(IFILE,'(I5,I7,1P,3E14.5)')
     1     JARG1,IARG1,EIGEN1(IARG1,JARG1),FN1AVF,FN1AVV
C END JAN 2011
   75    CONTINUE
C
         WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1   ' MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION ',
     1   '                              "fixed"       "total"',
     1   '                            Load Step 1   Load Step 2',
     1   ' Seg.J  Node I  EIGEN2(I,J)    N2FIX(I,J)    N2VAR(I,J)'
```

```
C
            DO 77 J = 1,KSEGS
              IARG2 = INODE2(J)
              JARG2 = ISEGE2(J)
C BEG JAN 2011
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
              IARG21 = IARG2 + 1
              FN2AVF = 0.5*(N2FIX(IARG2,JARG2) +N2FIX(IARG21,JARG2))
              FN2AVV = 0.5*(N2VAR(IARG2,JARG2) +N2VAR(IARG21,JARG2))
              WRITE(IFILE,'(I5,I7,1P,3E14.5)')
     1        JARG2,IARG2,EIGEN2(IARG2,JARG2),FN2AVF,FN2AVV
C END JAN 2011
   77       CONTINUE
C
         ENDIF
C        End of "IF (ISHAPE..." condition
C
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
         IF (ISHAPE.EQ.1) THEN
           WRITE(IFILE,'(/,A,A,/,A,A,/,A,A,/,A,A)')
     1   ' PREBUCKLING MEMBRANE STRESSES IN THE FIRST MODULE COMPUTED',
     1   ' FROM',
     1   ' N1FIX/thickness, N2FIX/thickness, N1VAR/thickness,',
     1   ' N2VAR/thickness:',
     1   '          "fixed" from Load Step No. 1',
     1   ' total from Load Step No. 2',
     1   ' Seg.J  Node I STRS1F(I,J)  STRS2F(I,J)',
     1   '  STRS1V(I,J)  STRS2V(I,J)'
           DO 90 J = 1,KSEGS
           DO 80 I = 1,1
             WRITE(IFILE,'(I5,I7,1P,4E13.4)')
     1       J,I,STRS1F(I,J),STRS2F(I,J),STRS1V(I,J),STRS2V(I,J)
   80      CONTINUE
   90      CONTINUE
         ELSE
           WRITE(IFILE,'(/,A,/,A,A)')
     1   ' PREBUCKLING MEMBRANE STRESSES COMPUTED FROM',
     1   ' N1FIX/thickness, N2FIX/thickness, N1VAR/thickness,',
     1   ' N2VAR/thickness:'
            WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1    ' MAXIMUM PREBUCKLING MERIDIONAL MEMBRANE STRESSES ',
     1    '                 "fixed"       "total"',
     1    '               Load Step 1   Load Step 2',
     1    ' Seg.J  Node I STRS1F(I,J)   STRS1V(I,J)'
C
            DO 100 J = 1,KSEGS
              IARG1 = INODM1(J)
              JARG1 = ISEGM1(J)
              WRITE(IFILE,'(I5,I7,1P,2E14.5)')
     1        JARG1,IARG1,STRS1F(1,J),STRS1V(1,J)
  100       CONTINUE
C
            WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1    ' MAXIMUM PREBUCKLING CIRCUMFERENTIAL MEMBRANE STRESSES ',
```

```
     1    '                  "fixed"       "total"',
     1    '                Load Step 1   Load Step 2',
     1    ' Seg.J  Node I STRS2F(I,J)   STRS2V(I,J)'
C
             DO 110 J = 1,KSEGS
               IARG2 = INODM2(J)
               JARG2 = ISEGM2(J)
               WRITE(IFILE,'(I5,I7,1P,2E14.5)')
     1         JARG2,IARG2,STRS2F(1,J),STRS2V(1,J)
  110        CONTINUE
          ENDIF
C         End "IF (ISHAPE...)" condition
C END NOV 2010
C
          WRITE(IFILE,'(/,A)')
     1 ' Behavior number, General buckling load factor:'
         ENDIF
C        End of (NPRINX.GE.2) condition.
C
         WRITE(IFILE,
     1  '(/,A,/,A,/,A,I3,/,A,1P,E12.4,/,A,/,A,/,A,I3,/,A,1P,E12.4,/)')
     1' Newton iterations required to solve the nonlinear',
     1' axisymmetric pre-buckling equilibrium state for the',
     1' "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=',ITRSTP(1),
     1' Maximum displacement,                         FMAX=',FMAXST(1),
     1' Newton iterations required to solve the nonlinear',
     1' axisymmetric pre-buckling equilibrium state for the',
     1' total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=',ITRSTP(2),
     1' Maximum displacement,                         FMAX=',FMAXST(2)
C
        ENDIF
C       End of (IMODX.EQ.0) condition.
C
C BEG DEC 2010
C       IF (EIGCRT.LE.0.0) THEN
        IF (IABORT.EQ.0.AND.EIGCRT.LE.0.0) THEN
C234567890123456789012345678901234567890123456789012345678901234567890
12
          WRITE(IFILE,'(/,A,/,A,1P,E12.4,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' ******************* RUN ABORT **********************',
     1 ' EIGCRT is less than or equal to zero. EIGCRT=',EIGCRT,
     1 ' Possible divergence or failure of convergence of nonlinear',
     1 ' pre-buckling solution either at Load Step No. 1 (fixed',
     1 ' loads: PINNER, PMIDDL, DELTAT) or at Load Step No. 2',
     1 ' (total loads: PINNER, PMIDDL, DELTAT, POUTER)',
     1 ' Probably you should increase either RINNER or ROUTER or',
     1 ' both RINNER and ROUTER.',
     1 ' ******************* RUN ABORT **********************'
          IABORT = 1
          CALL MOVER(0.,0,STRS1V,1,6)
          CALL MOVER(0.,0,STRS2V,1,6)
          EIGMIN = 10.E16
          WEIGHT = 10.E20
          TOTMAS = 10.E20
          IF (ITYPEX.EQ.2) CALL ERREX
```

```
         GO TO 1000
C END DEC 2010
      ENDIF
C BEG DEC 2010
      IF (ITYPEX.EQ.2.AND.IABORT.EQ.0) THEN
        EIGCRT = EIGCOM(1)
      ENDIF
C
 1000 CONTINUE
C
C END DEC 2010
C BEG NOV 2010
      IF (IABORT.EQ.1) THEN
        EIGCRT = EIGMIN
      ENDIF
C END NOV 2010
C
      BUCKB4(ILOADX) = EIGCRT
C
      RETURN
      END
C
C
C
C
C=DECK      BEHX2
      SUBROUTINE BEHX2
     1 (IFILE,NPRINX,IMODX,IFAST,ILOADX,PHRASE)
C
C   PURPOSE: OBTAIN load factor for tension loss
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE RESPONSE VARIABLE FOR
C   THE ith LOAD CASE, ILOADX:
C
C     TENLOS(ILOADX)
C
C   AS OUTPUT. THE ith CASE REFERS
C   TO ith ENVIRONMENT (e.g. load com-
C   bination).
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
```

```
C
C      ILOADX = ith LOADING COMBINATION
C      PHRASE = load factor for tension loss
C
C    OUTPUT:
C
C      TENLOS(ILOADX)
C
        CHARACTER*80 PHRASE
C   INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C   INSERT SUBROUTINE STATEMENTS HERE.
C
      COMMON/EIGMNX/EIGMIN
C
      TENLOS(ILOADX) = EIGMIN
C
      RETURN
      END
C
C
C
C
C=DECK      BEHX3
      SUBROUTINE BEHX3
     1 (IFILE,NPRINX,IMODX,IFAST,ILOADX,JCOL,PHRASE)
C
```

```
C   PURPOSE: OBTAIN stress component in material 1
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE RESPONSE VARIABLE FOR
C   THE ith LOAD CASE, ILOADX:
C
C     STRM1(ILOADX,JCOL)
C
C   AS OUTPUT. THE ith CASE REFERS
C   TO ith ENVIRONMENT (e.g. load com-
C   bination).
C   THE jth COLUMN  (JCOL)
C   INDEX IS DEFINED AS FOLLOWS:
C     stress component number
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
C
C     ILOADX = ith LOADING COMBINATION
C     JCOL   = jth column of STRM1
C     JCOL   = stress component number
C     PHRASE = stress component in material 1
C
C   OUTPUT:
C
C     STRM1(ILOADX,JCOL)
C
      CHARACTER*80 PHRASE
C  INSERT ADDITIONAL COMMON BLOCKS:
     COMMON/FV03/EMOD1(10),IEMOD1
     REAL EMOD1
     COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
     REAL EMOD2,G12,G13,G23,NU,ALPHA1
     COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
     REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
     COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
     REAL ALPHA2,TEMPER,DENSTY
     COMMON/FV21/PINNER(20)
     REAL PINNER
     COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
     REAL BUCKB4,BUCKB4A,BUCKB4F
     COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
     REAL TENLOS,TENLOSA,TENLOSF
```

```
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  INSERT SUBROUTINE STATEMENTS HERE.
C
C BEG DEC 2010
      COMMON/IABRTX/IABORT
C END DEC 2010
C BEG NOV 2010
      COMMON/MEMSTR/STRS1F(1,6),STRS2F(1,6),STRS1V(1,6),STRS2V(1,6)
C END NOV 2010
      COMMON/FINNER/C44FIN,DELTAT,DELT,NODSEG,MSEGS
      COMMON/ERROR/ERR
      COMMON/NUMPAR/IPARX,IVARX,IALLOW,ICONSX,NDECX,NLINKX,NESCAP,ITYPEX
      COMMON/LAMSTR/STRRAT(99)
      COMMON/WRDSTR/STRWRD(99)
      CHARACTER*80 STRWRD
      DIMENSION ILET1(15,6),ILET2(15,3)
      common/caseblock/CASE
      CHARACTER*28 CASE
      CHARACTER*35 CASA
      COMMON/STRCMP/STRC1(20,5),STRC2(20,5),STRC3(20,5)
C
C BEG DEC 2010 (activate the following statement)
      IF (JCOL.GT.1) GO TO 500
C END DEC 2010
C
C  NOTE IMPORTANT CHANGE:
C
C  October 7, 2010: Use the MEMBRANE stresses computed in
C  SUBROUTINE BEHX1 because the
C  meridional curvature change, KAPPA1, from BIGBOSOR4 is
C  sometimes much too large in the immediate neighborhoods
C  of the ends of the shell segments, generating maximum
C  stress components that are much too high in this particular
C  case that involves a balloon-like (membrane) structure,
C  This is especially true for the outer and inner curved
C  membranes, that is, segments 2 (outer) and 4 (inner)
C  of each module of the multi-module model. For example,
C  here is some BIGBOSOR4 output for Segment 4 (inner
C  curved membrane) for Load Step No. 1 (applied loads
C  are PINNER, PMIDDL, and DELTAT):
C
```

```
C      AXISYMMETRIC PRESTRESS DISTRIBUTION FOR SEGMENT 4
C POINT   EPSILON 1  EPSILON 2   KAPPA 1      KAPPA 2
C           MERID.     CIRCUMF.    MERID.      CIRCUMF.
C           STRAIN     STRAIN     CHANGES IN CURVATURE
C   1    1.070E-01   7.019E-15   5.784E-01   1.795E-08
C   2    1.062E-01  -1.695E-09  -1.015E+01  -4.307E-10
C   3    1.059E-01   1.154E-08   2.981E+00  -8.949E-09
C   4    1.074E-01   1.021E-08  -1.251E+00  -2.625E-09
C   5    1.077E-01   1.483E-08   6.715E-01  -5.319E-09
C   6    1.085E-01   1.647E-08  -2.629E-01  -3.690E-09
C   7    1.090E-01   1.910E-08   1.910E-01  -4.184E-09
C   8    1.096E-01   2.095E-08  -3.076E-02  -3.533E-09
C   9    1.100E-01   2.283E-08   7.706E-02  -3.398E-09
C  10    1.104E-01   2.441E-08   2.394E-02  -2.950E-09
C
C  Note that the meridional change in curvature, KAPPA 1,
C  is very large at nodal points 2, 3, 4, especially at
C  nodal point 2. This very local edge effect gives rise to
C  artificially high local bending meridional strain, which
C  probably does not exist in a balloon (membrane
C  pressure-stabilized "shell" structure). The extreme
C  fiber meridional strain from BIGBOSOR4 is given by:
C  EPS1 = EPSILON1 + THICK*KAPPA1/2.
C  in which EPSILON1 is the reference (middle) surface
C  meridional strain and THICK is the thickness of the
C  shell segment.
C
C  Because of this spurious and extremely high meridional
C  bending strain predicted by BIGBOSOR4 (which has difficulty
C  predicting accurate bending stresses in membrane-like structures
C  but which works well for shell structures with "finite"
C  bending stiffness), the previous FORTRAN statement:
C     IF (JCOL.GT.1) GO TO 500
C  has been commented out and replaced by the following
C  statement, "GO TO 500". Because of this important change
C  the file, *.BEHX2, is no longer created and you can
C  therefore no longer obtain plots of the pre-buckled states
C  at Load Steps 1 and 2 unless you remove the "C" in column
C  1 of the statement, "IF (JCOL.GT.1) GO TO 500", and insert
C  a "C" in column 1 of the following statement, "GO TO 500".
C  and then re-compile via the GENOPT command, "genprograms".
C
C BEG DEC 2010 (make the following statement dependent on ITYPEX)
      IF (IABORT.NE.0.OR.ITYPEX.NE.2) GO TO 500
C END DEC 2010
C
      IF (IMODX.EQ.0) ERR = 0.
      IF (IMODX.EQ.1) ERR = 0.01
C
      INDIC = 0
      RAVE = RADIUS/PI
      RBIGG = RAVE
C BEG NOV 2010
      IF (ISHAPE.EQ.2.AND.KSEGS.EQ.5) RBIGG = 0.0
```

```
C     IF (ISHAPE.EQ.2.AND.KSEGS.EQ.6) RBIGG = 0.0
C BEG DEC 2010
      IF (ISHAPE.EQ.2.AND.KSEGS.EQ.6) RBIGG = 0.025*RAVE
C END DEC 2010
C END NOV 2010
C
      CALL BOSDEC(2,24,ILOADX,INDIC)
C
      IF (ITYPEX.EQ.2) THEN
C      Get CASE.BEHX2 file for input for BIGBOSOR4...
C      CASE.BEHX2 is an input file for BIGBOSOR4 for behavior no. 2:
C      STRM1(ILOADX,JCOL), JCOL=1,5: stress components in material 1
C
C      NOTE: Also computed in SUBROUTINE BEHX2 are the following:
C      STRM2(ILOADX,JCOL), JCOL=1,5: stress components in material 2
C      STRM3(ILOADX,JCOL), JCOL=1,5: stress components in material 3
C
C      STRM2(ILOADX,JCOL) is available in SUBROUTINE BEHX3 because
C                         it is in a labelled common block.
C      STRM3(ILOADX,JCOL) is available in SUBROUTINE BEHX4 because
C                         it is in a labelled common block.
C
C BEG DEC 2010
C234567890123456789012345678901234567890123456789012345678901234567890112
         IF (ISHAPE.EQ.2)
     1   WRITE(IFILE,'(/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' **********************************************************',
     1 ' ****** MIN.STRESS CONSTRAINTS INCLUDING BENDING STRESS ******',
     1 ' Bending stresses are printed here only for your information.',
     1 ' Bending stresses are NOT included in the computation of the',
     1 ' stress constraints or the stress margins, which are obtained',
     1 ' from the maximum stress resultants divided by the "shell"',
     1 ' segment wall thickness. Therefore, the stress margins printed',
     1 ' below are probably unconservative, especially at "shell"',
     1 ' segment junctions where there are probably large, very local',
     1 ' bending stress concentrations. In fabricating the balloon,',
     1 ' reinforce the seams at "shell" junctions to avoid failure.'
         I=INDEX(CASE,' ')
         IF(I.NE.0) THEN
C BEG DEC 2010
            CASA=CASE(:I-1)//'.BEHX3'
         ELSE
            CASA=CASE//'.BEHX3'
         ENDIF
C END DEC 2010
         OPEN(UNIT=61,FILE=CASA,STATUS='UNKNOWN')
         CALL BOSDEC(2,61,ILOADX,INDIC)
         CLOSE(UNIT=61)
         WRITE(IFILE,'(/,/,A,A,/,A)')
     1 ' BIGBOSOR4 input file for:',
     1 ' stress components in materials 1,2,3',
     1   CASA
C BEG DEC 2010
C234567890123456789012345678901234567890123456789012345678901234567890112
```

```
        WRITE(IFILE,'(A,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Ordinarily, the file called ',CASA,
     1 ' which contains valid input data for BIGBOSOR4,',
     1 ' would be used for an execution of BIGBOSOR4 independently',
     1 ' of the GENOPT environment. However, that BIGBOSOR4 execution',
     1 ' will probably fail in this case because of failure of the',
     1 ' Newton iterations for solution of the nonlinear pre-buckling',
     1 ' equilibrium equations corresponding to the application of the',
     1 ' "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and',
     1 ' PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not',
     1 ' presently have the capability to divide Load Set B into sub-',
     1 ' steps.'
C END DEC 2010
      ENDIF
C
      CALL B4READ
C
      CALL B4MAIN
      CALL GASP(DUM1,DUM2,-2,DUM3)
C
C With INDIC = 0,
C BIGBOSOR4 generates stress constraints for laminated composite
C material in the following form (in this case all shell segments
C have only one layer, and the balloon is in tension everywhere.:
C
C****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
C 1  3.1045E+00 fiber tension : matl=1 ,  A , seg=50, node=32, layer=1
,z=0.01   ;FS=1.
C 2  1.7557E+00 transv tension: matl=1 ,  A , seg=92, node=33, layer=1
,z=0.01   ;FS=1.
C 3  5.1415E+02 fiber tension : matl=2 ,  A , seg=1 , node=33, layer=1
,z=1.     ;FS=1.
C 4  1.7557E+02 transv tension: matl=2 ,  A , seg=91, node=33, layer=1
,z=1.     ;FS=1.
C 5  4.9549E+00 fiber tension : matl=3 ,  A , seg=11, node=1 , layer=1
,z=-0.01  ;FS=1.
C 6  1.7557E+00 transv tension: matl=3 ,  A , seg=90, node=33, layer=1
,z=0.01   ;FS=1.
C*****************************************************
C
C or, for an isotropic material:
C
C****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
C 1  1.5325E+00 effect. stress: matl=1 ,  A , seg=52, node=32, layer=1
,z=0.01   ;FS=1.
C 2  1.0960E+00 effect. stress: matl=2 ,  A , seg=81, node=32, layer=1
,z=0.01   ;FS=1.
C 3  1.9372E+00 effect. stress: matl=3 ,  A , seg=84, node=33, layer=1
,z=0.01   ;FS=1.
C*****************************************************
C
      ICONST = 5*3
C
      DO 10 J = 1,5
```

```
         STRC1(ILOADX,J) = 0.
         STRC2(ILOADX,J) = 0.
         STRC3(ILOADX,J) = 0.
   10 CONTINUE
C
      DO 50 I = 1,ICONST
         IF (STRRAT(I).EQ.0.) THEN
            ICONS2 = ICONST - 1
            GO TO 60
         ENDIF
         IF (ITYPEX.EQ.2.AND.IMODX.EQ.0) THEN
           IF (I.EQ.1) WRITE(IFILE,'(/,A,A)')
     1     ' Minimum stress constraints in the entire structure',
     1     ' at the last load step (from BIGBOSOR4):'
           WRITE(IFILE,40) I,STRRAT(I),STRWRD(I)(1:64)
         ENDIF
   40 FORMAT(I3,1P,E12.4,1X,A)
   50 CONTINUE
   60 CONTINUE
C
      DO 100 I = 1,ICONS2
C
        ILET1(I,1)  = INDEX(STRWRD(I),'fiber tension')
        ILET1(I,2)  = INDEX(STRWRD(I),'fiber compres')
        ILET1(I,3)  = INDEX(STRWRD(I),'transv tension')
        ILET1(I,4)  = INDEX(STRWRD(I),'transv compres')
        ILET1(I,5)  = INDEX(STRWRD(I),'in-plane shear')
        ILET1(I,6)  = INDEX(STRWRD(I),'effect. stress')
C
        ILET2(I,1)  = INDEX(STRWRD(I),'matl=1')
        ILET2(I,2)  = INDEX(STRWRD(I),'matl=2')
        ILET2(I,3)  = INDEX(STRWRD(I),'matl=3')
  100 CONTINUE
C
      DO 200 I = 1,ICONS2
C23456789012345678901234567890123456789012345678901234567890123456789012
        IF (ILET1(I,1).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,1)=STRM1A(ILOADX,1)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,1)=STRM2A(ILOADX,1)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,1)=STRM3A(ILOADX,1)/STRRAT(I)
        ENDIF
C
        IF (ILET1(I,2).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,2)=STRM1A(ILOADX,2)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,2)=STRM2A(ILOADX,2)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,2)=STRM3A(ILOADX,2)/STRRAT(I)
        ENDIF
C
        IF (ILET1(I,3).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,3)=STRM1A(ILOADX,3)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,3)=STRM2A(ILOADX,3)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,3)=STRM3A(ILOADX,3)/STRRAT(I)
        ENDIF
C
```

```
        IF (ILET1(I,4).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,4)=STRM1A(ILOADX,4)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,4)=STRM2A(ILOADX,4)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,4)=STRM3A(ILOADX,4)/STRRAT(I)
        ENDIF
C
        IF (ILET1(I,5).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,5)=STRM1A(ILOADX,5)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,5)=STRM2A(ILOADX,5)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,5)=STRM3A(ILOADX,5)/STRRAT(I)
        ENDIF
C
        IF (ILET1(I,6).NE.0) THEN
         IF (ILET2(I,1).NE.0) STRC1(ILOADX,1)=STRM1A(ILOADX,1)/STRRAT(I)
         IF (ILET2(I,2).NE.0) STRC2(ILOADX,1)=STRM2A(ILOADX,1)/STRRAT(I)
         IF (ILET2(I,3).NE.0) STRC3(ILOADX,1)=STRM3A(ILOADX,1)/STRRAT(I)
        ENDIF
C
  200 CONTINUE
C
C23456789012345678901234567890123456789012345678901234567890123456789012
      IF (IMODX.EQ.0) THEN
         WRITE(IFILE,'(/,A,A,/,A,A,/,A)')
     1 ' FIVE STRESS COMPONENTS (including bending) FOR MATL i,',
     1 ' STRCi(ILOADX,J), J=1,5:',
     1 '    fiber tension  fiber compres ',
     1 ' transv tension transv compres in-plane shear',
     1 '  or effect.stress'
         WRITE(IFILE,'(A,/,1P,5E15.4)')
     1 ' Material 1 stress: STRC1(ILOADX,J),J=1,5)=',
     1   (STRC1(ILOADX,J),J=1,5)
         WRITE(IFILE,'(A,/,1P,5E15.4)')
     1 ' Material 2 stress: STRC2(ILOADX,J),J=1,5)=',
     1   (STRC2(ILOADX,J),J=1,5)
         WRITE(IFILE,'(A,/,1P,5E15.4,/)')
     1 ' Material 3 stress: STRC3(ILOADX,J),J=1,5)=',
     1   (STRC3(ILOADX,J),J=1,5)
C23456789012345678901234567890123456789012345678901234567890123456789012
        IF (ISHAPE.EQ.1)
     1  WRITE(IFILE,'(/,A,/,A,/,A,/,A,/,A,1P,E12.4,A,/,A,/,A,1P,E12.4)')
     1' Changes in temperature required to create 2 total axial loads:',
     1'  ',
     1'  1. Change in temperature required to create the axial thermal',
     1'     strain that generates the axial tension due to closing the',
     1'     two ends of the pressurized volume (PMIDDL=',
     1  PMIDDL(ILOADX),')',
     1'     between the inner and outer walls of the balloon in',
     1'     Load Step No. 1:                                 DELTAT=',
     1  DELTAT
        IF (ISHAPE.EQ.1)
     1  WRITE(IFILE,'(/,A,/,A,/,A,1P,1E12.4,A,1P,E12.4,/,/)')
     1'  2. Change in temperature required to simulate the Poisson',
     1'     axial expansion caused by the application of the outer',
     1'     pressure, POUTER =',
```

```
     1  POUTER(ILOADX),' in Load Step No. 2:  DELT=',
     1  DELT
        IF (ITYPEX.NE.2) WRITE(IFILE,'(A)')
     1' BEHAVIOR OVER J =  stress component number'
        WRITE(IFILE,'(A,/,A,/,A,/,/,A,/,A,/,A,/,A)'),
     1' ********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM',
     1' STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********',
     1' ************************************************************',
     1' The maximum stresses from membrane theory (no bending)',
     1' follow. It is these much smaller stress components that are',
     1' used to compute the stress margins listed below and that are',
     1' used as constraints during optimization cycles.'
      ENDIF
C
  500 CONTINUE
C
C   NOTE: the quantities, STRS1V and STRS2V, are computed
C         in SUBROUTINE BEHX1.
C
      STRC1(ILOADX,1) = MAX(STRS1V(1,2),STRS1V(1,4))
      STRC1(ILOADX,2) = 0.
      STRC1(ILOADX,3) = MAX(STRS2V(1,2),STRS2V(1,4))
      STRC1(ILOADX,4) = 0.
      STRC1(ILOADX,5) = 0.
C
      STRM1(ILOADX,JCOL) = STRC1(ILOADX,JCOL)
C
      RETURN
      END
C
C
C
C
C=DECK      BEHX4
      SUBROUTINE BEHX4
     1 (IFILE,NPRINX,IMODX,IFAST,ILOADX,JCOL,PHRASE)
C
C   PURPOSE: OBTAIN stress component in material 2
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE RESPONSE VARIABLE FOR
C   THE ith LOAD CASE, ILOADX:
C
C     STRM2(ILOADX,JCOL)
C
C   AS OUTPUT. THE ith CASE REFERS
C   TO ith ENVIRONMENT (e.g. load com-
C   bination).
C   THE jth COLUMN  (JCOL)
C   INDEX IS DEFINED AS FOLLOWS:
C     stress component number
C
```

```
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
C
C     ILOADX = ith LOADING COMBINATION
C     JCOL   = jth column of STRM2
C     JCOL   = stress component number
C     PHRASE = stress component in material 2
C
C   OUTPUT:
C
C     STRM2(ILOADX,JCOL)
C
      CHARACTER*80 PHRASE
C  INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  INSERT SUBROUTINE STATEMENTS HERE.
C
C BEG NOV 2010
```

```
      COMMON/MEMSTR/STRS1F(1,6),STRS2F(1,6),STRS1V(1,6),STRS2V(1,6)
C END NOV 2010
      COMMON/STRCMP/STRC1(20,5),STRC2(20,5),STRC3(20,5)
C
C    Do not need any calculations added here because
C    STRC2(ILOADX,JCOL), JCOL = 1,2,3,4,5
C    are computed in SUBROUTINE BEHX2
C
C  NOTE IMPORTANT CHANGE:
C
C  October 7, 2010: Use the MEMBRANE stresses because the
C  meridional curvature change, KAPPA1, from BIGBOSOR4 is
C  sometimes much too large in the immediate neighborhoods
C  of the ends of the shell segments, generating maximum
C  stress components that are much too high in this particular
C  case that involves a balloon-like (membrane) structure,
C  This is especially true for the outer and inner curved
C  membranes, that is, segments 2 (outer) and 4 (inner)
C  of each module of the multi-module model. For example,
C  here is some BIGBOSOR4 output for Segment 4 (inner
C  curved membrane) for Load Step No. 1:
C
C      AXISYMMETRIC PRESTRESS DISTRIBUTION FOR SEGMENT 4
C POINT   EPSILON 1  EPSILON 2   KAPPA 1      KAPPA 2
C          MERID.     CIRCUMF.    MERID.      CIRCUMF.
C          STRAIN     STRAIN     CHANGES IN CURVATURE
C   1    1.070E-01   7.019E-15   5.784E-01   1.795E-08
C   2    1.062E-01  -1.695E-09  -1.015E+01  -4.307E-10
C   3    1.059E-01   1.154E-08   2.981E+00  -8.949E-09
C   4    1.074E-01   1.021E-08  -1.251E+00  -2.625E-09
C   5    1.077E-01   1.483E-08   6.715E-01  -5.319E-09
C   6    1.085E-01   1.647E-08  -2.629E-01  -3.690E-09
C   7    1.090E-01   1.910E-08   1.910E-01  -4.184E-09
C   8    1.096E-01   2.095E-08  -3.076E-02  -3.533E-09
C   9    1.100E-01   2.283E-08   7.706E-02  -3.398E-09
C  10    1.104E-01   2.441E-08   2.394E-02  -2.950E-09
C
C
C   NOTE: the quantities, STRS1V and STRS2V, are computed
C         in SUBROUTINE BEHX1.
C
      STRC2(ILOADX,1) = MAX(STRS1V(1,1),STRS1V(1,3))
      STRC2(ILOADX,2) = 0.
      STRC2(ILOADX,3) = MAX(STRS2V(1,1),STRS2V(1,3))
      STRC2(ILOADX,4) = 0.
      STRC2(ILOADX,5) = 0.
C
      STRM2(ILOADX,JCOL) = STRC2(ILOADX,JCOL)
C
      RETURN
      END
C
C
C
```

```
C
C=DECK      BEHX5
      SUBROUTINE BEHX5
     1 (IFILE,NPRINX,IMODX,IFAST,ILOADX,JCOL,PHRASE)
C
C   PURPOSE: OBTAIN stress component in material 3
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE RESPONSE VARIABLE FOR
C   THE ith LOAD CASE, ILOADX:
C
C     STRM3(ILOADX,JCOL)
C
C   AS OUTPUT. THE ith CASE REFERS
C   TO ith ENVIRONMENT (e.g. load com-
C   bination).
C   THE jth COLUMN  (JCOL)
C   INDEX IS DEFINED AS FOLLOWS:
C     stress component number
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
C
C     ILOADX = ith LOADING COMBINATION
C     JCOL   = jth column of STRM3
C     JCOL   = stress component number
C     PHRASE = stress component in material 3
C
C   OUTPUT:
C
C     STRM3(ILOADX,JCOL)
C
       CHARACTER*80 PHRASE
C  INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
```

```
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  INSERT SUBROUTINE STATEMENTS HERE.
C
C BEG NOV 2010
      COMMON/MEMSTR/STRS1F(1,6),STRS2F(1,6),STRS1V(1,6),STRS2V(1,6)
C END NOV 2010
      COMMON/STRCMP/STRC1(20,5),STRC2(20,5),STRC3(20,5)
C
C    Do not need any calculations added here because
C    STRC3(ILOADX,JCOL), JCOL = 1,2,3,4,5
C    are computed in SUBROUTINE BEHX2
C
C  NOTE IMPORTANT CHANGE:
C
C  October 7, 2010: Use the MEMBRANE stresses because the
C  meridional curvature change, KAPPA1, from BIGBOSOR4 is
C  sometimes much too large in the immediate neighborhoods
C  of the ends of the shell segments, generating maximum
C  stress components that are much too high in this particular
C  case that involves a balloon-like (membrane) structure,
C  This is especially true for the outer and inner curved
C  membranes, that is, segments 2 (outer) and 4 (inner)
C  of each module of the multi-module model. For example,
C  here is some BIGBOSOR4 output for Segment 4 (inner
C  curved membrane) for Load Step No. 1:
C
C      AXISYMMETRIC PRESTRESS DISTRIBUTION FOR SEGMENT 4
C POINT   EPSILON 1  EPSILON 2   KAPPA 1      KAPPA 2
C           MERID.     CIRCUMF.    MERID.      CIRCUMF.
C           STRAIN     STRAIN     CHANGES IN CURVATURE
C   1    1.070E-01   7.019E-15   5.784E-01   1.795E-08
C   2    1.062E-01  -1.695E-09  -1.015E+01  -4.307E-10
C   3    1.059E-01   1.154E-08   2.981E+00  -8.949E-09
C   4    1.074E-01   1.021E-08  -1.251E+00  -2.625E-09
C   5    1.077E-01   1.483E-08   6.715E-01  -5.319E-09
C   6    1.085E-01   1.647E-08  -2.629E-01  -3.690E-09
```

```
C   7    1.090E-01   1.910E-08   1.910E-01  -4.184E-09
C   8    1.096E-01   2.095E-08  -3.076E-02  -3.533E-09
C   9    1.100E-01   2.283E-08   7.706E-02  -3.398E-09
C  10    1.104E-01   2.441E-08   2.394E-02  -2.950E-09
C
C
C   NOTE: the quantities, STRS1V and STRS2V, are computed
C         in SUBROUTINE BEHX1.
C
      IF (IWEBS.EQ.1) STRC3(ILOADX,1) = STRS1V(1,5)
      IF (IWEBS.EQ.2) STRC3(ILOADX,1) = MAX(STRS1V(1,5),STRS1V(1,6))
      STRC3(ILOADX,2) = 0.
      IF (IWEBS.EQ.1) STRC3(ILOADX,3) = STRS2V(1,5)
      IF (IWEBS.EQ.2) STRC3(ILOADX,3) = MAX(STRS2V(1,5),STRS2V(1,6))
      STRC3(ILOADX,4) = 0.
      STRC3(ILOADX,5) = 0.
C
      STRM3(ILOADX,JCOL) = STRC3(ILOADX,JCOL)
C
      RETURN
      END
C
C
C
C
C=DECK      USRCON
      SUBROUTINE USRCON(INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,
     1  WORDCX,WORDMX,PCWORD,CPLOTX,ICARX,IFILEX)
C   PURPOSE: GENERATE USER-WRITTEN
C   INEQUALITY CONSTRAINT CONDITION
C   USING ANY COMBINATION OF PROGRAM
C   VARIABLES.
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS A CONSTRAINT CONDITION,
C   CALLED "CONX" IN THIS ROUTINE.
      DIMENSION WORDCX(*),WORDMX(*),IPOINC(*),CONSTX(*)
      DIMENSION PCWORD(*),CPLOTX(*)
      CHARACTER*80 WORDCX,WORDMX,PCWORD
C  INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
```

```
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
      CONX = 0.0
C
C  INSERT USER-WRITTEN STATEMENTS
C  HERE. THE CONSTRAINT CONDITION
C  THAT YOU CALCULATE IS CALLED "CONX"
C
      IF (CONX.EQ.0.0) RETURN
      IF (CONX.LT.0.0) THEN
         WRITE(IFILEX,*)' CONX MUST BE GREATER THAN ZERO.'
         CALL EXIT
      ENDIF
C
C  DO NOT CHANGE THE FOLLOWING STATEMENTS, EXCEPT WORDC
C
      ICARX = ICARX + 1
      INUMTT = INUMTT + 1
      WORDCX(ICARX) = ' USER: PROVIDE THIS.'
      CPLOTX(ICARX) = CONX - 1.
      CALL BLANKX(WORDCX(ICARX),IENDP)
      PCWORD(ICARX)  = WORDCX(ICARX)(1:IENDP)//' -1'
      IF (IMODX.EQ.0.AND.CONX.GT.CONMAX) GO TO 200
      IF (IMODX.EQ.1.AND.IPOINC(INUMTT).EQ.0) GO TO 200
      ICONSX = ICONSX + 1
      IF (IMODX.EQ.0) IPOINC(INUMTT) = 1
      CONSTX(ICONSX) = CONX
      WORDMX(ICONSX)  = WORDCX(ICARX)(1:IENDP)//' -1'
  200 CONTINUE
C  END OF USRCON
C
C
      RETURN
      END
C
C
C
C=DECK      USRLNK
      SUBROUTINE USRLNK(VARI,I,VARIAB)
C Purpose: generate user-written
C linking conditions using any
C combination of decision variables.
```

```
C You must write conde that, using
C the variables in the subroutine
C argument VARIAB as input, ultimately
C yield a value for the linked variable
C VARI.
C
C VARI is the Ith entry of the array
C VARIAB.  You have decided that this
C is to be a linked variable with user
C defined linking.  It is linked to
C the decision variables in the array
C VARIAB.
C An example will provide the simplest
C explanation of this:
C Let"s say that the 5th decision
C variable candidate (I=5) is linked
C to the decision variable candidates
C 2 and 7. (You used DECIDE to select
C these as decision variables.
C In this case VARI is equal to
C VARIAB(I).  You then write your
C linking equation in the form
C VARI=f(VARIAB(2),VARIAB(7)).
C Use the index I in an IF statement if
C you have more than one user-defined
C linked variable.
C
C
      REAL VARI,VARIAB(50)
      INTEGER I
C
C  INSERT USER-WRITTEN DECLARATION
C  STATEMENTS HERE.
C
C  INSERT USER-WRITTEN
C  STATEMENTS HERE.
C
C
C  END OF USRLNK
      RETURN
      END
C=DECK      OBJECT
      SUBROUTINE OBJECT(IFILE,NPRINX,IMODX,OBJGEN,PHRASE)
C   PURPOSE:weight/length of the balloon
C
C   YOU MUST WRITE CODE THAT, USING
C   THE VARIABLES IN THE LABELLED
C   COMMON BLOCKS AS INPUT, ULTIMATELY
C   YIELDS THE OBJECTIVE FUNCTION
C         WEIGHT
C   AS OUTPUT. MAKE SURE TO INCLUDE AT
C   THE END OF THE SUBROUTINE, THE
C   STATEMENT: OBJGEN = WEIGHT
C
```

```
C
C   DEFINITIONS OF INPUT DATA:
C    IMODX  = DESIGN CONTROL INTEGER:
C     IMODX = 0 MEANS BASELINE DESIGN
C     IMODX = 1 MEANS PERTURBED DESIGN
C     IFAST = 0 MEANS FEW  SHORTCUTS FOR PERTURBED DESIGNS
C     IFAST = 1 MEANS MORE SHORTCUTS FOR PERTURBED DESIGNS
C    IFILE = FILE FOR OUTPUT LIST:
C    NPRINX= OUTPUT CONTROL INTEGER:
C     NPRINX=0 MEANS SMALLEST AMOUNT
C     NPRINX=1 MEANS MEDIUM AMOUNT
C     NPRINX=2 MEANS LOTS OF OUTPUT
C
C   DEFINITION OF PHRASE:
C     PHRASE = weight/length of the balloon
C
       CHARACTER*80 PHRASE
C  INSERT ADDITIONAL COMMON BLOCKS:
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  INSERT SUBROUTINE STATEMENTS HERE.
C
C FOR CYLINDRICAL BALLOONS:
C Get the weight per axial length of the balloon.
C The quantity, WEIGHT, is computed as follows in
C SUBROUTINE BOSDEC:
C
C     WEIGHT = 4.*(ARCOUT*TOUTER*DENSTY(1) +ARCINR*TINNER*DENSTY(1)
```

```
C    1         +ARCFOT*TFOUTR*DENSTY(2) +ARCFIN*TFINNR*DENSTY(2)
C    1         +ARCWEB*TFWEBS*DENSTY(3))
C
C in which
C    ARCOUT = total arc length of the outer curved membranes
C    ARCINR = total arc length of the inner curved membranes
C    ARCFOT = total arc length of the outer flat membranes
C    ARCFIN = total arc length of the inner flat membranes
C    ARCWEB = total length of the slanted webs.
C
C BEG NOV 2010
      COMMON/TOTMAX/TOTMAS
C
      IF (ISHAPE.EQ.1) THEN
         OBJGEN =WEIGHT
      ELSE
C BEG DEC 2010
         OBJGEN = 2.0*TOTMAS
C END DEC 2010
      ENDIF
C END NOV 2010
C
      RETURN
      END
C
C
C
======================================================================
```

Table 6 This is the file, struct.balloon, which is the "fleshed out" version of the skeletal file, struct.new, that is automatically produced by GENTEXT. In this case the GENOPT user, whose duty it is to do the "fleshing out", added only three statements: CALL OPNGEN, CALL RWDGEN, and CALL CLSGEN. These three lines are shown in bold face.

```
=============================================================================
C=DECK      STRUCT
      SUBROUTINE STRUCT(IMODX,CONSTX,OBJGEN,CONMAX,NCONSX,IPOINC,
     1 PCWORD,CPLOTX,ILOADX,ISTARX,NUSERC,IBEHV,IDV,IFAST,JJJ1)
C
C  PURPOSE IS TO PERFORM THE ANALYSIS FOR A GIVEN DESIGN AND LOADING.
C  CONSTRAINT CONDITIONS ARE ALSO GENERATED.
C
C  Common blocks already present in the struct.tmpl file, that is,
C  in the "skeletal" file possibly to be augmented by the user:
      COMMON/PRMFIL/IFILEX,IFILE2,IOUT,IPRM(5)
      COMMON/PRMOUT/IFILE3,IFILE4,IFILE8,IFILE9,IFIL11
      COMMON/INDAT/INFILE
      COMMON/LWRUPR/VLBX(50),VUBX(50),CLINKX(50,45),VLINKX(50),VBVX(99)
      COMMON/NUMPAR/IPARX,IVARX,IALLOW,ICONSX,NDECX,NLINKX,NESCAP,ITYPEX
      COMMON/PARAMS/PARX(99),VARX(50),ALLOWX(99),CONSXX(99),DECX(50),
     1              ESCX(50)
      COMMON/WORDS1/WORDPX(99),WORDVX(50),WORDAX(99),WORDCC(99),
     1              WORDDX(50)
      COMMON/WORDS2/WORDLX(50),WORDEX(50),WORDIQ(45)
      COMMON/OPTVAR/IDVX(50),ILVX(50),IDLINK(50,45),IEVX(50),JTERMS(45)
      COMMON/NUMPR2/ILARX,ICARX,IOARX,IFLATX,NCASES,NPRINX
      COMMON/PARAM2/FLARX(50),CARX(99),OARX(50),FSAFEX(99),CPWRX(50,45)
      COMMON/PARAM3/CINEQX(45,45),DPWREQ(45,45)
      COMMON/PARAM4/IDINEQ(45,45),NINEQX,JINEQX(45),IEQTYP(45)
      COMMON/WORDS3/WORDFX(50),WORDBX(99),WORDOB(50),WORDSX(99)
      COMMON/WORDS4/WORDMX(99)
      COMMON/PWORD/PHRASE
      COMMON/PWORD2/IBLANK
      COMMON/ISKIPX/ISKIP(30)
      DIMENSION IBEHV(99)
C
C==============================================================================
=
C  Start of first part of STRUCT written by "GENTEXT"
C  INSERT ADDITIONAL COMMON BLOCKS HERE: (THESE ARE "GENTEXT" VARIABLES)
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
```

```
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
      CHARACTER*80 PHRASE,CODPHR,PCWORD
      CHARACTER*80 WORDPX,WORDVX,WORDAX,WORDCX,WORDDX,WORDLX,WORDEX
      CHARACTER*80 WORDFX,WORDBX,WORDOB,WORDSX,WORDMX,WORDCC,WORDIQ
c     CHARACTER*4 ANSOUT,CHARAC,ANSWER
      CHARACTER*2 CIX
      character*2 CJX
      CHARACTER*13 CODNAM
c     DIMENSION ISUBX(100)
c     LOGICAL ANSL1
C
      DIMENSION CONSTX(*),IPOINC(*),PCWORD(*),CPLOTX(*)
C  End of first part of STRUCT written by "GENTEXT"
C=========================================================================
=
C
C  INSERT ADDITIONAL DIMENSION AND/OR LABELLED COMMON BLOCKS HERE,
C  IF NECESSARY. THESE WOULD BE STATEMENTS THAT ARE CONSISTENT WITH
C  SUBROUTINES THAT YOU OR OTHERS MAY HAVE WRITTEN THAT ARE REQUIRED
C  FOR WHATEVER ANALYSIS YOU ARE PERSUING.  MAKE SURE THAT YOU DO NOT
C  INTRODUCE NAME CONFLICTS WITH THE "GENTEXT" LABELLED COMMON BLOCKS
C  LISTED ABOVE.
C
C  Please note that you do not have to modify STRUCT.NEW if you would
C  rather provide all of your algorithms via the BEHAVIOR.NEW library.
C  (See instructions in BEHAVIOR.NEW).
C
C  If you are using a lot of software previously written either by
C  yourself or others, or if there are a lot of behavioral constraints
C  that are best generated by looping over array indices (such as
C  occurs, for example, with stress constraints in laminates of
C  composite materials), then it may be best to insert your common
C  blocks and dimension statements here, your subroutine calls
C  below (where indicated), and your subroutines in any of the libraries
```

```
C  called ADDCODEn.NEW, n = 1,2,...,5.  Please note that you
C  may also have to add statements to SUBROUTINE TRANFR, the
C  purpose of which is described below (in TRANFR).
C
C  The several test cases provided with GENOPT demonstrate different
C  methods:
C
C  PLATE  : leave STRUCT.NEW unchanged and modify BEHAVIOR.NEW
C  SPHERE : leave STRUCT.NEW unchanged and modify BEHAVIOR.NEW
C  TORISPH: leave BEHAVIOR.NEW unchanged except possibly for the objective
C           function (SUBROUTINE OBJECT), modify STRUCT.NEW,
C           possibly add a subroutine library called ADDCODE1.NEW, and
C           possibly augment the usermake.linux file to collect object
C           libraries from other directories. In the "TORISPH" case
C           BEHAVIOR.NEW remains unchanged, no ADDCODE1.NEW library is
C           added, and usermake.linux is not changed.  Instead, the
C           BIGBOSOR4 code is added and SUBROUTINE BOSDEC is written
C           by the genopt user. The BIGBOSOR4 code and SUBROUTINE
C           BOSDEC must be stored in /home/progs/bosdec/sources, as
C           follows:
C    BIGBOSOR4 code:
C     -rw-r--r--  1 bush bush 579671 Feb 29 07:19 addbosor4.src
C     -rw-r--r--  1 bush bush  83175 Feb 22 09:13 b4plot.src
C     -rw-r--r--  1 bush bush  89671 Feb 28 16:20 b4util.src
C     -rw-r--r--  1 bush bush  22723 Feb 10 14:27 bio.c
C     -rw-r--r--  1 bush bush  31175 Feb 10 14:27 bio_linux.c
C     -rw-r--r--  1 bush bush  37152 Feb 10 14:27 bio_linux.o
C     -rw-r--r--  1 bush bush  15650 Feb 10 14:26 gasp.F
C     -rw-r--r--  1 bush bush  18364 Feb 10 14:26 gasp_linux.o
C     -rw-r--r--  1 bush bush   6310 Feb 13 10:12 opngen.src
C     -rw-r--r--  1 bush bush  22440 Feb 10 14:25 prompter.src
C     -rw-r--r--  1 bush bush  13426 Feb 22 09:14 resetup.src
C    BOSDEC.src code:
C     -rw-r--r--  1 bush bush  33851 Mar  1 08:34 bosdec.src
C
C  WAVYCYL: both BEHAVIOR.NEW and STRUCT.NEW are both changed. Otherwise
C           the activity is the same as that described for TORISPH,
C           except, of course, that struct.new is different from
C           that used in connection with TORISPH.
C
C  CYLINDER:same as the description for WAVYCYL.
C
C
C  INSERT YOUR ADDITIONAL COMMON BLOCKS FOR THIS GENERIC CASE HERE:
C
C
C  THE FOLLOWING CODE WAS WRITTEN BY "GENTEXT":
C
C==================================================================
C  Start the second portion of STRUCT written by "GENTEXT":
C
      ICARX   = ISTARX
      INUMTT = 0
      ICONSX = 0
```

```
      KCONX   = 0
      IF (IMODX.EQ.0) THEN
         CALL MOVERX(0.,0,CONSTX,1,99)
         CALL MOVERX(0, 0,IPOINC,1,1500)
      ENDIF
C
      IF (ILOADX.EQ.1) THEN
C
C  ESTABLISH FIRST ANY CONSTRAINTS THAT ARE INEQUALITY RELATIONSHIPS
C  AMONG THE VARIABLES IN THE ARRAY VARX(*) (THAT IS, VARIABLES THAT
C  ARE EITHER DECISION VARIABLES, LINKED VARIABLES, ESCAPE VARIABLES,
C  OR CANDIDATES FOR ANY OF THESE TYPES OF VARIABLES.
C
         IF (NINEQX.GT.0)
     1        CALL VARCON(WORDIQ,WORDMX,CINEQX,DPWREQ,IDINEQ,
     1        NINEQX,JINEQX,IEQTYP,INUMTT,IMODX,CONMAX,IPOINC,
     1        ICONSX,CONSTX,VARX,PCWORD,CPLOTX,ICARX)
C
C  NEXT, ESTABLISH USER-WRITTEN CONSTRAINTS. AT PRESENT, THE PROGRAM
C  ALLOWS ONLY ONE USER-WRITTEN CONSTRAINT. HOWEVER, THE USER CAN
C  EASILY EXPAND THIS CAPABILITY SIMPLY BY ADDING SUBROUTINES THAT
C  ARE ANALOGOUS TO USRCON (WITH NAMES SUCH AS USRCN2, USRCN3, ETC.
C  TO THE  BEHAVIOR.NEW LIBRARY, AND ADD CALLS TO THESE ADDITIONAL
C  SUBROUTINES FOLLOWING THE CALL TO USRCON IMMEDIATELY BELOW.
C
         CALL USRCON(INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1            WORDMX,PCWORD,CPLOTX,ICARX,IFILE8)
C
         NUSERC = ICARX - NINEQX
      ENDIF
C
      IF (NPRINX.GT.0) THEN
         WRITE(IFILE8,'(1X,A,I2,A)')
     1 ' BEHAVIOR FOR ',ILOADX,' ENVIRONMENT (LOAD SET)'
         WRITE(IFILE8,'(A)')'  '
         WRITE(IFILE8,'(A)')
     1 ' CONSTRAINT  BEHAVIOR              DEFINITION'
         WRITE(IFILE8,'(A)')
     1 '   NUMBER     VALUE'
      ENDIF
C
      CALL CONVR2(ILOADX,CIX)
      IF (NPRINX.GT.0) THEN
         WRITE(IFILE8,'(1X,A)')'  '
         WRITE(IFILE8,'(1X,A,I2)')
     1 ' BEHAVIOR FOR LOAD SET NUMBER, ILOADX=',ILOADX
      ENDIF
C
C  End of the second portion of STRUCT written by "GENTEXT"
C=====================================================================
C
C  USER: YOU MAY WANT TO INSERT SUBROUTINE CALLS FROM SOFTWARE DEVELOPED
C        ELSEWHERE FOR ANY CALCULATIONS PERTAINING TO THIS LOAD SET.
C
```

```
      CALL OPNGEN
      CALL RWDGEN
C
C=========================================================================
C  Start of the final portion of STRUCT written by "GENTEXT"
C
C  INSERT THE PROGRAM FILE HERE:
C
C  Behavior and constraints generated next for BUCKB4:
C  BUCKB4 = buckling load factor from BIGBOSOR4
C
      PHRASE =
     1 'buckling load factor from BIGBOSOR4'
      CALL BLANKX(PHRASE,IENDP4)
      JXX = 0
      JXX = JXX + 1
      BUCKB4(ILOADX) = 0.0
      IF (IBEHV(JXX).EQ.0) CALL BEHX1
     1 (IFILE8,NPRINX,IMODX,IFAST,ILOADX  ,
     1 'buckling load factor from BIGBOSOR4')
      IF (BUCKB4(ILOADX  ).EQ.0.)  BUCKB4(ILOADX  ) = 1.E+10
      IF (BUCKB4A(ILOADX  ).EQ.0.)  BUCKB4A(ILOADX  ) = 1.0
      IF (BUCKB4F(ILOADX  ).EQ.0.)  BUCKB4F(ILOADX  ) = 1.0
      KCONX = KCONX + 1
      CARX(KCONX) =BUCKB4(ILOADX  )
      WORDCX= '(BUCKB4('//CIX//')/BUCKB4A('//CIX//
     1  ')) / BUCKB4F('//CIX//')'
      CALL CONX(BUCKB4(ILOADX  ),BUCKB4A(ILOADX  ),BUCKB4F(ILOADX  )
     1,'buckling load factor from BIGBOSOR4',
     1 'allowable for buckling load factor from BIGBOSOR4',
     1 'buckling from BIGBOSOR4 factor of safety',
     1 2,INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1 WORDMX,PCWORD,CPLOTX,ICARX)
      IF (IMODX.EQ.0) THEN
         CODPHR =
     1 '  buckling load factor from BIGBOSOR4: '
         IENDP4 =39
         CODNAM ='BUCKB4('//CIX//')'
         MLET4 =6 + 4
         WORDBX(KCONX)= CODPHR(1:IENDP4)//CODNAM(1:MLET4)
         IF (NPRINX.GT.0) WRITE(IFILE8,'(I5,6X,G14.7,A,A)')
     1    KCONX,CARX(KCONX),CODPHR(1:IENDP4),CODNAM(1:MLET4)
      ENDIF
  190 CONTINUE
  191 CONTINUE
C
C  Behavior and constraints generated next for TENLOS:
C  TENLOS = load factor for tension loss
C
      PHRASE =
     1 'load factor for tension loss'
      CALL BLANKX(PHRASE,IENDP4)
      JXX = JXX + 1
      TENLOS(ILOADX) = 0.0
```

```
      IF (IBEHV(JXX).EQ.0) CALL BEHX2
     1 (IFILE8,NPRINX,IMODX,IFAST,ILOADX  ,
     1 'load factor for tension loss')
      IF (TENLOS(ILOADX  ).EQ.0.)  TENLOS(ILOADX  ) = 1.E+10
      IF (TENLOSA(ILOADX  ).EQ.0.)  TENLOSA(ILOADX  ) = 1.0
      IF (TENLOSF(ILOADX  ).EQ.0.)  TENLOSF(ILOADX  ) = 1.0
      KCONX = KCONX + 1
      CARX(KCONX) =TENLOS(ILOADX  )
      WORDCX= '(TENLOS('//CIX//')/TENLOSA('//CIX//
     1  ')) / TENLOSF('//CIX//')'
      CALL CONX(TENLOS(ILOADX  ),TENLOSA(ILOADX  ),TENLOSF(ILOADX  )
     1,'load factor for tension loss',
     1 'tension loss allowable (Use 1.0)',
     1 'tension loss factor of safety',
     1 2,INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1 WORDMX,PCWORD,CPLOTX,ICARX)
      IF (IMODX.EQ.0) THEN
         CODPHR =
     1 '  load factor for tension loss: '
         IENDP4 =32
         CODNAM ='TENLOS('//CIX//')'
         MLET4 =6 + 4
         WORDBX(KCONX)= CODPHR(1:IENDP4)//CODNAM(1:MLET4)
         IF (NPRINX.GT.0) WRITE(IFILE8,'(I5,6X,G14.7,A,A)')
     1    KCONX,CARX(KCONX),CODPHR(1:IENDP4),CODNAM(1:MLET4)
      ENDIF
  210 CONTINUE
  211 CONTINUE
C
C  Behavior and constraints generated next for STRM1:
C  STRM1 = stress component in material 1
C
      IF (JSTRM1 .EQ.0) GO TO 231
      IF (NPRINX.GT.0) THEN
         IF (JSTRM1 .GT.1) THEN
            WRITE(IFILE8,'(1X,A)')'  '
            WRITE(IFILE8,'(1X,A,$)')' BEHAVIOR OVER J = '
            WRITE(IFILE8,'(1X,A)')
     1      'stress component number'
         ENDIF
      ENDIF
      DO 230  J=1,JSTRM1
      CALL CONVR2(J,CJX)
      PHRASE =
     1 'stress component in material 1'
      CALL BLANKX(PHRASE,IENDP4)
      JXX = JXX + 1
      STRM1(ILOADX,J) = 0.0
      IF (IBEHV(JXX).EQ.0) CALL BEHX3
     1 (IFILE8,NPRINX,IMODX,IFAST,ILOADX,J,
     1 'stress component in material 1')
      IF (STRM1(ILOADX,J).EQ.0.)  STRM1(ILOADX,J) = 1.E-10
      IF (STRM1A(ILOADX,J).EQ.0.)  STRM1A(ILOADX,J) = 1.0
      IF (STRM1F(ILOADX,J).EQ.0.)  STRM1F(ILOADX,J) = 1.0
```

```fortran
      KCONX = KCONX + 1
      CARX(KCONX) =STRM1(ILOADX,J)
      WORDCX= '(STRM1A('//CIX//','//CJX//')/STRM1('//CIX//','//CJX//
     1  ')) / STRM1F('//CIX//','//CJX//')'
      CALL CONX(STRM1(ILOADX,J),STRM1A(ILOADX,J),STRM1F(ILOADX,J)
     1,'stress component in material 1',
     1 'allowable stress in material 1',
     1 'factor of safety for stress in material 1',
     1 3,INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1 WORDMX,PCWORD,CPLOTX,ICARX)
      IF (IMODX.EQ.0) THEN
         CODPHR =
     1 '  stress component in material 1: '
         IENDP4 =34
         CODNAM ='STRM1('//CIX//','//CJX//')'
         MLET4 =5 + 7
         WORDBX(KCONX)= CODPHR(1:IENDP4)//CODNAM(1:MLET4)
         IF (NPRINX.GT.0) WRITE(IFILE8,'(I5,6X,G14.7,A,A)')
     1    KCONX,CARX(KCONX),CODPHR(1:IENDP4),CODNAM(1:MLET4)
      ENDIF
  230 CONTINUE
  231 CONTINUE
C
C  Behavior and constraints generated next for STRM2:
C  STRM2 = stress component in material 2
C
      IF (JSTRM1 .EQ.0) GO TO 246
      IF (NPRINX.GT.0) THEN
         IF (JSTRM1 .GT.1) THEN
            WRITE(IFILE8,'(1X,A)')'  '
            WRITE(IFILE8,'(1X,A,$)')' BEHAVIOR OVER J = '
            WRITE(IFILE8,'(1X,A)')
     1      'stress component number'
         ENDIF
      ENDIF
      DO 245  J=1,JSTRM1
      CALL CONVR2(J,CJX)
      PHRASE =
     1 'stress component in material 2'
      CALL BLANKX(PHRASE,IENDP4)
      JXX = JXX + 1
      STRM2(ILOADX,J) = 0.0
      IF (IBEHV(JXX).EQ.0) CALL BEHX4
     1 (IFILE8,NPRINX,IMODX,IFAST,ILOADX,J,
     1 'stress component in material 2')
      IF (STRM2(ILOADX,J).EQ.0.)  STRM2(ILOADX,J) = 1.E-10
      IF (STRM2A(ILOADX,J).EQ.0.)  STRM2A(ILOADX,J) = 1.0
      IF (STRM2F(ILOADX,J).EQ.0.)  STRM2F(ILOADX,J) = 1.0
      KCONX = KCONX + 1
      CARX(KCONX) =STRM2(ILOADX,J)
      WORDCX= '(STRM2A('//CIX//','//CJX//')/STRM2('//CIX//','//CJX//
     1  ')) / STRM2F('//CIX//','//CJX//')'
      CALL CONX(STRM2(ILOADX,J),STRM2A(ILOADX,J),STRM2F(ILOADX,J)
     1,'stress component in material 2',
```

```
     1 'allowable for stress in material 2',
     1 'factor of safety for stress in material 2',
     1 3,INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1 WORDMX,PCWORD,CPLOTX,ICARX)
      IF (IMODX.EQ.0) THEN
         CODPHR =
     1 '  stress component in material 2: '
         IENDP4 =34
         CODNAM ='STRM2('//CIX//','//CJX//')'
         MLET4 =5 + 7
         WORDBX(KCONX)= CODPHR(1:IENDP4)//CODNAM(1:MLET4)
         IF (NPRINX.GT.0) WRITE(IFILE8,'(I5,6X,G14.7,A,A)')
     1    KCONX,CARX(KCONX),CODPHR(1:IENDP4),CODNAM(1:MLET4)
      ENDIF
  245 CONTINUE
  246 CONTINUE
C
C  Behavior and constraints generated next for STRM3:
C  STRM3 = stress component in material 3
C
      IF (JSTRM1 .EQ.0) GO TO 261
      IF (NPRINX.GT.0) THEN
         IF (JSTRM1 .GT.1) THEN
            WRITE(IFILE8,'(1X,A)')'   '
            WRITE(IFILE8,'(1X,A,$)')' BEHAVIOR OVER J = '
            WRITE(IFILE8,'(1X,A)')
     1      'stress component number'
         ENDIF
      ENDIF
      DO 260  J=1,JSTRM1
      CALL CONVR2(J,CJX)
      PHRASE =
     1 'stress component in material 3'
      CALL BLANKX(PHRASE,IENDP4)
      JXX = JXX + 1
      STRM3(ILOADX,J) = 0.0
      IF (IBEHV(JXX).EQ.0) CALL BEHX5
     1 (IFILE8,NPRINX,IMODX,IFAST,ILOADX,J,
     1 'stress component in material 3')
      IF (STRM3(ILOADX,J).EQ.0.)  STRM3(ILOADX,J) = 1.E-10
      IF (STRM3A(ILOADX,J).EQ.0.)  STRM3A(ILOADX,J) = 1.0
      IF (STRM3F(ILOADX,J).EQ.0.)  STRM3F(ILOADX,J) = 1.0
      KCONX = KCONX + 1
      CARX(KCONX) =STRM3(ILOADX,J)
      WORDCX= '(STRM3A('//CIX//','//CJX//')/STRM3('//CIX//','//CJX//
     1  ')) / STRM3F('//CIX//','//CJX//')'
      CALL CONX(STRM3(ILOADX,J),STRM3A(ILOADX,J),STRM3F(ILOADX,J)
     1,'stress component in material 3',
     1 'allowable for stress in material 3',
     1 'factor of safety for stress in material 3',
     1 3,INUMTT,IMODX,CONMAX,ICONSX,IPOINC,CONSTX,WORDCX,
     1 WORDMX,PCWORD,CPLOTX,ICARX)
      IF (IMODX.EQ.0) THEN
         CODPHR =
```

```
     1 '  stress component in material 3: '
         IENDP4 =34
         CODNAM ='STRM3('//CIX//','//CJX//')'
         MLET4 =5 + 7
         WORDBX(KCONX)= CODPHR(1:IENDP4)//CODNAM(1:MLET4)
         IF (NPRINX.GT.0) WRITE(IFILE8,'(I5,6X,G14.7,A,A)')
     1    KCONX,CARX(KCONX),CODPHR(1:IENDP4),CODNAM(1:MLET4)
      ENDIF
  260 CONTINUE
  261 CONTINUE
C
C  NEXT, EVALUATE THE OBJECTIVE, OBJGEN:
      IF (ILOADX.EQ.1) THEN
         PHRASE ='weight/length of the balloon'
         CALL BLANKX(PHRASE,IENDP4)
         CALL OBJECT(IFILE8,NPRINX,IMODX,OBJGEN,
     1    'weight/length of the balloon')
      ENDIF
      NCONSX = ICONSX
C
      CALL CLSGEN
C
      RETURN
      END
C
C
C
C
C
C  End of the final portion of STRUCT written by "GENTEXT"
C=====================================================================
C
C=DECK      TRANFR
      SUBROUTINE TRANFR(ARG1,ARG2,ARG3,ARG4,ARG5)
C
C  USER:  DO NOT FORGET TO MODIFY THE ARGUMENT LIST OF TRANFR AS
C         APPROPRIATE FOR YOUR CASE!
C
C  PURPOSE IS TO TRANSFER DATA FROM THE LABELLED COMMON BLOCKS
C  SET UP BY THE GENOPT CODE TO LABELLED COMMON OR ARGUMENTS IN
C  THE SUBROUTINE ARGUMENT LIST THAT MATCH PREVIOUSLY WRITTEN CODE
C  BY YOURSELF OR OTHER PROGRAM DEVELOPERS.  THE USER SHOULD ESTABLISH
C  THE ARGUMENT LIST AND/OR LABELLED COMMON BLOCKS THAT MATCH VARIABLES
C  IN THE PREVIOUSLY WRITTEN CODE.  FOR AN EXAMPLE, SEE THE DISCUSSION
C  OF THE CASE CALLED "PANEL".
C
C=======================================================================
=
C  Start of part of TRANFR written by "GENTEXT"
C  INSERT ADDITIONAL COMMON BLOCKS HERE: (THESE ARE "GENTEXT" VARIABLES)
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
```

```
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C
C
C  End of part of TRANFR written by "GENTEXT"
C=========================================================================
C  INSERT ADDITIONAL DIMENSION AND/OR LABELLED COMMON BLOCKS HERE,
C  IF NECESSARY. THESE WOULD BE STATEMENTS THAT ARE CONSISTENT WITH
C  SUBROUTINES THAT YOU OR OTHERS MAY HAVE WRITTEN THAT ARE REQUIRED
C  FOR WHATEVER ANALYSIS YOU ARE NOW PERSUING.  MAKE SURE THERE ARE
C  NO NAME CONFLICTS WITH THE "GENTEXT" LABELLED COMMON BLOCKS.
C
C
C  INSERT APPROPRIATE FORTRAN STATEMENTS HERE (DON'T FORGET TO CORRECT
C  THE ARGUMENT LIST OF SUBROUTINE TRANFR!)
C  PROGRAM FILE:
C
C
      RETURN
      END
C
==========================================================================
```

Table 7 The file, bosdec.balloon, which is created entirely by the GENOPT user. One of the purposes of SUBROUTINE BOSDEC is to create a valid input file for BIGBOSOR4 with the use of data from the generic case, "balloon", for the current design and for perturbed designs. Because of SUBROUTINE BOSDEC, BIGBOSOR4 can be used in the optimization loop. Note: The bosdec.src file listed here is somewhat different from the out-of-date version listed in Table 7 of [1].

```
============================================================================
C=DECK      BOSDEC
C
C  PURPOSE IS TO SET UP BIGBOSOR4 INPUT FILE FOR "balloon"
C
      SUBROUTINE BOSDEC(INDX,IFIL14,ILOADX,INDIC)
C
C  Insert labelled common blocks: balloon.COM
      COMMON/FV03/EMOD1(10),IEMOD1
      REAL EMOD1
      COMMON/FV04/EMOD2(10),G12(10),G13(10),G23(10),NU(10),ALPHA1(10)
      REAL EMOD2,G12,G13,G23,NU,ALPHA1
      COMMON/FV01/LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      REAL LENGTH,RADIUS,HEIGHT,RINNER,ROUTER,TINNER,TOUTER
      COMMON/FV10/ALPHA2(10),TEMPER(10),DENSTY(10)
      REAL ALPHA2,TEMPER,DENSTY
      COMMON/FV21/PINNER(20)
      REAL PINNER
      COMMON/FV26/BUCKB4(20),BUCKB4A(20),BUCKB4F(20)
      REAL BUCKB4,BUCKB4A,BUCKB4F
      COMMON/FV29/TENLOS(20),TENLOSA(20),TENLOSF(20)
      REAL TENLOS,TENLOSA,TENLOSF
      COMMON/FV32/STRM1(20,5 ),JSTRM1 ,STRM1A(20,5 ),STRM1F(20,5 )
      REAL STRM1,STRM1A,STRM1F
      COMMON/FV35/STRM2(20,5 ),STRM2A(20,5 ),STRM2F(20,5 )
      REAL STRM2,STRM2A,STRM2F
      COMMON/FV38/STRM3(20,5 ),STRM3A(20,5 ),STRM3F(20,5 )
      REAL STRM3,STRM3A,STRM3F
      COMMON/IV01/NMODUL,ISHAPE,IWEBS
      INTEGER NMODUL,ISHAPE,IWEBS
      COMMON/FV18/TFINNR,TFOUTR,TFWEBS,WEIGHT
      REAL TFINNR,TFOUTR,TFWEBS,WEIGHT
      COMMON/FV22/PMIDDL(20),POUTER(20)
      REAL PMIDDL,POUTER
C  end of trusscomp.COM
C BEG NOV 2010
      COMMON/ITRYX/ITRY,NSTEPS,KSEGS
C END NOV 2010
      COMMON/FLNFLO/FLINNR,FLOUTR
      COMMON/N2DIFX/N2DIFF(6)
```

```
      REAL N2DIFF
      COMMON/FINNER/C44FIN,DELTAT,DELT,NODSEG,MSEGS
      COMMON/MODULX/MODULL,MODULG
      COMMON/NUMPAR/IPARX,IVARX,IALLOW,ICONSX,NDECX,NLINKX,NESCAP,ITYPEX
      COMMON/NUMSEG/NSEGS
      common/caseblock/CASE
      CHARACTER*28 CASE
      CHARACTER*35 CASA2,CASA3
      CHARACTER*10 CN
      COMMON/RBEGX/RBIG0,RBIGL,RBIGG
C BEG DEC 2010
C BEG JAN 2011
      DIMENSION RA(55),RB(55),ZA(55),ZB(55)
      DIMENSION RCL(55),RDL(55),ZCL(55),ZDL(55)
      DIMENSION R1(9,55),R2(9,55),Z1(9,55),Z2(9,55)
      DIMENSION RC(9,55),ZC(9,55),SROT(9,55),PFIXED(9,55),PEIGEN(9,55)
      DIMENSION MATTYP(9,55),THICK(9,55),MATLJ(295),THICKJ(295)
      DIMENSION LAYTYP(9,55),LTYPEJ(295)
      DIMENSION R1J(295),Z1J(295),R2J(295),Z2J(295),RCJ(295),ZCJ(295)
      DIMENSION NODJ(295),NSHPJ(295),SROTJ(295),PFIXJ(295),PEIGJ(295)
      DIMENSION NSHAPE(9,55),NGRND(9,55),NODGRD(9,55),NPREV(9,55)
      DIMENSION JPREV1(9,55),NDCUR1(9,55),NDPRV1(9,55)
      DIMENSION JPREV2(9,55),NDCUR2(9,55),NDPRV2(9,55)
C END JAN 2011
C END DEC 2010
      DIMENSION NGRNDJ(295),NODGRJ(295),NPREVJ(295)
      DIMENSION JPREVJ(295,2),NDCURJ(295,2),NDPRVJ(295,2)
      COMMON/PRMOUT/IFILE3,IFILE4,IFILE8,IFILE9,IFIL11
      REWIND IFIL14
C
      WRITE(IFILE4,3)
    3 FORMAT(//'  ****************  BOSDEC  *******************'/
     1'  The purpose of BOSDEC is to set up an input file, NAME.ALL,'/
     1'  for a cylindrical shell. NAME is your name for'/
     1'  the case. The file NAME.ALL is a BOSOR4 input "deck" used'/
     1'  by SUBROUTINE B4READ.'/
     1'  **********************************************'/)
C
      NSEGS = 6
      PI = 3.1415927
      IF (INDX.EQ.0) THEN
         NMODUL = NMODUL
         RBEG = RBIGG
      ENDIF
      IF (INDX.EQ.1) THEN
         NMODUL = NMODUL
         RBEG = RBIGG
      ENDIF
      IF (INDX.EQ.2) THEN
         NMODUL = NMODUL
         RBEG = RBIGG
      ENDIF
      RSTART = RBEG
C
```

```
C BEG DEC 2010
C BEG JAN 2011
      CALL MOVER(0.,0,R1,1,495)
      CALL MOVER(0.,0,Z1,1,495)
      CALL MOVER(0.,0,R2,1,495)
      CALL MOVER(0.,0,Z2,1,495)
      CALL MOVER(0.,0,RC,1,495)
      CALL MOVER(0.,0,ZC,1,495)
      CALL MOVER(0.,0,PFIXED,1,495)
      CALL MOVER(0.,0,PEIGEN,1,495)
      CALL MOVER(0,0,NGRND,1,495)
      CALL MOVER(0,0,NODGRD,1,495)
      CALL MOVER(0,0,NPREV,1,495)
      CALL MOVER(0,0,JPREV1,1,495)
      CALL MOVER(0,0,NDCUR1,1,495)
      CALL MOVER(0,0,NDPRV1,1,495)
      CALL MOVER(0,0,JPREV2,1,495)
      CALL MOVER(0,0,NDCUR2,1,495)
      CALL MOVER(0,0,NDPRV2,1,495)
C END JAN 2011
C END DEC 2010
C
      IF (IMODX.EQ.0) MODULL = NMODUL
      MODULS = MODULL
C
C   INDX   = 0 means SUBROUTINE BOSDEC solves the pre-buckling state
C               for the "fixed" loads only and for multiple load steps.
C   INDX   = 1 means SUBROUTINE BOSDEC generates BIGBOSOR4 buckling model
C   INDX   = 2 means SUBROUTINE BOSDEC computes maximum stresses.
C
C   IMODUL = the module number in a multi-module model
C   MODULS = number of modules in the model
C   RBEG   = horizontal radius to the beginning of the first module
C            in the multi-module model, where
C BEG NOV 2010
C   ISHAPE = 1 means cylindrical vacuum chamber
C   ISHAPE = 2 means spherical vacuum chamber
C END NOV 2010
C   RADIUS  = radius of the vacuum chamber measured to
C             the inner membrane with thickness, TFINNR,
C             where this membrane intersects neighboring segments.
C
C   NSHAPE = BIGBOSOR4 index for shape of shell segment:
C            NSHAPE = 1 means cone, cylinder, flat plate
C            NSHAPE = 2 means toroidal, spherical
C   SROT   = BIGBOSOR4 index for direction of travel along
C            a spherical or toroidal shell segment:
C            SROT = 1 means clockwise travel
C            SROT =-1 means anticlockwise travel
C
C   R1(i),R2(i),Z1(i),Z2(i),RC(i),ZC(i) =
C                 (r,z) end points and center of curvature (rc,zc)
C                 for the ith shell segment
C
```

```
C23456789012345678901234567890123456789012345678901234567890123456789012
C
      DANGLE = 0.5*PI/FLOAT(2*MODULS)
      FLOUTR = 2.*(RADIUS + HEIGHT)*SIN(DANGLE)
      FLINNR = 2.*RADIUS*SIN(DANGLE)
      PHIOUT = ASIN(0.5*FLOUTR/ROUTER)
      PHIINR = ASIN(0.5*FLINNR/RINNER)
      DSMALO = (RADIUS+HEIGHT)*(1.-COS(DANGLE))
      DSMALI = RADIUS*(1.-COS(DANGLE))
      RCOUTR = RADIUS+HEIGHT -DSMALO - ROUTER*COS(PHIOUT)
      RCINNR = RADIUS -DSMALI + RINNER*COS(PHIINR)
C
      IF (IMODX.EQ.0) THEN
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' DANGLE=',DANGLE
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' FLOUTR=',FLOUTR
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' FLINNR=',FLINNR
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' PHIOUT=',PHIOUT
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' PHIINR=',PHIINR
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' DSMALO=',DSMALO
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' DSMALI=',DSMALI
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' RCOUTR=',RCOUTR
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' RCINNR=',RCINNR
        WRITE(IFILE4,'(A,1P,E12.4)')
     1 ' RSTART=',RSTART
      ENDIF
C     CALL EXIT
C
      NODSEG = 31
C BEG DEC 2010
C     IF (ITYPEX.EQ.1.AND.MODULS.GT.35) NODSEG = 21
C BEG JAN 2010
      IF (IWEBS.EQ.2.AND.MODULS.GE.45) NODSEG = 27
      IF (IWEBS.EQ.1.AND.MODULS.GE.55) NODSEG = 27
C END JAN 2010
C END DEC 2010
C
      DO 100 IMODUL = 1,MODULS
C
         FMODUL = IMODUL
         ANGLE = DANGLE*(2.*FMODUL -1.0)
         ANGLEM = ANGLE - DANGLE
         ANGLEP = ANGLE + DANGLE
         RA(IMODUL) = RSTART + (RADIUS+HEIGHT)*SIN(ANGLE)
         ZA(IMODUL) = (RADIUS + HEIGHT)*COS(ANGLE)
C BEG NOV 2010
```

```
         RCL(IMODUL)= RSTART + RCOUTR*SIN(ANGLEM)
         ZCL(IMODUL)= RCOUTR*COS(ANGLEM)
         IF (KSEGS.EQ.5) THEN
            RB(IMODUL) = RSTART + RADIUS*SIN(ANGLE)
            ZB(IMODUL) = RADIUS*COS(ANGLE)
            RDL(IMODUL)= RSTART + RCINNR*SIN(ANGLEM)
            ZDL(IMODUL)= RCINNR*COS(ANGLEM)
         ENDIF
         IF (KSEGS.EQ.6) THEN
            RB(IMODUL) = RSTART + RADIUS*SIN(ANGLEP)
            ZB(IMODUL) = RADIUS*COS(ANGLEP)
            RDL(IMODUL)= RSTART + RCINNR*SIN(ANGLE)
            ZDL(IMODUL)= RCINNR*COS(ANGLE)
         ENDIF
C END NOV 2010
C
         IF (IMODX.EQ.0) THEN
           WRITE(IFILE4,'(A,I5)')
     1    ' IMODUL=',IMODUL
           WRITE(IFILE4,'(A,1P,E12.4)')
     1    ' ANGLE =',ANGLE
           WRITE(IFILE4,'(A,1P,E12.4)')
     1    ' ANGLEM=',ANGLEM
           WRITE(IFILE4,'(A,1P,E12.4)')
     1    ' ANGLEP=',ANGLEP
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' RA(',IMODUL,') =',RA(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' ZA(',IMODUL,') =',ZA(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' RB(',IMODUL,') =',RB(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' ZB(',IMODUL,') =',ZB(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' RCL(',IMODUL,')=',RCL(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' ZCL(',IMODUL,')=',ZCL(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' RDL(',IMODUL,')=',RDL(IMODUL)
           WRITE(IFILE4,'(A,I2,A,1P,E12.4)')
     1    ' ZDL(',IMODUL,')=',ZDL(IMODUL)
         ENDIF
  100 CONTINUE
C
C        CALL EXIT
C
      DO 110 IMODUL = 1,MODULS
C
C  Segment 1 in module, IMODUL
         IMODUL1 = IMODUL - 1
         NSHAPE(1,IMODUL) = 1
         IF (IMODUL.GT.1) THEN
           NGRND(1,IMODUL) = 0
           NPREV(1,IMODUL) = 1
```

```
C BEG NOV 2010
           IF (KSEGS.EQ.5) JPREV1(1,IMODUL) = -5
           IF (KSEGS.EQ.6) JPREV1(1,IMODUL) = -6
C END NOV 2010
           NDCUR1(1,IMODUL) = 1
           NDPRV1(1,IMODUL) = NODSEG
           R1(1,IMODUL) = RA(IMODUL1)
           Z1(1,IMODUL) = ZA(IMODUL1)
         ELSE
           NGRND(1,IMODUL) = 1
           NODGRD(1,IMODUL) = 1
           NPREV(1,IMODUL) = 0
           R1(1,IMODUL) = RSTART
           Z1(1,IMODUL) = RADIUS + HEIGHT - DSMALO
         ENDIF
         R2(1,IMODUL) = RA(IMODUL)
         Z2(1,IMODUL) = ZA(IMODUL)
         MATTYP(1,IMODUL) = 2
         THICK(1,IMODUL) = TFOUTR
         LAYTYP(1,IMODUL) = 1
C
C  Segment 2 in module, IMODUL
         NSHAPE(2,IMODUL) = 2
         SROT(2,IMODUL) = 1.
         IF (IMODUL.GT.1) THEN
           NGRND(2,IMODUL) = 0
           NPREV(2,IMODUL) = 2
C BEG NOV 2010
           IF (KSEGS.EQ.5) JPREV1(2,IMODUL) = -6
           IF (KSEGS.EQ.6) JPREV1(2,IMODUL) = -7
C END NOV 2010
           NDCUR1(2,IMODUL) = 1
           NDPRV1(2,IMODUL) = NODSEG
           JPREV2(2,IMODUL) = -1
           NDCUR2(2,IMODUL) = NODSEG
           NDPRV2(2,IMODUL) = NODSEG
           R1(2,IMODUL) = RA(IMODUL1)
           Z1(2,IMODUL) = ZA(IMODUL1)
         ELSE
           NGRND(2,IMODUL) = 1
           NODGRD(2,IMODUL) = 1
           NPREV(2,IMODUL) = 1
           JPREV1(2,IMODUL) = -1
           NDCUR1(2,IMODUL) = NODSEG
           NDPRV1(2,IMODUL) = NODSEG
           R1(2,IMODUL) = RSTART
           Z1(2,IMODUL) = RCOUTR + ROUTER
         ENDIF
         R2(2,IMODUL) = RA(IMODUL)
         Z2(2,IMODUL) = ZA(IMODUL)
         RC(2,IMODUL) = RCL(IMODUL)
         ZC(2,IMODUL) = ZCL(IMODUL)
         MATTYP(2,IMODUL) = 1
         THICK(2,IMODUL) = TOUTER
```

```
          LAYTYP(2,IMODUL) = 2
          PFIXED(2,IMODUL) = -PMIDDL(ILOADX)
          PEIGEN(2,IMODUL) =  POUTER(ILOADX)
C
C  Segment 3 in module, IMODUL
          NSHAPE(3,IMODUL) = 1
          IF (IMODUL.GT.1) THEN
            NGRND(3,IMODUL) = 0
C BEG NOV 2010
            IF (KSEGS.EQ.6) THEN
              IF (IMODUL.EQ.MODULS) THEN
                 NGRND(3,IMODUL) = 1
                 NODGRD(3,IMODUL) = NODSEG
              ENDIF
            ENDIF
C END NOV 2010
            NPREV(3,IMODUL) = 1
C BEG NOV 2010
            IF (KSEGS.EQ.5) JPREV1(3,IMODUL) = -5
            IF (KSEGS.EQ.6) JPREV1(3,IMODUL) = -6
C END NOV 2010
            NDCUR1(3,IMODUL) = 1
            NDPRV1(3,IMODUL) = NODSEG
            R1(3,IMODUL) = RB(IMODUL1)
            Z1(3,IMODUL) = ZB(IMODUL1)
          ELSE
            NGRND(3,IMODUL) = 1
            NODGRD(3,IMODUL) = 1
            NPREV(3,IMODUL) = 0
            R1(3,IMODUL) = RSTART
C BEG NOV 2010
            IF (KSEGS.EQ.5) Z1(3,IMODUL) = RADIUS - DSMALI
            IF (KSEGS.EQ.6) Z1(3,IMODUL) = RADIUS
C END NOV 2010
          ENDIF
          R2(3,IMODUL) = RB(IMODUL)
          Z2(3,IMODUL) = ZB(IMODUL)
          MATTYP(3,IMODUL) = 2
          THICK(3,IMODUL) = TFINNR
          LAYTYP(3,IMODUL) = 3
C
C  Segment 4 in module, IMODUL
          NSHAPE(4,IMODUL) = 2
          SROT(4,IMODUL) = -1.
C BEG NOV 2010
          IF (KSEGS.EQ.6) THEN
            NGRND(4,IMODUL) = 0
            NPREV(4,IMODUL) = 2
            IF (IMODUL.EQ.1) JPREV1(4,IMODUL) = -1
            IF (IMODUL.GT.1) JPREV1(4,IMODUL) = -7
            NDCUR1(4,IMODUL) = 1
            IF (IMODUL.EQ.1) NDPRV1(4,IMODUL) = 1
            IF (IMODUL.GT.1) NDPRV1(4,IMODUL) = NODSEG
            JPREV2(4,IMODUL) = -1
```

```
          NDCUR2(4,IMODUL) = NODSEG
          NDPRV2(4,IMODUL) = NODSEG
        ENDIF
C END NOV 2010
        IF (IMODUL.GT.1) THEN
C BEG NOV 2010
          IF (KSEGS.EQ.5) THEN
            NGRND(4,IMODUL) = 0
            NPREV(4,IMODUL) = 2
            JPREV1(4,IMODUL) = -6
            NDCUR1(4,IMODUL) = 1
            NDPRV1(4,IMODUL) = NODSEG
            JPREV2(4,IMODUL) = -1
            NDCUR2(4,IMODUL) = NODSEG
            NDPRV2(4,IMODUL) = NODSEG
          ENDIF
C END NOV 2010
          R1(4,IMODUL) = RB(IMODUL1)
          Z1(4,IMODUL) = ZB(IMODUL1)
        ELSE
C BEG NOV 2010
          IF (KSEGS.EQ.5) THEN
            NGRND(4,IMODUL) = 1
            NODGRD(4,IMODUL) = 1
            NPREV(4,IMODUL) = 1
            JPREV1(4,IMODUL) = -1
            NDCUR1(4,IMODUL) = NODSEG
            NDPRV1(4,IMODUL) = NODSEG
          ENDIF
C END NOV 2010
          R1(4,IMODUL) = RSTART
C BEG NOV 2010
          IF (KSEGS.EQ.5) Z1(4,IMODUL) = RCINNR - RINNER
          IF (KSEGS.EQ.6) Z1(4,IMODUL) = RADIUS
C END NOV 2010
        ENDIF
        R2(4,IMODUL) = RB(IMODUL)
        Z2(4,IMODUL) = ZB(IMODUL)
        MATTYP(4,IMODUL) = 1
        THICK(4,IMODUL) = TINNER
        LAYTYP(4,IMODUL) = 4
        RC(4,IMODUL) = RDL(IMODUL)
        ZC(4,IMODUL) = ZDL(IMODUL)
        PFIXED(4,IMODUL) = PMIDDL(ILOADX) - PINNER(ILOADX)
        PEIGEN(4,IMODUL) =  0.
C
C  Segment 5 in module, IMODUL
        NGRND(5,IMODUL) = 0
        NPREV(5,IMODUL) = 2
C BEG NOV 2010
        IF (KSEGS.EQ.6) THEN
          IF (IMODUL.EQ.1) JPREV1(5,IMODUL) = -2
          IF (IMODUL.GT.1) JPREV1(5,IMODUL) = -8
        ENDIF
```

```
          IF (KSEGS.EQ.5) JPREV1(5,IMODUL) = -2
C END NOV 2010
          NDCUR1(5,IMODUL) = 1
C BEG NOV 2010
          IF (KSEGS.EQ.6) THEN
            IF (IMODUL.EQ.1) NDPRV1(5,IMODUL) = 1
            IF (IMODUL.GT.1) NDPRV1(5,IMODUL) = NODSEG
          ENDIF
          IF (KSEGS.EQ.5) NDPRV1(5,IMODUL) = NODSEG
C END NOV 2010
          JPREV2(5,IMODUL) = -4
          NDCUR2(5,IMODUL) = NODSEG
          NDPRV2(5,IMODUL) = NODSEG
          NSHAPE(5,IMODUL) = 1
C BEG NOV 2010
          IF (KSEGS.EQ.6) THEN
            IF (IMODUL.GT.1) THEN
              R1(5,IMODUL) = RB(IMODUL1)
              Z1(5,IMODUL) = ZB(IMODUL1)
            ELSE
              R1(5,IMODUL) = RSTART
              Z1(5,IMODUL) = RADIUS
            ENDIF
          ENDIF
          IF (KSEGS.EQ.5) THEN
            R1(5,IMODUL) = RB(IMODUL)
            Z1(5,IMODUL) = ZB(IMODUL)
          ENDIF
C END NOV 2010
          R2(5,IMODUL) = RA(IMODUL)
          Z2(5,IMODUL) = ZA(IMODUL)
          MATTYP(5,IMODUL) = 3
          THICK(5,IMODUL) = TFWEBS
          LAYTYP(5,IMODUL) = 5
C BEG NOV 2010
          IF (KSEGS.EQ.6) THEN
C  Segment 6 in module, IMODUL
            NGRND(6,IMODUL) = 0
            NPREV(6,IMODUL) = 2
            JPREV1(6,IMODUL) = -3
            NDCUR1(6,IMODUL) = 1
            NDPRV1(6,IMODUL) = NODSEG
            JPREV2(6,IMODUL) = -5
            NDCUR2(6,IMODUL) = NODSEG
            NDPRV2(6,IMODUL) = NODSEG
            NSHAPE(6,IMODUL) = 1
            R1(6,IMODUL) = RB(IMODUL)
            Z1(6,IMODUL) = ZB(IMODUL)
            R2(6,IMODUL) = RA(IMODUL)
            Z2(6,IMODUL) = ZA(IMODUL)
            MATTYP(6,IMODUL) = 3
            THICK(6,IMODUL) = TFWEBS
            LAYTYP(6,IMODUL) = 5
C
```

```
C Additional two shell segments at the end of the model...
         ENDIF
C END NOV 2010
C
C Additional four shell segments at the end of the model...
         IF (IMODUL.EQ.MODULS) THEN
C BEG NOV 2010
           IF (KSEGS.EQ.5) THEN
             NGRND(6,IMODUL) = 1
             NODGRD(6,IMODUL) = NODSEG
             NPREV(6,IMODUL) = 1
             JPREV1(6,IMODUL) = -5
             NDCUR1(6,IMODUL) = 1
             NDPRV1(6,IMODUL) = NODSEG
             NSHAPE(6,IMODUL) = 1
             R1(6,IMODUL) = RA(IMODUL)
             Z1(6,IMODUL) = ZA(IMODUL)
             R2(6,IMODUL) = RSTART + RADIUS + HEIGHT -DSMALO
             Z2(6,IMODUL) = 0.
             MATTYP(6,IMODUL) = 2
             THICK(6,IMODUL) = TFOUTR
             LAYTYP(6,IMODUL) = 1
           ENDIF
C END NOV 2010
C
           NGRND(7,IMODUL) = 1
           NODGRD(7,IMODUL) = NODSEG
           NPREV(7,IMODUL) = 1
           JPREV1(7,IMODUL) = -6
           NDCUR1(7,IMODUL) = 1
           NDPRV1(7,IMODUL) = NODSEG
C BEG NOV 2010
           IF (KSEGS.EQ.5) THEN
             NSHAPE(7,IMODUL) = 2
             SROT(7,IMODUL) = 1.
           ENDIF
           IF (KSEGS.EQ.6) NSHAPE(7,IMODUL) = 1
C END NOV 2010
           R1(7,IMODUL) = RA(IMODUL)
           Z1(7,IMODUL) = ZA(IMODUL)
C BEG NOV 2010
           IF (KSEGS.EQ.5) R2(7,IMODUL) = RSTART + RCOUTR + ROUTER
           IF (KSEGS.EQ.6)
     1             R2(7,IMODUL) = RSTART + RADIUS + HEIGHT -DSMALO
C END NOV 2010
           Z2(7,IMODUL) = 0.
C BEG NOV 2010
           IF (KSEGS.EQ.6) THEN
             MATTYP(7,IMODUL) = 2
             THICK(7,IMODUL) = TFOUTR
             LAYTYP(7,IMODUL) = 1
           ENDIF
           IF (KSEGS.EQ.5) THEN
             RC(7,IMODUL) = RSTART + RCOUTR
```

```
              ZC(7,IMODUL) = 0.
              MATTYP(7,IMODUL) = 1
              THICK(7,IMODUL) = TOUTER
              LAYTYP(7,IMODUL) = 2
              PFIXED(7,IMODUL) = -PMIDDL(ILOADX)
              PEIGEN(7,IMODUL) =  POUTER(ILOADX)
            ENDIF
C END NOV 2010
C
            NGRND(8,IMODUL) = 1
            NODGRD(8,IMODUL) = NODSEG
            NPREV(8,IMODUL) = 1
C BEG NOV 2010
            IF (KSEGS.EQ.5) JPREV1(8,IMODUL) = -5
            IF (KSEGS.EQ.6) JPREV1(8,IMODUL) = -7
C END NOV 2010
            NDCUR1(8,IMODUL) = 1
            NDPRV1(8,IMODUL) = NODSEG
C BEG NOV 2010
            IF (KSEGS.EQ.6) THEN
              NSHAPE(8,IMODUL) = 2
              SROT(8,IMODUL) = 1.
              R1(8,IMODUL) = RA(IMODUL)
              Z1(8,IMODUL) = ZA(IMODUL)
              R2(8,IMODUL) = RSTART + RCOUTR + ROUTER
            ENDIF
            IF (KSEGS.EQ.5) THEN
              NSHAPE(8,IMODUL) = 1
              R1(8,IMODUL) = RB(IMODUL)
              Z1(8,IMODUL) = ZB(IMODUL)
              R2(8,IMODUL) = RSTART + RADIUS - DSMALI
            ENDIF
C END NOV 2010
            Z2(8,IMODUL) = 0.
C BEG NOV 2010
            IF (KSEGS.EQ.6) THEN
              RC(8,IMODUL) = RSTART + RCOUTR
              ZC(8,IMODUL) = 0.
              MATTYP(8,IMODUL) = 1
              THICK(8,IMODUL) = TOUTER
              LAYTYP(8,IMODUL) = 2
              PFIXED(8,IMODUL) = -PMIDDL(ILOADX)
              PEIGEN(8,IMODUL) =  POUTER(ILOADX)
            ENDIF
            IF (KSEGS.EQ.5) THEN
              MATTYP(8,IMODUL) = 2
              THICK(8,IMODUL) = TFINNR
              LAYTYP(8,IMODUL) = 3
C
              NGRND(9,IMODUL) = 1
              NODGRD(9,IMODUL) = NODSEG
              NPREV(9,IMODUL) = 1
              JPREV1(9,IMODUL) = -6
              NDCUR1(9,IMODUL) = 1
```

```
            NDPRV1(9,IMODUL) = NODSEG
            NSHAPE(9,IMODUL) = 2
            SROT(9,IMODUL) = -1.
            R1(9,IMODUL) = RB(IMODUL)
            Z1(9,IMODUL) = ZB(IMODUL)
            R2(9,IMODUL) = RSTART + RCINNR - RINNER
            Z2(9,IMODUL) = 0.
            RC(9,IMODUL) = RSTART + RCINNR
            ZC(9,IMODUL) = 0.
            MATTYP(9,IMODUL) = 1
            THICK(9,IMODUL) = TINNER
            LAYTYP(9,IMODUL) = 4
            PFIXED(9,IMODUL) = PMIDDL(ILOADX)
            PEIGEN(9,IMODUL) = 0.
          ENDIF
C END NOV 2010
C
        ENDIF
  110 CONTINUE
C
      DO 115 J = 1,MODULS
C BEG NOV 2010
      IF (KSEGS.EQ.6) KSEGUP = 8
      IF (KSEGS.EQ.5) KSEGUP = 9
      DO 114 I = 1,KSEGUP
C END NOV 2010
        WRITE(IFILE4,'(A,2I3,1P6E12.4)')
     1 ' J,I,R1(I,J),Z1(I,J),R2(I,J),Z2(I,J),RC(I,J),ZC(I,J)=',
     1   J,I,R1(I,J),Z1(I,J),R2(I,J),Z2(I,J),RC(I,J),ZC(I,J)
  114 CONTINUE
  115 CONTINUE
C     CALL EXIT
C
      ISEGT = 0
      DO 150 IMODUL = 1,MODULS
C BEG NOV 2010
        DO 120 ISEG = 1,KSEGS
C END NOV 2010
           ISEGT = ISEGT + 1
           NGRNDJ(ISEGT) = NGRND(ISEG,IMODUL)
           NODGRJ(ISEGT) = NODGRD(ISEG,IMODUL)
           NPREVJ(ISEGT) = NPREV(ISEG,IMODUL)
           JPREVJ(ISEGT,1) = JPREV1(ISEG,IMODUL)
           NDCURJ(ISEGT,1) = NDCUR1(ISEG,IMODUL)
           NDPRVJ(ISEGT,1) = NDPRV1(ISEG,IMODUL)
           JPREVJ(ISEGT,2) = JPREV2(ISEG,IMODUL)
           NDCURJ(ISEGT,2) = NDCUR2(ISEG,IMODUL)
           NDPRVJ(ISEGT,2) = NDPRV2(ISEG,IMODUL)
           NSHPJ(ISEGT) = NSHAPE(ISEG,IMODUL)
           NODJ(ISEGT) = NODSEG
           R1J(ISEGT) = R1(ISEG,IMODUL)
           Z1J(ISEGT) = Z1(ISEG,IMODUL)
           R2J(ISEGT) = R2(ISEG,IMODUL)
           Z2J(ISEGT) = Z2(ISEG,IMODUL)
```

```
            MATLJ(ISEGT) = MATTYP(ISEG,IMODUL)
            THICKJ(ISEGT) = THICK(ISEG,IMODUL)
            LTYPEJ(ISEGT) = LAYTYP(ISEG,IMODUL)
            IF (NSHAPE(ISEG,IMODUL).EQ.2) THEN
               RCJ(ISEGT) = RC(ISEG,IMODUL)
               ZCJ(ISEGT) = ZC(ISEG,IMODUL)
               SROTJ(ISEGT) = SROT(ISEG,IMODUL)
               PFIXJ(ISEGT) = PFIXED(ISEG,IMODUL)
               PEIGJ(ISEGT) = PEIGEN(ISEG,IMODUL)
            ENDIF
  120    CONTINUE
         IF (IMODUL.EQ.MODULS) THEN
C BEG NOV 2010
          KSEGBG = KSEGS + 1
          IF (KSEGS.EQ.6) KSEGUP = KSEGS + 2
          IF (KSEGS.EQ.5) KSEGUP = KSEGS + 4
          DO 130 ISEG = KSEGBG,KSEGUP
C END NOV 2010
            ISEGT = ISEGT + 1
            NGRNDJ(ISEGT) = NGRND(ISEG,IMODUL)
            NODGRJ(ISEGT) = NODGRD(ISEG,IMODUL)
            NPREVJ(ISEGT) = NPREV(ISEG,IMODUL)
            JPREVJ(ISEGT,1) = JPREV1(ISEG,IMODUL)
            NDCURJ(ISEGT,1) = NDCUR1(ISEG,IMODUL)
            NDPRVJ(ISEGT,1) = NDPRV1(ISEG,IMODUL)
            JPREVJ(ISEGT,2) = JPREV2(ISEG,IMODUL)
            NDCURJ(ISEGT,2) = NDCUR2(ISEG,IMODUL)
            NDPRVJ(ISEGT,2) = NDPRV2(ISEG,IMODUL)
            NSHPJ(ISEGT) = NSHAPE(ISEG,IMODUL)
            NODJ(ISEGT) = NODSEG
            R1J(ISEGT) = R1(ISEG,IMODUL)
            Z1J(ISEGT) = Z1(ISEG,IMODUL)
            R2J(ISEGT) = R2(ISEG,IMODUL)
            Z2J(ISEGT) = Z2(ISEG,IMODUL)
            MATLJ(ISEGT) = MATTYP(ISEG,IMODUL)
            THICKJ(ISEGT) = THICK(ISEG,IMODUL)
            LTYPEJ(ISEGT) = LAYTYP(ISEG,IMODUL)
            IF (NSHAPE(ISEG,IMODUL).EQ.2) THEN
               RCJ(ISEGT) = RC(ISEG,IMODUL)
               ZCJ(ISEGT) = ZC(ISEG,IMODUL)
               SROTJ(ISEGT) = SROT(ISEG,IMODUL)
               PFIXJ(ISEGT) = PFIXED(ISEG,IMODUL)
               PEIGJ(ISEGT) = PEIGEN(ISEG,IMODUL)
            ENDIF
  130     CONTINUE
         ENDIF
  150 CONTINUE
C
C Get correct temperature to generate membrane tension in the
C axial direction;
C
C
      FMODS = MODULS
      ARCOUT = 2.*PHIOUT*ROUTER*FMODS
```

```
      ARCINR = 2.*PHIINR*RINNER*FMODS
      SLANT = SQRT((R2J(5)-R1J(5))**2 +(Z2J(5)-Z1J(5))**2)
      ARCFOT = FLOUTR*FMODS
      ARCFIN = FLINNR*FMODS
C BEG NOV 2010
      IF (KSEGS.EQ.5) ARCWEB = SLANT*FMODS
      IF (KSEGS.EQ.6) ARCWEB = 2.*SLANT*FMODS
C END NOV 2010
      ENDFCE = PMIDDL(ILOADX)*PI*((RADIUS+HEIGHT)**2 -RADIUS**2)/4.
      FNU21O = EMOD1(1)*NU(1)/EMOD2(1)
      FNU21I = EMOD1(2)*NU(2)/EMOD2(2)
      FNU21M = EMOD1(3)*NU(3)/EMOD2(3)
      C22OUT = EMOD2(1)*TOUTER/(1.-NU(1)*FNU21O)
      C22INR = EMOD2(1)*TINNER/(1.-NU(1)*FNU21O)
      C22FOT = EMOD2(2)*TFOUTR/(1.-NU(2)*FNU21I)
      C22FIN = EMOD2(2)*TFINNR/(1.-NU(2)*FNU21I)
      C22WEB = EMOD2(3)*TFWEBS/(1.-NU(3)*FNU21M)
      C44FIN = (EMOD1(2)*TFINNR**3)/(12.*(1.-NU(2)*FNU21I))
C
      ARCTOT = ARCOUT*C22OUT*ALPHA2(1)
     1        +ARCINR*C22INR*ALPHA2(1)
     1        +ARCFOT*C22FOT*ALPHA2(2)
     1        +ARCFIN*C22FIN*ALPHA2(2)
     1        +ARCWEB*C22WEB*ALPHA2(3)
C
C Get the weight per axial length of the balloon:
C
      WEIGHT = 4.*(ARCOUT*TOUTER*DENSTY(1) +ARCINR*TINNER*DENSTY(1)
     1            +ARCFOT*TFOUTR*DENSTY(2) +ARCFIN*TFINNR*DENSTY(2)
     1            +ARCWEB*TFWEBS*DENSTY(3))
C
C  Load set A delta temperature = DELT:
      ENDF12 = 0.
      DELT = 0.
      IF (INDX.EQ.2) THEN
C BEG NOV 2010
        IF (KSEGS.EQ.5) THEN
          WRITE(IFILE4,'(/,A,1P,5E12.4)')
     1  ' N2DIFF(J),J=1,5)=',(N2DIFF(J),J=1,5)
        ENDIF
        IF (KSEGS.EQ.6) THEN
          WRITE(IFILE4,'(/,A,1P,6E12.4)')
     1  ' N2DIFF(J),J=1,6)=',(N2DIFF(J),J=1,6)
        ENDIF
C END NOV 2010
        ENDF12 = N2DIFF(1)*ARCFIN +N2DIFF(2)*ARCFOT +N2DIFF(3)*ARCFIN
     1          +N2DIFF(4)*ARCINR +N2DIFF(5)*ARCWEB
        DELT = -ENDF12/ARCTOT
      ENDIF
C
C  Load set B delta temperature = DELTAT:
      DELTAT = -ENDFCE/ARCTOT
C BEG NOV 2010
      IF (ISHAPE.EQ.2) THEN
```

```
C      We have a spherical vacuum chamber
          DELTAT = 0.0
          DELT   = 0.0
       ENDIF
C END NOV 2010
C23456789012345678901234567890123456789012345678901234567890123456789012
       WRITE(IFILE4,'(/,A,1P,2E12.4)')
      1' delta temps for generating axial resultants, DELTAT,DELT=',
      1 DELTAT,DELT
       WRITE(IFILE4,'(A,1P,E12.4)') ' PMIDDL(ILOADX)=',PMIDDL(ILOADX)
       WRITE(IFILE4,'(A,1P,E12.4)') ' FMODS =',FMODS
       WRITE(IFILE4,'(A,1P,E12.4)') ' ENDFCE=',ENDFCE
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCTOT=',ARCTOT
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCOUT=',ARCOUT
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCINR=',ARCINR
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCFOT=',ARCFOT
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCFIN=',ARCFIN
       WRITE(IFILE4,'(A,1P,E12.4)') ' ARCWEB=',ARCWEB
       WRITE(IFILE4,'(A,1P,E12.4)') ' SLANT =',SLANT
       WRITE(IFILE4,'(A,1P,E12.4)') ' C22OUT=',C22OUT
       WRITE(IFILE4,'(A,1P,E12.4)') ' C22INR=',C22INR
       WRITE(IFILE4,'(A,1P,E12.4)') ' C22FOT=',C22FOT
       WRITE(IFILE4,'(A,1P,E12.4)') ' C22FIN=',C22FIN
       WRITE(IFILE4,'(A,1P,E12.4)') ' C22WEB=',C22WEB
       WRITE(IFILE4,'(A,1P,E12.4)') ' FNU21O=',FNU21O
       WRITE(IFILE4,'(A,1P,E12.4)') ' FNU21I=',FNU21I
       WRITE(IFILE4,'(A,1P,E12.4)') ' FNU21M=',FNU21M
C      CALL EXIT
C
       MSEGS = ISEGT
C
C23456789012345678901234567890123456789012345678901234567890123456789012
C
C  Next, we generate a valid input data file, *.ALL, for BIGBOSOR4
C
C  Global input before segment data...
C
C      IF (INDX.EQ.0.OR.INDX.EQ.1) WRITE(IFIL14,'(A,I3,A)')
C     1' local buckling, ',MODULS,'-module model (INDIC=0) ixprism'
C BEG NOV 2010
       IF (ISHAPE.EQ.1) THEN
         IF (INDX.EQ.0) WRITE(IFIL14,'(A,I3,A)')
      1' Load B equilib, ',MODULS,'-module model (INDIC=0) ixprism'
         IF (INDX.EQ.1) WRITE(IFIL14,'(A,I3,A)')
      1' general buckling, ',MODULS,'-module model (INDIC=1) ixprism'
         IF (INDX.EQ.2) WRITE(IFIL14,'(A,I3,A)')
      1' stress components, ',MODULS,'-module model (INDIC=0) ixprism'
         IF (INDX.EQ.0.OR.INDX.EQ.1.OR.INDX.EQ.2)
      1  WRITE(IFIL14,'(1P,E14.6,A)') LENGTH,
      1' $ AXIALL = axial length of cyl.'
       ELSE
         IF (INDX.EQ.0) WRITE(IFIL14,'(A,I3,A)')
      1' Load B equilib, ',MODULS,'-module model (INDIC=0)'
         IF (INDX.EQ.1) WRITE(IFIL14,'(A,I3,A)')
```

```
     1' general buckling, ',MODULS,'-module model (INDIC=1)'
        IF (INDX.EQ.2) WRITE(IFIL14,'(A,I3,A)')
     1' stress components, ',MODULS,'-module model (INDIC=0)'
      ENDIF
C END NOV 2010
      IF (INDX.EQ.0.OR.INDX.EQ.1) WRITE(IFIL14,'(I5,A,I3,A)')
     1 INDIC,'  1, 0, ',MSEGS,' $ INDIC,NPRT,ISTRESS,NSEG'
      IF (INDX.EQ.2) WRITE(IFIL14,'(I5,A,I3,A)')
     1 INDIC,'  1, 1, ',MSEGS,' $ INDIC,NPRT,ISTRESS,NSEG'
C
C  Segment data...
C
C  First, provide the input for each of the MSEGS shell segments
C
      DO 200 ISEG = 1,MSEGS
         I = ISEG
         WRITE(IFIL14,'(A,4I6)')' H   $ Segment number ',I,I,I,I
         WRITE(IFIL14,'(I4,A,I3,A)') NODJ(ISEG),', 3, ',NSHPJ(ISEG),
     1 ' $ NMESH,NTYPEH,NSHAPE'
         WRITE(IFIL14,'(1P,4E14.6,A)')
     1   R1J(ISEG),Z1J(ISEG),R2J(ISEG),Z2J(iSEG),' $ R1,Z1,R2,Z2'
C END JUL 2010
         IF (NSHPJ(ISEG).EQ.2) THEN
          WRITE(IFIL14,'(1P,3E14.6,A)') RCJ(ISEG),ZCJ(ISEG),SROTJ(ISEG),
     1  ' $ RC,ZC,SROT'
         ENDIF
C23456789012345678901234567890123456789012345678901234567890123456789012
         WRITE(IFIL14,'(A,1P,E14.6,A)')' 0, 3, ',0.5*THICKJ(ISEG),
     1 ' $ IMP,NTYPEZ,ZVAL'
         WRITE(IFIL14,'(A)')' N  $ do not print r(s), etc.'
         NRINGS = 0
         FOUND = 0.
         LINTYP = 0
C
         IF (INDX.EQ.0) THEN
C
            IDISAB = 1
            WRITE(IFIL14,'(I5,1PE14.6,2I4,A)')
     1       NRINGS,FOUND,LINTYP,IDISAB, ' $ NRINGS,K,LINTYP,IDISAB'
C Load Set A...
            NLTYPE = 3
C normal pressure...
            NPSTAT = 2
            NLOAD1 = 0
            NLOAD2 = 0
            NLOAD3 = 1
            WRITE(IFIL14,'(5I5,A)')
     1      NLTYPE,NPSTAT,NLOAD1,NLOAD2,NLOAD3,
     1    '  $ NLTYPE,NPSTAT,NLOAD(1),NLOAD(2),NLOAD(3)'
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      PFIXJ(ISEG),PFIXJ(ISEG),'  $ PN(1),PN(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
```

```
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C temperature...
            NTSTAT = 2
            NTGRAD = 1
            NLOAD1 = 1
            NLOAD2 = 0
            NLOAD3 = 0
            WRITE(IFIL14,'(5I5,A)')
     1      NTSTAT,NTGRAD,NLOAD1,NLOAD2,NLOAD3,
     1    '  $ NTSTAT,NTGRAD,NLOAD(1),NLOAD(2),NLOAD(3)'
            MATJ = MATLJ(ISEG)
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      DELTAT,DELTAT,'  $ T1(1),T1(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C     End of INDX.EQ.0 condition
         ELSE
C     Begin  INDX.NE.0 condition
C
            IDISAB = 3
            WRITE(IFIL14,'(I5,1PE14.6,2I4,A)')
     1       NRINGS,FOUND,LINTYP,IDISAB, ' $ NRINGS,K,LINTYP,IDISAB'
C Load set A...
            NLTYPE = 3
C normal pressure...
            NPSTAT = 2
            NLOAD1 = 0
            NLOAD2 = 0
            NLOAD3 = 1
            WRITE(IFIL14,'(5I5,A)')
     1      NLTYPE,NPSTAT,NLOAD1,NLOAD2,NLOAD3,
     1    '  $ NLTYPE,NPSTAT,NLOAD(1),NLOAD(2),NLOAD(3)'
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      PEIGJ(ISEG),PEIGJ(ISEG),'  $ PN(1),PN(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C temperature...
            NTSTAT = 2
            NTGRAD = 1
            NLOAD1 = 1
            NLOAD2 = 0
            NLOAD3 = 0
            WRITE(IFIL14,'(5I5,A)')
     1      NTSTAT,NTGRAD,NLOAD1,NLOAD2,NLOAD3,
```

```
     1    '  $ NTSTAT,NTGRAD,NLOAD(1),NLOAD(2),NLOAD(3)'
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      DELT,DELT,'  $ T1(1),T1(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C Load Set B...
            NLTYPE = 3
C normal pressure...
            NPSTAT = 2
            NLOAD1 = 0
            NLOAD2 = 0
            NLOAD3 = 1
            WRITE(IFIL14,'(5I5,A)')
     1      NLTYPE,NPSTAT,NLOAD1,NLOAD2,NLOAD3,
     1    '  $ NLTYPE,NPSTAT,NLOAD(1),NLOAD(2),NLOAD(3)'
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      PFIXJ(ISEG),PFIXJ(ISEG),'  $ PN(1),PN(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C temperature...
            NTSTAT = 2
            NTGRAD = 1
            NLOAD1 = 1
            NLOAD2 = 0
            NLOAD3 = 0
            WRITE(IFIL14,'(5I5,A)')
     1      NTSTAT,NTGRAD,NLOAD1,NLOAD2,NLOAD3,
     1    '  $ NTSTAT,NTGRAD,NLOAD(1),NLOAD(2),NLOAD(3)'
            MATJ = MATLJ(ISEG)
            WRITE(IFIL14,'(1P,2E14.6,A)')
     1      DELTAT,DELTAT,'  $ T1(1),T1(2)'
            NTYPE = 1
            ISTA1 = 1
            ISTA2 = NODJ(ISEG)
            WRITE(IFIL14,'(3I5,A)')
     1      NTYPE,ISTA1,ISTA2,'  $ NTYPE,IPOINT(1),IPOINT(2)'
C
C   End of INDX.NE.0 condition
         ENDIF
C
C shell wall construction...
         NWALL = 4
         LAYERS = 1
         WRITE(IFIL14,'(2I3,A)') NWALL,LAYERS,' $ NWALL,NLAYER'
         WRITE(IFIL14,'(I3,A)') LTYPEJ(ISEG),' $ layer index'
         IF (ISEG.LE.5) THEN
```

```
            ANGLE2 = 0.
            WRITE(IFIL14,'(A)')' Y  $ is this a new layer type?'
            WRITE(IFIL14,'(1P2E14.6,I3,A)') THICKJ(ISEG),
     1       ANGLE2,MATLJ(ISEG),' $ thickness,angle,material'
         ELSE
            WRITE(IFIL14,'(A)')' N  $ is this a new layer type?'
         ENDIF
         NEWMAT = 0
         IF (ISEG.LE.5) THEN
            IF (ISEG.LE.2.OR.ISEG.EQ.5) NEWMAT = 1
         ENDIF
         IF (NEWMAT.EQ.0) THEN
            IF (ISEG.LE.5)
     1       WRITE(IFIL14,'(A)')' N  $ Is this material new?'
         ELSE
            IMATL = MATLJ(ISEG)
            WRITE(IFIL14,'(A)')' Y  $ Is this material new?'
            WRITE(IFIL14,'(1P4E14.6,A)') EMOD1(IMATL),EMOD2(IMATL),
     1       G12(IMATL),NU(IMATL),' $ E1,E2,G12,NU'
            WRITE(IFIL14,'(1P4E14.6,A)') ALPHA1(IMATL),ALPHA2(IMATL),
     1       TEMPER(IMATL),DENSTY(IMATL),' $ A1,A2,TEMPTUR,DENS'
            IF (IMATL.EQ.1) THEN
              WRITE(IFIL14,'(1P3E14.6,A)') STRM1A(ILOADX,1),
     1        STRM1A(ILOADX,2),STRM1A(ILOADX,3),' $ S(1),S(2),S(3)'
              WRITE(IFIL14,'(1P2E14.6,A)') STRM1A(ILOADX,4),
     1        STRM1A(ILOADX,5),' $ S(4),S(5)'
            ENDIF
            IF (IMATL.EQ.2) THEN
              WRITE(IFIL14,'(1P3E14.6,A)') STRM2A(ILOADX,1),
     1        STRM2A(ILOADX,2),STRM2A(ILOADX,3),' $ S(1),S(2),S(3)'
              WRITE(IFIL14,'(1P2E14.6,A)') STRM2A(ILOADX,4),
     1        STRM2A(ILOADX,5),' $ S(4),S(5)'
            ENDIF
            IF (IMATL.EQ.3) THEN
              WRITE(IFIL14,'(1P3E14.6,A)') STRM3A(ILOADX,1),
     1        STRM3A(ILOADX,2),STRM3A(ILOADX,3),' $ S(1),S(2),S(3)'
              WRITE(IFIL14,'(1P2E14.6,A)') STRM3A(ILOADX,4),
     1        STRM3A(ILOADX,5),' $ S(4),S(5)'
            ENDIF
         ENDIF
         WRITE(IFIL14,'(A)')' 0  $ no additional smeared stiffeners'
         WRITE(IFIL14,'(A)')' Y  $ do you want output for all nodes?'
         WRITE(IFIL14,'(A)')' N  $ do you want to print out Cij?'
         WRITE(IFIL14,'(A)')' N  $ do you want to print out loads?'
C
C  The old input for NWALL = 5 follows. (It is commented out).
C        WRITE(IFIL14,'(4I5,A)')
C    1   NWALL,LAYERS,NRS,NTYPET,'  $ NWALL,LAYERS,NRS,NTYPET'
C
C        MATJ = MATLJ(ISEG)
C        WRITE(IFIL14,'(1P,3E14.6,A)')
C    1   THICKJ(ISEG),G12(MATJ),EMOD1(MATJ),'  $ T,G,EX'
C        WRITE(IFIL14,'(1P,3E14.6,A)')
C    1   EMOD2(MATJ),NU(MATJ),DENSTY(MATJ),'  $ EY,UXY,SM'
```

```
C        WRITE(IFIL14,'(1P,2E14.6,A)')
C    1   ALPHA1(MATJ),ALPHA2(MATJ),'  $ ALPHA1,ALPHA2'
C
C        WRITE(IFIL14,'(A)')' N   $ do you want to print C(i,j)?'
C        WRITE(IFIL14,'(A)')' N   $ do you want to print distrib.loads?'
C23456789012345678901234567890123456789012345678901234567890123456789012
C
  200 CONTINUE
C End of loop over the number of shell segments in the model.
C
C Start the global data...
C
      NLAST = 0
C BEG NOV 2010
      IF (ISHAPE.EQ.1) THEN
         NOB = 1
         NMINB = 1
         NMAXB = 1
         INCRB = 1
      ELSE
         NOB = 0
         NMINB = 0
         NMAXB = 0
         INCRB = 1
         IF (ITYPEX.EQ.2) THEN
          NMAXB = 20*NMODUL
          INCRB = NMAXB/10
          IF (INCRB.LT.1) INCRB = 1
         ENDIF
      ENDIF
C END NOV 2010
      NVEC  = 1
      IF (INDX.EQ.0) THEN
         IF (ITRY.EQ.1) THEN
            PMULT = 0.002
            DPMULT= 0.1
            TEMP  = 0.002
            DTEMP = 0.1
            NUMSTP = 11
         ELSE
            IF (ITRY.EQ.3) THEN
               PMULT = 0.0005
               DPMULT= 0.02
               TEMP  = 0.0005
               DTEMP = 0.02
               NUMSTP = 51
            ELSE
               PMULT = 1.0
               DPMULT= 1.0
               TEMP  = 1.0
               DTEMP = 1.0
               NUMSTP = 1
            ENDIF
         ENDIF
```

```
      ELSE
         PMULT = 0.
         DPMULT = 1.0
         TEMP = 1.
         DTEMP = 0.
         NUMSTP = 2
      ENDIF
      OMEGA = 0.
      DOMEGA = 0.
      WRITE(IFIL14,'(I5,A)')
     1 NLAST,'  $ NLAST'
      WRITE(IFIL14,'(A)')' N  $ are there any expanded plots?'
      IF (INDIC.EQ.1) WRITE(IFIL14,'(5I5,A)')
     1 NOB,NMINB,NMAXB,INCRB,NVEC,' $ NOB,NMINB,NMAXB,INCRB,NVEC'
      WRITE(IFIL14,'(1P,4E14.6,A)')
     1 PMULT,DPMULT,TEMP,DTEMP,'  $ P,DP,TEMP,DTEMP'
      IF (INDIC.EQ.0) WRITE(IFIL14,'(I5,A)')
     1 NUMSTP,'  $ number of load steps'
      WRITE(IFIL14,'(1P,2E14.6,A)')
     1 OMEGA,DOMEGA,'  $ OMEGA,DOMEGA'
C
C  Constraint conditions follow...
C
      WRITE(IFIL14,'(I5,A)')
     1 MSEGS,'  $ How many segments in the structure?'
C
      DO 300 I = 1,MSEGS
C
         WRITE(IFIL14,'(A,4I6)')
     1 ' H  $ CONSTRAINT CONDITIONS FOR SEGMENT ',I,I,I,I
C BEG NOV 2010
         IF (KSEGS.EQ.5) IPOLUP = 4
         IF (KSEGS.EQ.6) IPOLUP = 5
         IF (RBIGG.GT.0.0.OR.ISHAPE.EQ.1.OR.I.GT.IPOLUP) THEN
            WRITE(IFIL14,'(A)')' 0  $ number of poles'
         ELSE
            IF (RBIGG.EQ.0.0) THEN
               IF (KSEGS.EQ.5) THEN
                IF (I.EQ.1.OR.I.EQ.2.OR.I.EQ.3.OR.I.EQ.4) THEN
                  WRITE(IFIL14,'(A)')' 1  $ number of poles'
                  WRITE(IFIL14,'(A)')' 1  $ nodal point of poles'
                  NGRNDJ(I) = 0
                ENDIF
               ENDIF
               IF (KSEGS.EQ.6) THEN
                IF (I.EQ.1.OR.I.EQ.2.OR.I.EQ.3.OR.I.EQ.4.OR.I.EQ.5) THEN
                  WRITE(IFIL14,'(A)')' 1  $ number of poles'
                  WRITE(IFIL14,'(A)')' 1  $ nodal point of poles'
                  NGRNDJ(I) = 0
                ENDIF
               ENDIF
            ENDIF
         ENDIF
C END NOV 2010
```

```
         WRITE(IFIL14,'(I3,A)') NGRNDJ(I),' $ connect to ground'
         IF (NGRNDJ(I).GT.0) THEN
            NGRNDI = NGRNDJ(I)
            DO 250 J = 1,NGRNDI
               WRITE(IFIL14,'(I3,A)') NODGRJ(I),' $ node to ground'
C BEG NOV 2010
               IF (KSEGS.EQ.5) THEN
                IF (I.EQ.1.OR.I.EQ.2.OR.I.EQ.3.OR.I.EQ.4) THEN
                  IUSTAR = 0
                  IVSTAR = 0
                  IWSTAR = 1
                  ICHI   = 1
                ELSE
                  IUSTAR = 1
                  IVSTAR = 0
C BEG NOV 2010
                  IF (ISHAPE.EQ.2) IVSTAR = 1
C END NOV 2010
                  IWSTAR = 0
                  ICHI   = 1
                ENDIF
               ENDIF
               IF (KSEGS.EQ.6) THEN
                IF (I.EQ.1.OR.I.EQ.2.OR.I.EQ.3) THEN
                  IUSTAR = 0
                  IVSTAR = 0
                  IWSTAR = 1
                  ICHI   = 1
                ELSE
                  IUSTAR = 1
                  IVSTAR = 0
C BEG NOV 2010
                  IF (ISHAPE.EQ.2) IVSTAR = 1
C END NOV 2010
                  IWSTAR = 0
                  ICHI   = 1
                ENDIF
               ENDIF
C END NOV 2010
               WRITE(IFIL14,'(4I5,A)')
     1          IUSTAR,IVSTAR,IWSTAR,ICHI,
     1      ' $ IUSTAR,IVSTAR,IWSTAR,ICHI'
               D1 = 0.
               D2 = 0.
               WRITE(IFIL14,'(1P,2E14.6,A)') D1,D2,' $ D1,D2'
               WRITE(IFIL14,'(A)')' Y  $ is constraint same for buck.?'
  250       CONTINUE
         ENDIF
C234567890123456789012345678901234567890123456789012345678901234567890
C
         IF (I.EQ.1.OR.I.EQ.3) THEN
             WRITE(IFIL14,'(A)')' N  $ joined to previous segments?'
         ELSE
             WRITE(IFIL14,'(A)')' Y  $ joined to previous segments?'
```

```
             WRITE(IFIL14,'(I3,A)') NPREVJ(I),' $ connects to prev.segs'
             NPREVI = NPREVJ(I)
             DO 220 J = 1,NPREVI
               WRITE(IFIL14,'(I3,A)') NDCURJ(I,J),' $ node current seg'
               WRITE(IFIL14,'(I3,A)')
     1                          I + JPREVJ(I,J),' $ prev.segment no.'
               WRITE(IFIL14,'(I3,A)') NDPRVJ(I,J),' $ node in prev.seg.'
C BEG DEC 2010
               IF (ISHAPE.EQ.1) THEN
                 WRITE(IFIL14,'(A)')' 1, 1, 1, 0 $ IU,IV,IW,ICHI'
               ELSE
                 WRITE(IFIL14,'(A)')' 1, 1, 1, 1 $ IU,IV,IW,ICHI'
               ENDIF
C END DEC 2010
               WRITE(IFIL14,'(A)')' 0., 0. $ D1,D2'
               WRITE(IFIL14,'(A)')' Y  $ is constraint same for buck.?'
C234567890123456789012345678901234567890123456789012345678901234567890123456789012
  220        CONTINUE
         ENDIF
C
  300 CONTINUE
C
      WRITE(IFIL14,'(A)')' N  $ are rigid body motions possible?'
C
      DO 410 ISEG = 1,MSEGS
         WRITE(IFIL14,'(A)')' Y  $ do you want to list seg. output?'
  410 CONTINUE
      WRITE(IFIL14,'(A)')' Y  $ do you want to list ring forces?'
C
      RETURN
      END
=======================================================================
```

Table 8 Changes in the "balloon" software, behavior.balloon, struct.balloon, and bosdec.balloon since [1] was written, and the difference in behavior of the spherical balloon from that of the cylindrical balloon.

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

balloon.sphere.readme

November 24 - 30 and December 13, 2010

Changes in the "balloon" software since release of the paper:

[1] Bushnell, David, "Use of GENOPT and BIGBOSOR4 to obtain optimum
designs of double-walled inflatable cylindrical vacuum chambers",
unpublished report, November, 2010.

Both bosdec.balloon and behavior.balloon were extensively modified.
These modifications, most (but not all) of which are bracketed by
the comments:

C BEG NOV 2010
C END NOV 2010

apply to both the cylindrical balloon and to the spherical balloon.


Several items are listed below.


ITEM 1. You can now use the same software, bosdec.balloon and
behavior.balloon, for all of the following cases:

a. cylindrical balloon with radial webs (There is no
   longer any "bosdec.balloon2" file.)

b. cylindrical balloon with truss-like (slanted) webs

c. spherical balloon with radial webs

d. spherical balloon with truss-like (slanted) webs

The modifications required to SUBROUTINE BOSDEC to
accomplish this are numerous and are bracketed by the lines:

C BEG NOV 2010
C END NOV 2010

For example, we now have the following statements:
```

```
C  Segment 1 in module, IMODUL
         IMODUL1 = IMODUL - 1
         NSHAPE(1,IMODUL) = 1
         IF (IMODUL.GT.1) THEN
           NGRND(1,IMODUL) = 0
           NPREV(1,IMODUL) = 1
C BEG NOV 2010
           IF (KSEGS.EQ.5) JPREV1(1,IMODUL) = -5
           IF (KSEGS.EQ.6) JPREV1(1,IMODUL) = -6
C END NOV 2010
           NDCUR1(1,IMODUL) = 1
           NDPRV1(1,IMODUL) = NODSEG
           R1(1,IMODUL) = RA(IMODUL1)
           Z1(1,IMODUL) = ZA(IMODUL1)
         ELSE
           NGRND(1,IMODUL) = 1
           NODGRD(1,IMODUL) = 1
           NPREV(1,IMODUL) = 0
           R1(1,IMODUL) = RSTART
           Z1(1,IMODUL) = RADIUS + HEIGHT - DSMALO
         ENDIF
```

There are numerous additional modifications to SUBROUTINE BOSDEC, the updated version of which is maintained in the file: /home/progs/genopt/case/balloon/bosdec.balloon.

*********** IMPORTANT NOTE *************************

The versions of the generic "balloon" software, behavior.balloon, struct.balloon, and bosdec.balloon, listed as Tables 5 - 7, respectively, of [1] are now out of date. The up-to-date versions of behavior.balloon, struct.balloon, and bosdec.balloon are listed as Tables 5 - 7 in the more recent paper, "Use of GENOPT and BIGBOSOR4 to obtain optimum designs of multi-walled inflatable spherical and cylindrical vacuum chambers, February, 2011. bosdec.balloon2 no longer exists. Also, the file, balloon.INP, listed in Table 3 of [1] is out of date. The up-to-date version of balloon.INP is listed as Table 3 in the "spherical balloon" paper just cited.

****

************** EMPHASIZE IMPORTANT NOTE *****************

Tables 5, 6, and 7 of [1] are now out-of-date and no longer applicable to the generic "balloon" case. Use only the versions of the balloon sofware, behavior.balloon, struct.balloon, and bosdec.balloon that are stored in the following files:

/home/progs/genopt/case/balloon/behavior.balloon
/home/progs/genopt/case/balloon/struct.balloon
/home/progs/genopt/case/balloon/bosdec.balloon

The up-to-date file, balloon.INP, is stored in the file:

/home/progs/genopt/case/balloon/balloon.INP

These versions of the generic "balloon" software and
the GENTEXT input file, balloon.INP, are always kept up to date.
****

ITEM 2. There are new variables introduced by the GENOPT user into the balloon.INP file via the GENOPT utility called "INSERT". Table 1 in [1] should be replaced with the following table:

TABLE 1 GLOSSARY OF VARIABLES USED IN "balloon"

ARRAY ?	NUMBER OF (ROWS,COLS)	ROLE	PROMPT NUMBER (balloon.PRO)	NAME	DEFINITION OF VARIABLE	NEW INPUT SINCE [1] WAS WRITTEN
n	(0, 0)	2	10	LENGTH	= length of the cylindrical shell	
n	(0, 0)	2	15	RADIUS	= inner radius of the cylindrical balloon	
n	(0, 0)	2	20	NMODUL	= number of modules over 90 degrees	
n	(0, 0)	2	30	ISHAPE	= balloon shape index	**(NEW)**
n	(0, 0)	2	40	IWEBS	= radial (1) or truss-like (2) webs	**(NEW)**
n	(0, 0)	2	50	IEMOD1	= material number in EMOD1(IEMOD1)	
y	(10, 0)	2	55	EMOD1	= elastic modulus, meridional direction	
y	(10, 0)	2	60	EMOD2	= elastic modulus, circumferential direction	
y	(10, 0)	2	65	G12	= in-plane shear modulus	
y	(10, 0)	2	70	G13	= out-of-plane (s,z) shear modulus	
y	(10, 0)	2	75	G23	= out-of-plane (y,z) shear modulus	
y	(10, 0)	2	80	NU	= Poisson ratio	
y	(10, 0)	2	85	ALPHA1	= meridional coef. thermal expansion	
y	(10, 0)	2	90	ALPHA2	= circumf.coef.thermal expansion	
y	(10, 0)	2	95	TEMPER	= delta-T from fabrication temperature	
y	(10, 0)	2	100	DENSTY	= weight density of material	
n	(0, 0)	1	110	HEIGHT	= height from inner to outer membranes	
n	(0, 0)	1	115	RINNER	= radius of curvature of inner membrane	
n	(0, 0)	1	120	ROUTER	= radius of curvature of outer membrane	
n	(0, 0)	1	125	TINNER	= thickness of the inner curved membrane	
n	(0, 0)	1	130	TOUTER	= thickness of the outer curved membrane	
n	(0, 0)	1	135	TFINNR	= thickness of inner truss-core segment	
n	(0, 0)	1	140	TFOUTR	= thickness of the outer truss segment	
n	(0, 0)	1	145	TFWEBS	= thickness of each truss-core web	
n	(0, 0)	2	155	NCASES	= Number of load cases (number of environments)	
y	(20, 0)	3	160	PINNER	= pressure inside the inner membrane	
y	(20, 0)	3	165	PMIDDL	= pressure between inner and outer membranes	
y	(20, 0)	3	170	POUTER	= pressure outside the outer membrane	
y	(20, 0)	4	180	BUCKB4	= buckling load factor from BIGBOSOR4	**(NEW NAME)**
y	(20, 0)	5	185	BUCKB4A	= allowable for buckling load factor from BIGBOSOR4	
y	(20, 0)	6	190	BUCKB4F	= buckling from BIGBOSOR4 factor of safety	**(NEW NAME)**
y	(20, 0)	4	200	TENLOS	= load factor for tension loss	**(NEW)**
y	(20, 0)	5	205	TENLOSA	= tension loss allowable (Use 1.0)	**(NEW)**
y	(20, 0)	6	210	TENLOSF	= tension loss factor of safety	**(NEW)**
n	(0, 0)	2	215	JSTRM1	= stress component number in STRM1(NCASES,JSTRM1)	
y	(20, 5)	4	220	STRM1	= stress component in material 1	
y	(20, 5)	5	225	STRM1A	= allowable stress in material 1	
y	(20, 5)	6	230	STRM1F	= factor of safety for stress in material 1	
y	(20, 5)	4	235	STRM2	= stress component in material 2	
y	(20, 5)	5	240	STRM2A	= allowable for stress in material 2	
y	(20, 5)	6	245	STRM2F	= factor of safety for stress in material 2	
y	(20, 5)	4	250	STRM3	= stress component in material 3	
y	(20, 5)	5	255	STRM3A	= allowable for stress in material 3	
y	(20, 5)	6	260	STRM3F	= factor of safety for stress in material 3	
n	(0, 0)	7	270	WEIGHT	= weight/length of the balloon	

Note that the name of the buckling behavior has been changed from

GENBUK, which erroneously implies general buckling, to BUCKB4, which denotes "buckling load factor obtained from BIGBOSOR4". In keeping with this name change are the changes in the names of the allowable and factor of safety from GENBUKA and GENBUKF in [1] to BUCKB4A and BUCKB4F, respectively.

The new input datum, ISHAPE, controls the shape of the balloon, either cylindrical (ISHAPE = 1) or spherical (ISHAPE = 2). The new input datum, IWEBS, controls whether the webs are radial as in Fig. 1 of [1] (IWEBS = 1) or truss-like (slanted) as in Fig. 2 of [1] (IWEBS = 2). (Also see Figs. 1 and 2 of the present paper on spherical balloons.)

The new input data, TENLOS, TENLOSA, TENLOSF, represent the introduction by the GENOPT user of a new behavioral constraint (TENLOS) and its associated allowable (TENLOSA) and factor of safety (TENLOSF). The segments of a balloon act as if they have no bending stiffness. As soon as they lose tension they wrinkle ("buckle"). TENLOS is the load factor to be multiplied by POUTER which corresponds to the initial loss of tension in one of the "shell" segments of the cross-section of the multi-walled balloon. The "wrinkling load factor", TENLOS, is computed from the equations:

```
TENLOS(loss of MERIDIONAL tension) =
         N1FIX(node,seg.)/[N1FIX(node,seg.) -N1VAR(node,seg.)]

TENLOS(loss of CIRCUMFERENTIAL tension) =
         N2FIX(node,seg.)/[N2FIX(node,seg.) -N2VAR(node,seg.)]
```

in which N1FIX(node,seg.) is the meridional stress resultant from the "fixed" (non-eigenvalue) loads, PINNER, PMIDDL, and DELTAT, at nodal point "node" and segment number "seg.", and N1VAR(node,seg.) is the meridional stress resultant from the total loads, PINNER, PMIDDL, DELTAT, and POUTER. N2FIX and N2VAR (circumferential stress resultants) are analogous respectively to N1FIX and N1VAR. For the cylindrical balloon the behavioral constraint, TENLOS, is the minimum value of N1FIX(node,seg.)/[N1FIX(node,seg.) -N1VAR(node,seg.)] over all the nodes of all the segments in the model, For the spherical balloon TENLOS is the minimum value of both N1FIX(node,seg.)/[N1FIX(node,seg.) -N1VAR(node,seg.)] and N2FIX(node,seg.)/[N2FIX(node,seg.) -N2VAR(node,seg.)]. The circumferential "wrinkling" from N2FIX(node,seg.)/[N2FIX(node,seg.) -N2VAR(node,seg.)] is assumed, in the "initial loss of tension" analsysis, not to occur in the case of the cylindrical balloon because it is assumed that under the external pressure, POUTER, the cylindrical balloon is free to expand in the axial direction (normal to the plane of the paper in Fig.1). This assumption does not apply in the case of the spherical balloon.

Since wrinkling from the initial loss of tension in one or more of the segments of the complex wall of the balloon is a kind of buckling, it is expected that the design margin corresponding to bifurcation buckling from a BIGBOSOR4 model (BUCKB4) will not be too different from the design margin corresponding to initial loss of tension (TENLOS). For an optimized spherical balloon with 8 modules over 90 degrees we have, for example, the following two "buckling" margins:

```
MARGIN CURRENT
NO.     VALUE           DEFINITION
 1    6.170E-02 (BUCKB4(1)/BUCKB4A(1))/BUCKB4F(1)-1; F.S.= 3.00
 2   -7.231E-03 (TENLOS(1)/TENLOSA(1))/TENLOSF(1)-1; F.S.= 3.00
```

Computer optimizations carried out so far show that the "initial loss of tension (TENLOS)" margin is always somewhat more critical than the "bifurcation buckling from BIGBOSOR4 (BUCKB4)" margin.

ITEM 3. The "behavior.balloon" library has been significantly modified. Because of the new behavioral constraint, TENLOS, there are now five subroutines, BEHXi, i = 1, 2, 3, 4, 5, instead of the four listed in Table 5 of [1]. The five subroutines, BEHXi, compute the following behavioral constraints:

```
SUBROUTINE BEHX1 = buckling as predicted by BIGBOSOR4 (BUCKB4)
SUBROUTINE BEHX2 = wrinkling due to initial loss of tension (TENLOS)
SUBROUTINE BEHX3 = 5 stress components in material type 1 (STRM1)
SUBROUTINE BEHX4 = 5 stress components in material type 2 (STRM2)
SUBROUTINE BEHX5 = 5 stress components in material type 3 (STRM3)
```

Typical margins produced by these five subroutines for an optimized design of a spherical balloon with 8 modules are as follows:

```
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
MARGIN CURRENT
NO.     VALUE           DEFINITION
 1    6.170E-02 (BUCKB4(1)/BUCKB4A(1))/BUCKB4F(1)-1; F.S.= 3.00
 2   -7.231E-03 (TENLOS(1)/TENLOSA(1))/TENLOSF(1)-1; F.S.= 3.00
 3   -2.840E-04 (STRM1A(1,1)/STRM1(1,1))/STRM1F(1,1)-1; F.S.= 1.00
 4    1.609E-01 (STRM1A(1,3)/STRM1(1,3))/STRM1F(1,3)-1; F.S.= 1.00
 5   -5.128E-03 (STRM2A(1,1)/STRM2(1,1))/STRM2F(1,1)-1; F.S.= 1.00
 6    3.480E-01 (STRM2A(1,3)/STRM2(1,3))/STRM2F(1,3)-1; F.S.= 1.00
 7    7.867E-03 (STRM3A(1,1)/STRM3(1,1))/STRM3F(1,1)-1; F.S.= 1.00
 8    3.024E-01 (STRM3A(1,3)/STRM3(1,3))/STRM3F(1,3)-1; F.S.= 1.00
```

There are more margins than the five subroutines, BEHXi, because there are up to five stress constraints corresponding to each of the three material types. In this example only two of the five stress components for each material produce margins: STRMi(1,1) (tensile stress along the fibers), i = 1 or 2 or 3, and STRMi(1,3) (tensile stress normal to the fibers), i = 1 or 2 or 3, in which "i" denotes "material type".

ITEM 4. SUBROUTINE BEHX1 of the file, behavior.balloon, now has the following additional statement:

```
      IF (ITYPEX.EQ.2) CALL B4POST
```

The BIGBOSOR4 processor, B4POST, creates the file, *.PLT2, that contains the buckling mode that corresponds to the variable called BUCKB4. One can obtain a plot of this buckling mode (which may be either local or general buckling) by porting the file, *.PLT2, to a directory from which one wants to execute BIGBOSOR4 in a context independent of GENOPT and then typing the command, "BOSORPLOT", there. Here is the run stream:

```
   COMMAND                    MEANING OF COMMAND

cd /home/progs/work6    (go to a working space, "work6")
bigbosor4log    (activate the BIGBOSOR4 set of commands)
cp /home/progs/genoptcase/try4.PLT2 .   (get BIGBOSOR4 plot file)

bosorplot        (choose what to plot. Use "x" in response to
                  prompt if you want plot on your screen. Use "p"
                  in response to prompt if you want plot to be
                  in the file called "metafile.ps".)

gv metafile.ps  (get a plot on your screen via the "ghost view"
                  utility, if "ghost view" is available on your
                  workstation. Figs. 10a – 10k are edited versions
                  of what appears on your screen.)
```

NOTE: One does not run BIGBSOSOR4, that is, one does not type the command, "BIGBOSORALL", as described in the file, balloon.runstream (Table 4 in the paper [1] cited at the beginning of this file). The "bosorplot" execution requires as input only the file, *.PLT2, in which "*" denotes the name that one has established for the specific case.

In the case of the cylindrical balloon the valid BIGBOSOR4 input data are contained in the *.BEHX1 file. Therefore, instead of the command listed above,

```
cp /home/progs/genoptcase/try4.PLT2 .   (get BIGBOSOR4 plot file)
```

there exists, in Table 4 of [1] the following command:

```
cp /home/progs/genoptcase/try4.BEHX1 try4.ALL   (get BIGBOSOR4 input file)
```

One can type the last command in the case of the spherical balloon also. However, the BIGBOSOR4 execution subsequently launched via the command, BIGBOSORALL, will bomb because of failure of convergence of the Newton iterations for the nonlinear solution of the pre-buckling equilibrium equations. It appears that (without modifying the BIGBOSOR4 computer program) one can obtain buckling modes of the spherical balloon only via the two commands,

```
cp /home/progs/genoptcase/try4.PLT2 .   (get BIGBOSOR4 plot file)
bosorplot
```

ITEM 5. SUBROUTINE BEHX1 of the behavior.balloon library now creates the additional file, *.LOADB, in which "*" signifies the specific name that you have assigned. The file, *.LOADB, contains a valid input file for BIGBOSOR4 for a case in which the BIGBOSOR4 analysis type, INDIC = 0, and for which only the "fixed" loads are applied, that is, only PINNER, PMIDDL, and DELTAT are applied. In order to get plots of the deformations at various load steps, you run BIGBOSOR4 in a context independent of GENOPT in the same manner as directed in the file, balloon.runstream (Table 4). You do the following:

```
   COMMAND                    MEANING OF COMMAND

cd /home/progs/work6    (go to a working space, "work6")
bigbosor4log    (activate the BIGBOSOR4 set of commands)
cp /home/progs/genoptcase/try4.LOADB try4.ALL   (get BIGBOSOR4 input file)
bigbosorall     (execute BIGBOSOR4: input file = try4.ALL .
                 NOTE: valid input files for bigbosor4 always have the
                 suffix, ".ALL")
```

Next, you want to plot the pre-buckling deformations for one or more load steps. For each load step for which you want a plot, do the following:

```
bosorplot       (choose what to plot. Use "x" in response to
                 prompt if you want plot on your screen. Use "p"
                 in response to prompt if you want plot to be
                 in the file called "metafile.ps".)

gv metafile.ps  (get a plot on your screen via the "ghost view"
                 utility, if "ghost view" is available on your
                 workstation. Figs. 5 and 6 are edited versions
                 of what appears on your screen.)
```

When you are finished, type the following command:

```
cleanup         (Clean up the files generated by BIGBOSOR4)
```

ITEM 6. Since [1] was written it was discovered that if a very small load is used as the initial value (1st step) in a nonlinear pre-buckling analysis, convergence of the nonlinear process is more reliable. Accordingly, SUBROUTINE BOSDEC (bosdec.balloon) was modified as follows:

```
      IF (INDX.EQ.0) THEN
         IF (ITRY.EQ.1) THEN
            PMULT = 0.002          <--very small value (used to be 0.1)
            DPMULT= 0.1
            TEMP  = 0.002          <--very small value (used to be 0.1)
            DTEMP = 0.1
```

```
            NUMSTP = 11               <--used to be 10
         ELSE
            IF (ITRY.EQ.3) THEN
               PMULT = 0.0005         <--very small value (used to be 0.02)
               DPMULT= 0.02
               TEMP  = 0.0005         <--very small value (used to be 0.02)
               DTEMP = 0.02
               NUMSTP = 51            <--used to be 50
            ELSE
               PMULT = 1.0
               DPMULT= 1.0
               TEMP  = 1.0
               DTEMP = 1.0
               NUMSTP = 1
            ENDIF
         ENDIF
      ELSE
         PMULT = 0.
         DPMULT = 1.0
         TEMP = 1.
         DTEMP = 0.
         NUMSTP = 2
      ENDIF
```

Note that very small initial values of PMULT and TEMP are now used, whereas previously PMULT had been set equal to DPMULT and TEMP had been set equal to DTEMP.

ITEM 7. Differences in behavior of the cylindrical vacuum chamber from that of the spherical vacuum chamber:

ITEM 7a. In the cylindrical vacuum chamber the pre-buckled state of every module is the same. Hence, one can use the pre-buckled state of the segments of the first module to represent that of every module. In the spherical vacuum chamber the pre-buckled stress resultants vary over the 90 degrees of meridian included in the model. The stress resultants vary not only from module to module, but also within each "shell" segment of each module.

ITEM 7b. The pre-buckling behavior of the cylindrical vacuum chamber is uniform over the entire 90 degrees of circumference included in the model, as displayed in Figs. 9 and 10 of [1]. In contrast, the pre-buckling behavior of the spherical vacuum chamber is not uniform over the 90 degrees of meridian included in the model. The spherical vacuum chamber is not isotropic because there are webs oriented only in the circumferential direction, not in the meridional direction. There cannot be webs in the meridional direction in the GENOPT/BIGBOSOR4 model because then the shell would not be axisymmetric. BIGBOSOR4 can handle only axisymmetric or prismatic shell structures. Figure 6 of the present paper on spherical balloons demonstrates the non-isotropic nature of the pre-buckling axisymmetric deformations of the spherical balloon. Under the loads in Load Set B (non-eigenvalue) loads, PINNER = 0 psi, PMIDDL = 60 psi, the originally spherical shell becomes slightly egg shaped (elongates in the axial direction more than in the radial direction).

ITEM 7c. The cylindrical vacuum chamber is modeled as a "true prismatic shell", whereas the spherical vacuum chamber is modeled as an ordinary shell of revolution. There is a difference in the governing equations, as described in Refs.[8] and [9] cited in the paper identified as [1] near the beginning of this file.

ITEM 7d. From the computer runs executed so far it appears that the nonlinear pre-buckling equilibrium states are often more difficult to obtain for the spherical vacuum chamber than for the cylindrical vacuum chamber. In the case of the spherical balloon there are more occurrences of failure of convergence of the Newton iterations required for generating the nonlinear pre-buckling equilibrium states. Failure of Newton convergence previously caused early termination of SUPEROPT optimization runs. The FORTRAN coding in SUBROUTINE BEHX1 was modified in order to prevent early termination of SUPEROPT runs caused by failure of Newton convergence. A typical modification in SUBROUTINE BEHX1 follows:

```
      ILETW = INDEX(WRDCOL,'INITIAL LOADS TOO HIGH FOR THIS STRUCT')
      IF (ILETW.NE.0) THEN
C BEG NOV 2010
         EIGMIN = 10.E+16
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(/,A)') ' ********* ABORT **********'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(/,A)') ' ********* WARNING **********'
         WRITE(IFILE,'(A)') ' THIS IS THE INDIC=1 BUCKLING ANALYSIS'
         WRITE(IFILE,'(A)') ' INITIAL LOADS TOO HIGH FOR THIS STRUCT'
         IF (ITYPEX.EQ.2)
     1   WRITE(IFILE,'(A,I2)') ' Run is now aborting: IMODX=',IMODX
         WRITE(IFILE,'(A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Look near the end of the *.OPP file for the "FEASIBLE" or for',
     1 ' the "ALMOST FEASIBLE" design. Choose whichever of those you',
     1 ' prefer, and use CHANGE to save that design. Then, if you want',
     1 ' to continue with SUPEROPT, execute SUPEROPT again. Bushnell',
     1 ' has found that this execution of SUPEROPT may run for many',
     1 ' iterations before bombing again, or it may run to completion',
     1 ' (a total of about 470 design iterations).'
         IF (ITYPEX.NE.2)
     1   WRITE(IFILE,'(A,I2)') ' IABORT is now set to 1: IMODX=',IMODX
         IF (ITYPEX.NE.2) WRITE(IFILE,'(/,A,/,A,/,A,/,A)')
     1 ' WEIGHT and TOTMAS and EIGMIN are being set equal to large',
     1 ' numbers. If you want a plot of the objective edit the *.PL5',
     1 ' file by removing all entries with very large numbers, then',
     1 ' execute DIPLOT.'
         WRITE(IFILE,'(A)') ' ********************************'
```

```
         IABORT = 1
C BEG DEC 2010
         CALL MOVER(0.,0,STRS1V,1,6)
         CALL MOVER(0.,0,STRS2V,1,6)
         EIGMIN = 10.E16
C END DEC 2010
         WEIGHT = 10.E20
         TOTMAS = 10.E20
         IF (ITYPEX.EQ.2) CALL ERREX
C BEG DEC 2010
         GO TO 1000
C END DEC 2010
C END NOV 2010
       ENDIF
```

In the FORTRAN fragment just listed the index, ITYPEX, governs the type of analysis:

ITYPEX = 1 means optimization
ITYPEX = 2 means analysis of a fixed design (no optimization)
ITYPEX = 3 means design sensitivity analysis.

Early termination of an execution (CALL ERREX) only occurs if ITYPEX = 2 The variables, WEIGHT and TOTMAS, are set equal to very high numbers so that the current objective will be much higher than the previously obtained objective values that correspond to FEASIBLE and to ALMOST FEASIBLE designs. The variable, EIGMIN, is set equal to a very high number so that the optimizer, ADS, will not change the design during the current execution of OPTIMIZE in the SUPEROPT script.

Now with optimization runs (ITYPEX = 1), instead of "CALL ERREX" to terminate execution in the event of failure of convergence of the Newton iterations for solution of the pre-buckling equilibrium equations, SUBROUTINE BEHX1 sets WEIGHT and TOTMAS to a very large number and keeps on executing. In a particular specific case (a spherical balloon with 12 modules and radial webs) the following typical entries now exist in the *.OPP file:

```
 -----------------------------------------------------OPTIMIZE
   215         5.8165E+03         FEASIBLE           3
   216         5.6096E+03     MILDLY UNFEASIB        4
   217         5.3223E+03     MILDLY UNFEASIB        4
   218         5.7909E+03     ALMOST FEASIBLE        4
   219         5.7172E+03     ALMOST FEASIBLE        4
   220         5.7791E+03     ALMOST FEASIBLE        4
 ---------------------------------------------------AUTOCHANGE
 -----------------------------------------------------OPTIMIZE
   221         1.0000E+21         FEASIBLE           0
 -----------------------------------------------------OPTIMIZE
   222         1.0000E+21         FEASIBLE           0
 -----------------------------------------------------OPTIMIZE
   223         1.0000E+21         FEASIBLE           0
 -----------------------------------------------------OPTIMIZE
```

```
  224         1.0000E+21        FEASIBLE           0
 -----------------------------------------------------------OPTIMIZE
  225         1.0000E+21        FEASIBLE           0
 ---------------------------------------------------------AUTOCHANGE
 -----------------------------------------------------------OPTIMIZE
  226         9.8328E+03     NOT FEASIBLE          3
  227         1.0274E+04     NOT FEASIBLE          3
  228         1.0879E+04    MORE UNFEASIBLE        2
  229         1.1307E+04    MORE UNFEASIBLE        2
  230         1.1601E+04    MILDLY UNFEASIB        2
  231         1.1822E+04    ALMOST FEASIBLE        2
 -----------------------------------------------------------OPTIMIZE
```

The large numbers, 1.0000E+21, for the objective signify that failure of convergence of the Newton iterations for the solution of the nonlinear pre-buckling equilibrium equations has occurred in design iterations 221 - 225. These large numbers affect the *.PL5 file, which is produced by the GENOPT processor called "CHOOSEPLOT" and which contains a "plot" of the objective versus design iterations. If the user wants meaningful plots of objective versus design iterations, he or she will have to eliminate any "large-number" entries in the *.PL5 file. The part of the unedited *.PL5 file that corresponds to the above list involving design iterations 215 - 231 follows:

```
 0.21500E+03 0.56096E+04
 0.21600E+03 0.53223E+04
 0.21700E+03 0.57909E+04
 0.21800E+03 0.57172E+04
 0.21900E+03 0.57791E+04
 0.22000E+03 0.10000E+22 <--- remove this entry before plotting
 0.22100E+03 0.10000E+22 <--- remove this entry before plotting
 0.22200E+03 0.10000E+22 <--- remove this entry before plotting
 0.22300E+03 0.10000E+22 <--- remove this entry before plotting
 0.22400E+03 0.10000E+22 <--- remove this entry before plotting
 0.22500E+03 0.98328E+04
 0.22600E+03 0.10274E+05
 0.22700E+03 0.10879E+05
 0.22800E+03 0.11307E+05
 0.22900E+03 0.11601E+05
 0.23000E+03 0.11822E+05
 0.23100E+03 0.11822E+05
```

For another case with 15 modules and truss-like (slanted) webs, Figure 21 shows the plot of objective versus design iterations before an editing of the *.PL5 file to remove all the "high-number" entries. Figure 22 shows the same plot after removal of all the "high-number" entries in the *.PL5 file.

In these cases the plots are obtained via the following commands:

```
diplot    (the input file is try4.PL5)
gv try4.5.ps  (obtain plot of objective versus design iterations)
```

ITEM 7e. For the cylindrical vacuum chamber the optimized balloons with truss-like (slanted) webs weigh significantly less than the optimized balloons with the radial webs. From the runs executed so far it appears that the reverse sometimes holds for optimized spherical balloons (Fig.28). For designs in which there are many modules over 90 degrees of the meridian of the spherical balloon made of polyethylene terephthalate, there is not much difference between the optimized weight for the spherical balloons with radial versus spherical balloons with truss-like (slanted) webs (Fig. 23).

ITEM 7f. In the case of the cylindrical balloons the buckling wave number used to compute buckling over the very long length, 6000 inches [1], is N = 1, which signifies one half wave over the axial length, 6000 inches. In the case of the spherical balloons the buckling wave number used to compute "critical" buckling in optimization or in design sensitivity runs (ITYPE = 1 or 3 in the *.OPT file) is N = 0, which signifies axisymmetric buckling. In runs involving the analysis of a "fixed" design (ITYPE = 2 in the *.OPT file) bifurcation buckling load factors from BIGBOSOR4 are sought over a wide range of N in order to search for a minimum. This occurs only in the case of a spherical balloon (ISHAPE = 2 in the *.BEG file). The output in the *.OPM file from this search for a minimum (critical) buckling load factor for an optimized spherical balloon with 8 modules and radial webs follows (Table 10):

```
 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)

        3.6727E+00(     0)  <--axisymmetric buckling (N=0 circ.waves)
        3.4612E+00(    16)
        3.2674E+00(    32)
        3.1965E+00(    48)
        3.1851E+00(    64)  <--critical buckling (N=64 circ.waves)
        3.2020E+00(    80)
        3.2379E+00(    96)
        3.2909E+00(   112)
        3.3580E+00(   128)
        3.4376E+00(   144)
        3.5291E+00(   160)
 Critical buckling load factor, BUCKB4=  3.1851E+00
 Critical number of circumferential full-waves, NWVCRT=   64
```

The same *.OPM file lists the following values for the minimum load factors corresponding to initial loss of meridional and circumferential tension in each segment (ISEG) of any module:

```
 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=
  4.1691E+00  1.0315E+01  3.6024E+00  3.7359E+01  1.2758E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=
```

```
  3.8769E+00  6.4317E+00  2.9783E+00  4.5277E+00  3.2721E+00
```

and the minimum load factor among those (the minimum minimum):

```
 Buckling load factor corresponding to the initial loss of
 either meridional or circumferential tension, EIGMIN=  2.9783E+00
```

The bifurcation buckling load factor (eigenvalue) from BIGBOSOR4 for N = 0 circumferential waves is: 3.6727E+00(0). This value is very close to the load factor corresponding to initial loss of meridional tension in Segment No. 38 (module no. 8): 3.6024E+00. (Segment No. 38 is one of the straight segments of the inner wall, the thickness of which is TFINNR.) The minimum bifurcation buckling load factor from BIGBOSOR4 corresponds to N = 64 circumferential waves and is: 3.1851E+00(64). This critical (minimum) value is above and fairly close to the minimum minimum load factor, 2.9783E+00, that corresponds in this particular case to initial loss of circumferential tension in Segment No. 38 (module no. 8). It is emphasized that the search for a critical (minimum) buckling load factor from BIGBOSOR4 is conducted **only if ITYPE = 2**, that is, analysis of a "fixed" design. **In order to save computer time during optimization runs (ITYPE = 1) and in order to avoid the use of spurious buckling data (Figs.30,31) only the bifurcation buckling load factor corresponding to N = 0 circumferential waves is computed.** Since the minimum buckling load factor (3.1851E+00 in this particular case) is somewhat lower than the buckling load factor corresponding to N=0 (3.6727E+00 in this particular case), one might think that optimum designs obtained with this strategy might be somewhat unconservative. However, recall that now there exists the behavioral constraint, TENLOS/TENLOSF, in which TENLOS/TENLOSF in this particular case is 2.9783E+00/3.0, which is somewhat lower than the minimum (critical) bifurcation buckling ratio computed from BIGBOSOR4: 3.1851E+00/3.0. Therefore, the optimum design should be somewhat conservative in spite of the lack of a search over circumferential wave number during optimization cycles.

ITEM 7g. In the case of the cylindrical balloons optimization is carried out with POUTER = 5.0 psi and the factor of safety for buckling, BUCKB4F = 3.0 (Table 8 in [1]). After optimization a case is run for the optimized design in which POUTER = 15 psi and BUCKB4F = 1.0, which, from the point of view of buckling, is equivalent to POUTER = 5.0 and BUCKB4F = 3.0. (See Table 17 in [1]). This worked in every "cylindrical"
case attempted. The situation may occasionally be more complicated in the case of spherical balloons. When the same procedure was attempted for an earlier optimized design obtained before the behavior, TENLOS, was introduced, the run in which POUTER = 15 psi bombed with the following message appearing at the end of the *.OPM file:

```
   ************* ABORT **********
    SHELL COLLAPSES AXISYMMETRICALLY
    The run is now aborting: IMODX= 0
   *********************************
```

This was not surprising in that earlier case because the bifurcation buckling eigenvalue for the earlier optimized design was very close to 2.97 with N = 0 circumferential waves when POUTER = 5.0 psi and BUCKB4F = 3.0. With POUTER = 15.0 psi the expected bifurcation buckling eigenvalue would have been 2.97/3.0 = 0.99 if the behavior were strictly linear. One would have expected axisymmetric collapse at POUTER somewhat lower than 15.0 x 0.99 psi with nonlinearity included. Therefore, it was, in that earlier case, necessary to use a slightly lower pressure, POUTER = 14.5 psi, instead of POUTER = 15.0 psi. The "ABORT" message reproduced above occurred with POUTER = 14.7 psi. Hence, the applied external pressure, POUTER, had to be a bit less than that. Since the new behavior, TENLOS, has been introduced this "premature" axisymmetric collapse is unlikely to occur when POUTER is reset to 15.0 psi because the load factor corresponding to the initial loss of tension has always been lower than that corresponding to bifurcation buckling in every optimized balloon. Since the load factor corresponding to the initial loss of tension is closely related to the load factor corresponding to bifurcation buckling, "FEASIBLE" and "ALMOST FEASIBLE" optimum designs always have bifurcation buckling margins that are somewhat positive. Therefore, for optimized designs with POUTER = 15.0 psi the axisymmetric collapse load factor computed from BIGBOSOR4 will most likely be greater than 1.0, and "premature" axisymmetric collapse will not occur.

ITEM 7h. After optimization the height, HEIGHT, between the inner and outer walls is greater in the cylindrical balloons than in the spherical balloons.

ITEM 7i. The objective in the case of cylindrical balloons is the weight per axial length of the balloon, and this objective is computed in SUBROUTINE BOSDEC as follows:

```
      WEIGHT = 4.*(ARCOUT*TOUTER*DENSTY(1) +ARCINR*TINNER*DENSTY(1)
     1            +ARCFOT*TFOUTR*DENSTY(2) +ARCFIN*TFINNR*DENSTY(2)
     1            +ARCWEB*TFWEBS*DENSTY(3))
```

In contrast, the objective in the case of spherical balloons is equal to the variable called "TOTMAS" in BIGBOSOR4. "TOTMAS" is transferred from BIGBOSOR4 to SUBROUTINE OBJECT via a labeled common block, COMMON/TOTMAX/TOTMAS. In SUBROUTINE OBJECT we now have the following statements:

```
C BEG NOV 2010
      COMMON/TOTMAX/TOTMAS
C
      IF (ISHAPE.EQ.1) THEN
         OBJGEN =WEIGHT
      ELSE
         OBJGEN = 2.0*TOTMAS
      ENDIF
```

C END NOV 2010

ISHAPE = 1 means "cylindrical balloon".

The factor, "2.0", occurs in the string, OBJGEN = 2.0*TOTMAS, because the BIGBOSOR4 quantity, TOTMAS, is the weight over 90 degrees of the meridian of the spherical shell.

The definition of the objective remains "weight/axial length":

```
 ******************* DESIGN OBJECTIVE ******************
 *************                            ***********
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1   16.462E+03  weight/length of the balloon: WEIGHT
 *************                         ************
 ******************* DESIGN OBJECTIVE ******************
```

In the case of the spherical balloon, just ignore that definition and know that the objective listed is actually the total "mass" of the spherical balloon, 2.0*TOTMAS, as computed in BIGBOSOR4. Since the input variable, DENSTY (Table 1), is weight density and not mass density, the BIGBOSOR4 variable, TOTMAS, is weight and not mass in the "balloon" software.

ITEM 7j. In the case of the spherical balloon there is no LENGTH. Hence, the variable, LENGTH (Table 8 in [1]), is not used if ISHAPE = 2. In spite of that, the end user still has to respond to the prompt for LENGTH. He or she can supply any positive value for LENGTH in the case of a spherical balloon.

ITEM 7k. In the case of the spherical balloon there is no need use a temperature, DELTAT, in order to generate the proper stress resultants normal to the plane of the paper in Fig.1 of [1], for example. Therefore, if ISHAPE = 2 (spherical balloon) DELTAT is set equal to zero in SUBROUTINE BEHX1 of the behavior.balloon library. The circumferential stress resultants, that is, the stress resultants normal to the plane of the paper in Fig. 1, are computed by BIGBOSOR4 in the case of the spherical balloon.

ITEM 7l. With respect to computation of the nonlinear prebuckling equilibrium states corresponding to Load Step No. 1 (only "fixed" loads, PINNER, PMIDDL, and DELTAT applied) and to Load Step No. 2 (total loads, PINNER, PMIDDL, DELTAT, and POUTER applied), the spherical balloon is more "cranky" than the cylindrical shell. Executions of SUPEROPT used to bomb well before the completion of 470 design iterations. See Item 7d above for modifications to SUBROUTINE BEHX1 that lead to the elimination of SUPEROPT "bombs". Modifications made to SUBROUTINE BEHX1 on November 28 and 29, 2010, cause early unintended terminations ("bombs") of optimizations via SUPEROPT to occur much less frequently than previously, as explained in the file, balloon.sphere.runstream (Table 4).

ITEM 7m. In the case of cylindrical balloons junctions between "shell" segments in the BIGBOSOR4 model are hinged, that is, a typical junction constraint condition is as follows:

```
  1      $ At how may stations is this segment joined to previous segs.?
 31      $ INODE = node in current segment (ISEG) of junction, INODE(  1)
  1      $ JSEG  = segment no. of lowest segment involved in junction
 31      $ JNODE = node in lowest segmnt (JSEG) of junction
  1      $ IUSTAR= axial displacement (0=not slaved, 1=slaved)
  1      $ IVSTAR= circumferential displacement (0=not slaved, 1=slaved)
  1      $ IWSTAR= radial displacement (0=not slaved, 1=slaved)
  0      $ ICHI  = meridional rotation (0=not slaved, 1=slaved) ← NOTE!
```

In the case of spherical balloons the typical segment junction condition is as follows:

```
  1      $ At how may stations is this segment joined to previous segs.?
 31      $ INODE = node in current segment (ISEG) of junction, INODE(  1)
  1      $ JSEG  = segment no. of lowest segment involved in junction
 31      $ JNODE = node in lowest segmnt (JSEG) of junction
  1      $ IUSTAR= axial displacement (0=not slaved, 1=slaved)
  1      $ IVSTAR= circumferential displacement (0=not slaved, 1=slaved)
  1      $ IWSTAR= radial displacement (0=not slaved, 1=slaved)
  1      $ ICHI  = meridional rotation (0=not slaved, 1=slaved) ← NOTE!
```

In the above two lists a “1” for IUSTAR, IVSTAR, IWSTAR, ICHI means “displacement component is restrained”. A “0” means “displacement component is free”.

ITEM 8. Loss of tension "eigenvalues":
SUBROUTINE BEHX1 in the behavior.balloon library was modified to print to the *.OPM file not only the stress resultants but also the wrinkling load factors ("eigenvalues") that correspond to initial loss of meridional and circumferential tension in the most critical "shell" segments in the model. These "eigenvalues" are not really eigenvalues computed from a numerical stability analysis, of course. They are computed as follows:

```
"eigenvalue" for loss of meridional tension,      EIGEN1 =N1FIX/(N1FIX-N1VAR)
"eigenvalue" for loss of circumferential tension, EIGEN2 =N2FIX/(N2FIX-N2VAR)
```

in which N1FIX, N2FIX = meridional, circumferential stress resultants from the "fixed" loads, PINNER, PMIDDL, and DELTAT, and N1VAR, N2VAR are the meridional, circumferential stress resultants from the total loads, PINNER, PMIDDL, DELTAT, and POUTER.

ITEM 8, CYLINDRICAL BALLOONS

In the case of the cylindrical balloons, for which the pre-buckled state in the first module is repeated in every module and for which the prebuckled state is the same at every nodal point in a given shell segment, the output included in the *.OPM file is as follows (in a particular case with 15 modules over 90 degrees of the circumference of the cylindrical shell):

```
LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,6)=
3.6328E+00  9.9292E+00  2.9687E+00  9.8764E+01  1.3552E+01  1.3582E+01

LOSS OF CIRCUMFERENTIAL TENSION: (EIGEN2(1,ISEG),ISEG=1,6)=
7.4567E+00  2.3560E+01  5.8579E+00  3.0855E+02  3.1759E+01  3.1847E+01

   PREBUCKLING STRESS RESULTANTS IN THE FIRST MODULE
           "fixed" from Load Step No. 1 total from Load Step No. 2
  Seg.J  Node I N1FIX(I,J)   N2FIX(I,J)   N1VAR(I,J)   N2VAR(I,J)
    1      1   7.9503E+02   4.8957E+02   5.7618E+02   4.2391E+02
    2      1   6.6087E+02   4.7043E+02   5.9431E+02   4.5046E+02
    3      1   1.8187E+03   1.0766E+03   1.2060E+03   8.9280E+02
    4      1   3.8914E+02   3.6472E+02   3.8520E+02   3.6354E+02
    5      1   4.9059E+02   3.4492E+02   4.5439E+02   3.3406E+02
    6      1   4.9013E+02   3.4478E+02   4.5405E+02   3.3396E+02
```

ITEM 8, SPHERICAL BALLOONS:

In the case of the spherical balloons, for which the pre-buckled state is different in every module and at every nodal point within each shell segment, the output included in the *.OPM file (with NPRINT = 2) is as follows (in a particular case with 8 modules over 90 degrees of the meridian of the spherical balloon with radial webs):

```
 MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS
                 "fixed"       "total"
               Load Step 1   Load Step 2
 Seg.J  Node I  N1FIX(I,J)    N1VAR(I,J)
   26      1   3.20114E+02   2.47268E+02
    7      2   1.22921E+03   1.14633E+03
   23      1   1.26495E+03   9.22114E+02
    9      1   1.12449E+03   1.11431E+03
    5      1   1.87964E+03   1.75817E+03

 MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS
                 "fixed"       "total"
               Load Step 1   Load Step 2
 Seg.J  Node I  N2FIX(I,J)    N2VAR(I,J)
    6      2   2.04872E+02   1.74672E+02
    7      2   1.11425E+03   9.87126E+02
    8      1   9.84081E+02   7.50764E+02
    9      1   1.05412E+03   8.84845E+02
    5      1   1.64854E+03   1.36057E+03

 MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION
                              "fixed"       "total"
                             Load Step 1   Load Step 2
```

```
 Seg.J  Node I  EIGEN1(I,J)    N1FIX(I,J)    N1VAR(I,J)
   11     23   4.16945E+00   2.27137E+02   1.72660E+02
    7     31   1.03148E+01   8.40298E+02   7.58833E+02
   38     30   3.60258E+00   1.21699E+03   8.79178E+02
   29     31   3.73586E+01   7.33646E+02   7.14008E+02
   40     31   1.27584E+01   1.62095E+03   1.49390E+03

 MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION
                                "fixed"       "total"
                               Load Step 1   Load Step 2
 Seg.J  Node I  EIGEN2(I,J)    N2FIX(I,J)    N2VAR(I,J)
   16     16   3.87690E+00   1.28506E+02   9.53595E+01
   12      9   6.43172E+00   7.52156E+02   6.35211E+02
   38     17   2.97831E+00   4.29922E+02   2.85571E+02
   39     17   4.52765E+00   3.97527E+02   3.09727E+02
    5     13   3.27211E+00   3.86260E+00   2.68214E+00
```

Notice that the lowest positive "eigenvalue" for the loss of MERIDIONAL tension is EIGEN1 = 3.60258. The initial loss of MERIDIONAL tension is predicted to occur at Nodal Point 30 in "shell" Segment No. 38. Segment 38 is in Module No. 8. Segment 38 corresponds to the inner wall with straight segments of thickness, TFINNR. This "eigenvalue" is very close to the actual eigenvalue for axisymmetric buckling (N = 0 circumferential waves) computed by BIGBOSOR4 from an actual stability (bifurcation buckling) analysis:

```
 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.6727E+00(     0)  <--axisymmetric buckling (0 circ.waves)
        3.4612E+00(    16)
        3.2674E+00(    32)
        3.1965E+00(    48)
        3.1851E+00(    64)  <--critical buckling (64 circ.waves)
        3.2020E+00(    80)
        3.2379E+00(    96)
        3.2909E+00(   112)
        3.3580E+00(   128)
        3.4376E+00(   144)
        3.5291E+00(   160)
 Critical buckling load factor, BUCKB4=  3.1851E+00
 Critical number of circumferential full-waves, NWVCRT=   64
```

The local buckling mode corresponding to the eigenvalue, 3.6727, obtained from BIGBOSOR4 is displayed in Fig. 18. Local buckling corresponding to N = 0 circumferential waves predicted from the actual BIGBOSOR4 eigenvalue analysis occurs in the same shell segment as predicted by the analysis of initial loss of pre-buckling MERIDIONAL tension.

The same relationship between predictions from the analysis of initial loss of tension and the bifurcation buckling load factor from the BIGBOSOR4 bifurcation buckling (eigenvalue) analysis holds for the minimum load factor corresponding to the initial loss of CIRCUMFERENTIAL tension. This load factor, called "EIGEN2" above, is equal to 2.97831 and occurs at nodal point 17 in "shell" segment 38. The "initial loss of CIRCUMFERENTIAL tension" load factor, 2.97831, is fairly close to the critical buckling load factor obtained from BIGBOSOR4, 3.1851, corresponding to 64 circumferential waves. The local buckling mode corresponding to the eigenvalue, 3.1851, obtained from BIGBOSOR4 is displayed in Fig. 19. Local buckling corresponding to N = 64 circumferential waves predicted from the actual BIGBOSOR4 eigenvalue analysis occurs in the same shell segment as predicted by the analysis of initial loss of pre-buckling CIRCUMFERENTIAL tension.

Note that the minimum of these loss-of-tension "eigenvalues" (load factors) is used as a new behavioral variable called TENLOS, with associated allowable, TENLOSA, and factor of safety, TENLOSF. A new buckling margin:

```
  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
```

has been introduced, as described in ITEMs 2 and 3 above.

ITEM 9. At the date of this writing it has not been possible to obtain a general buckling mode for the spherical balloon. As with the cylindrical balloon, the local buckling eigenvalues are clustered closely together. However, in the case of the cylindrical balloon the general buckling mode is sometimes the mode that corresponds to the lowest eigenvalue. That seems always to be so for optimized cylindrical balloons with radial webs. In the case of the spherical balloon the general buckling mode as of this writing has corresponded to an eigenvalue that is higher than at least 50 eigenvalues all of which correspond to local buckling. For example, for the optimized spherical balloon with 8 modules over 90 meridional degrees and with radial webs, the following 50 eigenvalues, all of which correspond to local buckling with N = 0 circumferential waves (axisymmetric buckling), are:

3.6727, 3.6789, 3.6817, 3.6818, 3.6823, 3.6842, 3.6951, 3.6958, 3.7016, 3.7037,
3.7158, 3.7172, 3.7190, 3.7237, 3.7322, 3.7328, 3.7379, 3.7388, 3.7449, 3.7506,
3.7521, 3.7558, 3.7671, 3.7703, 3.7725, 3.7764, 3.7767, 3.7825, s.7929, 3.8004,
3.8024, 3.8052, 3.8120, 3.8157, 3.8164, 3.8251, 3.8292, 3.8337, 3.8413, 3.8524,
3.8555, 3.8661, 3.8727, 3.8772, 3.8854, 3.8856, 3.8899, 3.8921, 3.8961, 3.9024

In order to obtain more than one eigenvalue for a given number of circumferential waves it was necessary temporarily to change behavior.new and bosdec.src. SUBROUTINE BEHX1 of the behavior.new library was temporarily changed by commenting out the following statements:

```
        IF (ITYPEX.EQ.2) THEN
          NMAXB = 20*NMODUL
```

```
          INCRB = NMAXB/10
          IF (INCRB.LT.1) INCRB = 1
        ENDIF
```

SUBROUTINE BOSDEC was temporarily changed by setting NVEC = 50 instead of NVEC = 1 .

A plot of the buckling mode corresponding to the 45th eigenvalue for N = 0 circumferential waves (axisymmetric buckling) is given in **Fig. 20.**

==

Table 9 The try4.OPM file corresponding to the optimized spherical balloon with 8 modules over 90 degrees of the meridian and with truss-like (slanted) webs (Figs. 5, 6, 10a-k). The material is polyethylene terephthalate.

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

 ************ END OF THE  try4.OPT  FILE ***********
 ************ AUGUST, 2010 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  try4.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 try4.  Results are stored in the file  try4.OPM.
 Please inspect try4.OPM before doing more design iterations.
 ************************************************************


Item 2
 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     N     N      0    0.00E+00  3.00E+01 3.6330E+01  4.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.20E+01 1.2000E+01  2.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  1.60E+01 1.6000E+01  3.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  3.00E-02 9.0320E-02  3.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  3.00E-02 1.0370E-01  3.00E-01
thickness of the outer curved membrane: TOUTER
```

```
   6   Y     N     N      O    0.00E+00  3.00E-02 7.0670E-02  3.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     N     N      O    0.00E+00  2.00E-02 4.6630E-02  3.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      O    0.00E+00  3.00E-02 1.0730E-01  3.00E-01
thickness of each truss-core web: TFWEBS

BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************* TYPE OF BALLOON AND WEBS **************
 ISHAPE = 2
 IWEBS  = 2
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL=  8
 The balloon has truss-like (slanted) webs (Fig. 2).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************
```

Item 3:
Pressures: PINNER,PMIDDL,POUTER= 0.0000E+00 6.0000E+01 5.0000E+00
Factors of safety: BUCKB4F,TENLOSF= 3.0000E+00 3.0000E+00
****

Item 4:
BIGBOSOR4 input file for: pre-buckling state of the balloon, Load Set B try4.LOADB

Item 5:
Total weight of the spherical balloon from BIGBOSOR4, 2 x TOTMAS= 1.6817E+04

Item 6:
Newton iterations required to solve the nonlinear axisymmetric pre-buckling equilibrium state for the "fixed" loads, PINNER= 0.0000E+00, PMIDDL= 6.0000E+01, DELTAT= 0.0000E+00

LOAD STEP	Newton iterations	Maximum displacement
1	3	3.722723E-02 ←See Fig. 5
2	7	6.107878E-01
3	3	1.183419E+00
4	2	1.744881E+00
5	2	2.298252E+00
6	2	2.845447E+00
7	2	3.387824E+00
8	2	3.926395E+00
9	2	4.461987E+00
10	2	4.997915E+00
11	2	5.532170E+00 ←See Fig. 6

Item 7:
BIGBOSOR4 input file for: general buckling load
try4.BEHX1
Ordinarily, the file called try4.BEHX1 which contains valid input data for BIGBOSOR4, would be used for an execution of BIGBOSOR4 independently of the GENOPT environment. However, that BIGBOSOR4 execution will probably fail in this case because of failure of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to the application of the "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not presently have the capability to divide Load Set B into sub-steps.

```
 (FN1MAX(ISEG),ISEG=1,6)=
  5.4538E+02  1.1624E+03  1.0047E+03  9.0444E+02  9.2940E+02  1.1563E+03
 (FN2MAX(ISEG),ISEG=1,6)=
  5.3897E+02  8.2642E+02  3.9622E+02  5.6418E+02  5.9253E+02  6.0698E+02
```

Item 8:

```
 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,6)=
  4.1852E+00  1.0336E+01  3.3225E+00  4.1526E+01  1.3756E+01  1.0723E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,6)=
  3.9706E+00  6.1667E+00  2.9975E+00  4.7607E+00  6.4252E+00  4.3811E+00
```

Buckling load factor corresponding to the initial loss of either meridional or circumferential tension, EIGMIN= 2.9975E+00

Item 9:

```
 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.4014E+00(     0)  ←Fig. 10a
        3.3378E+00(     8)  ←Fig. 10b
        3.2024E+00(    16)  ←Fig. 10c
        3.1641E+00(    24)  ←Fig. 10d
        3.1438E+00(    32)  ←Fig. 10e
        3.1331E+00(    40)  ←Fig. 10f
        3.1332E+00(    48)  ←Fig. 10g
        3.1311E+00(    56)  ←Fig. 10h
        3.1317E+00(    64)  ←Fig. 10i
        3.1313E+00(    72)  ←Fig. 10j
        3.1318E+00(    80)  ←Fig. 10k
 Critical buckling load factor, BUCKB4=  3.1311E+00
 Critical number of circumferential full-waves, NWVCRT=   56

 MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS
                  "fixed"       "total"
                Load Step 1   Load Step 2
```

Seg.J	Node I	N1FIX(I,J)	N1VAR(I,J)
25	5	5.45383E+02	4.16955E+02
8	5	1.16242E+03	1.07982E+03
45	5	1.00473E+03	7.17405E+02
10	5	9.04444E+02	9.01592E+02
47	5	9.29396E+02	8.69615E+02
6	29	1.15628E+03	1.07464E+03

MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS

		"fixed"	"total"
		Load Step 1	Load Step 2
Seg.J	Node I	N2FIX(I,J)	N2VAR(I,J)
1	29	5.38969E+02	4.68784E+02
20	11	8.26417E+02	6.96938E+02
33	5	3.96220E+02	2.75190E+02
4	18	5.64182E+02	5.73719E+02
29	29	5.92533E+02	5.10820E+02
24	29	6.06976E+02	5.07974E+02

Item 10:

MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION

			"fixed"	**"total"**
			Load Step 1	**Load Step 2**
Seg.J	**Node I**	**EIGEN1(I,J)**	**N1FIX(I,J)**	**N1VAR(I,J)**
19	**23**	**4.18542E+00**	**5.04333E+02**	**3.83836E+02**
8	**29**	**1.03357E+01**	**8.62023E+02**	**7.78621E+02**
15	**26**	**3.32273E+00**	**5.53936E+02**	**3.87225E+02**
40	**29**	**4.15260E+01**	**7.50176E+02**	**7.32110E+02**
47	**29**	**1.37559E+01**	**8.44419E+02**	**7.83033E+02**
18	**29**	**1.07235E+01**	**1.01530E+03**	**9.20618E+02**

MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION

			"fixed"	**"total"**
			Load Step 1	**Load Step 2**
Seg.J	**Node I**	**EIGEN2(I,J)**	**N2FIX(I,J)**	**N2VAR(I,J)**
19	**16**	**3.97058E+00**	**3.09937E+02**	**2.31879E+02**
14	**9**	**6.16668E+00**	**7.85770E+02**	**6.58348E+02**
45	**17**	**2.99753E+00**	**3.57905E+02**	**2.38506E+02**
46	**17**	**4.76068E+00**	**3.72913E+02**	**2.94581E+02**
47	**5**	**6.42517E+00**	**4.66795E+02**	**3.94144E+02**
18	**16**	**4.38109E+00**	**2.22888E+02**	**1.72013E+02**

Item 11:

PREBUCKLING MEMBRANE STRESSES COMPUTED FROM
N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:

MAXIMUM PREBUCKLING MERIDIONAL MEMBRANE STRESSES

		"fixed"	**"total"**
		Load Step 1	**Load Step 2**
Seg.J	**Node I**	**STRS1F(I,J)**	**STRS1V(I,J)**
25	**5**	**1.16960E+04**	**8.94178E+03**
8	**5**	**1.12094E+04**	**1.04129E+04**

```
  45      5   1.42172E+04   1.01515E+04
  10      5   1.00138E+04   9.98220E+03
  47      5   8.66166E+03   8.10452E+03
   6     29   1.07762E+04   1.00153E+04

 MAXIMUM PREBUCKLING CIRCUMFERENTIAL MEMBRANE STRESSES
                "fixed"       "total"
              Load Step 1   Load Step 2
 Seg.J  Node I STRS2F(I,J)   STRS2V(I,J)
    1     29   1.15584E+04   1.00533E+04
   20     11   7.96930E+03   6.72072E+03
   33      5   5.60662E+03   3.89401E+03
    4     18   6.24647E+03   6.35207E+03
   29     29   5.52221E+03   4.76067E+03
   24     29   5.65681E+03   4.73414E+03
```

Item 12:

```
 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=  1
 Maximum displacement,                         FMAX=  5.5215E+00

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=  2
 Maximum displacement,                         FMAX=  4.2222E+00

    1        3.131052      buckling load factor from BIGBOSOR4: BUCKB4(1 )
    2        2.997535      load factor for tension loss: TENLOS(1 )
```

************************** **IMPORTANT NOTE** *****************************

NOTE: After these results were obtained the "balloon" software, SUBROUTINE BEHX1, was modified so that the buckling constraint, "**buckling load factor from BIGBOSOR4: BUCKB4(1)**" is now computed with the use of only the load factor corresponding to n = 0 circumferential waves, in this case: **3.4014E+00(n = 0)** Therefore, if this case was to be re-run the first behavioral constraint would now read:

1   3.40140   buckling load factor from BIGBOSOR4: BUCKB4(1)

and the buckling margin (Margin No. 1 listed below in Item 15 as:

1   4.368E-02 (BUCKB4(1)/BUCKB4A(1)) / BUCKB4F(1)-1; F.S.= 3.00

would now read:

1   1.338E-01 (BUCKB4(1)/BUCKB4A(1)) / BUCKB4F(1)-1; F.S.= 3.00

************************ **END OF IMPORTANT NOTE** ***************************

Item 13:

```
 ***************************************************************
 ****** MIN.STRESS CONSTRAINTS INCLUDING BENDING STRESS ******
 Bending stresses are printed here only for your information.
 Bending stresses are NOT included in the computation of the
 stress constraints or the stress margins, which are obtained
 from the maximum stress resultants divided by the "shell"
```

segment wall thickness. Therefore, the stress margins printed below are probably unconservative, especially at "shell" segment junctions where there are probably large, very local bending stress concentrations. In fabricating the balloon, reinforce the seams at "shell" junctions to avoid failure.

BIGBOSOR4 input file for: stress components in materials 1,2,3
try4.BEHX3
Ordinarily, the file called try4.BEHX3 which contains valid input data for BIGBOSOR4, would be used for an execution of BIGBOSOR4 independently of the GENOPT environment. However, that BIGBOSOR4 execution will probably fail in this case because of failure of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to the application of the "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not presently have the capability to divide Load Set B into sub-steps.

```
 Minimum stress constraints in the entire structure at the last load step (from
BIGBOSOR4):
  1  1.2174E-01 effect. stress: matl=1 ,  A , seg=4 , node=1 , layer=1 ,z=-0.05
  2  4.1881E-01 effect. stress: matl=2 ,  A , seg=7 , node=1 , layer=1 ,z= 0.02
  3  1.1871E-01 effect. stress: matl=3 ,  A , seg=5 , node=1 , layer=1 ,z= 0.05

 FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
    fiber tension  fiber compres  transv tension transv compres in-plane shear
  or effect.stress
 Material 1 stress: STRC1(ILOADX,J),J=1,5)=
    8.2143E+04     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 Material 2 stress: STRC2(ILOADX,J),J=1,5)=
    2.3877E+04     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 Material 3 stress: STRC3(ILOADX,J),J=1,5)=
    8.4242E+04     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
```

********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********
****

Item 14:
The maximum stresses from membrane theory (no bending) follow. It is these much smaller stress components that are used to compute the stress margins listed below and that are used as constraints during optimization cycles.

```
    3        10412.90      stress component in material 1: STRM1(1 ,1 )
    4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
    5        6720.717      stress component in material 1: STRM1(1 ,3 )
    6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
    7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
    8        10151.48      stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
```

```
  10        10053.28      stress component in material 2: STRM2(1 ,3 )
  11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
  12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

 BEHAVIOR OVER J =  stress component number
  13        10015.27      stress component in material 3: STRM3(1 ,1 )
  14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
  15        4760.668      stress component in material 3: STRM3(1 ,3 )
  16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
  17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

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

BEH.   CURRENT
NO.     VALUE            DEFINITION
 1    3.131E+00    buckling load factor from BIGBOSOR4: BUCKB4(1 )
 2    2.998E+00    load factor for tension loss: TENLOS(1 )
 3    1.041E+04    stress component in material 1: STRM1(1 ,1 )
 4    1.000E-10    stress component in material 1: STRM1(1 ,2 )
 5    6.721E+03    stress component in material 1: STRM1(1 ,3 )
 6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
 7    1.000E-10    stress component in material 1: STRM1(1 ,5 )
 8    1.015E+04    stress component in material 2: STRM2(1 ,1 )
 9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
10    1.005E+04    stress component in material 2: STRM2(1 ,3 )
11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
13    1.002E+04    stress component in material 3: STRM3(1 ,1 )
14    1.000E-10    stress component in material 3: STRM3(1 ,2 )
15    4.761E+03    stress component in material 3: STRM3(1 ,3 )
16    1.000E-10    stress component in material 3: STRM3(1 ,4 )
17    1.000E-10    stress component in material 3: STRM3(1 ,5 )

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

Item 15:

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

MARGIN CURRENT
NO.     VALUE            DEFINITION
 1    4.368E-02  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
 2   -8.217E-04  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
 3   -3.965E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
 4    4.879E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
 5   -1.492E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
 6   -5.300E-03  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
 7   -1.524E-03  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
 8    1.101E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00
```

Item 16:

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

 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.682E+04  weight/length of the balloon: WEIGHT
```

(NOTE: Although the definition of the objective is:
"**weight/length of the balloon**"
the objective, 1.682E+04, is actually the total weight of the spherical balloon.)

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

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


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

 VAR.   CURRENT
 NO.     VALUE            DEFINITION
```

Item 17:

```
  1    6.000E+03  length of the cylindrical shell: LENGTH
  2    1.200E+02  inner radius of the balloon: RADIUS
  3    4.351E+05  elastic modulus, meridional direction: EMOD1(1 )
  4    4.351E+05  elastic modulus, meridional direction: EMOD1(2 )
  5    4.351E+05  elastic modulus, meridional direction: EMOD1(3 )
  6    4.351E+05  elastic modulus, circumferential direction: EMOD2(1 )
  7    4.351E+05  elastic modulus, circumferential direction: EMOD2(2 )
  8    4.351E+05  elastic modulus, circumferential direction: EMOD2(3 )
  9    1.673E+05  in-plane shear modulus: G12(1 )
 10    1.673E+05  in-plane shear modulus: G12(2 )
 11    1.673E+05  in-plane shear modulus: G12(3 )
 12    1.673E+05  out-of-plane (s,z) shear modulus: G13(1 )
 13    1.673E+05  out-of-plane (s,z) shear modulus: G13(2 )
 14    1.673E+05  out-of-plane (s,z) shear modulus: G13(3 )
 15    1.673E+05  out-of-plane (y,z) shear modulus: G23(1 )
 16    1.673E+05  out-of-plane (y,z) shear modulus: G23(2 )
 17    1.673E+05  out-of-plane (y,z) shear modulus: G23(3 )
 18    3.000E-01  Poisson ratio: NU(1 )
 19    3.000E-01  Poisson ratio: NU(2 )
 20    3.000E-01  Poisson ratio: NU(3 )
 21    1.000E-10  meridional coef. thermal expansion: ALPHA1(1 )
 22    1.000E-10  meridional coef. thermal expansion: ALPHA1(2 )
 23    1.000E-10  meridional coef. thermal expansion: ALPHA1(3 )
 24    1.000E-04  circumf.coef.thermal expansion: ALPHA2(1 )
 25    1.000E-04  circumf.coef.thermal expansion: ALPHA2(2 )
```

```
 26    1.000E-04  circumf.coef.thermal expansion: ALPHA2(3 )
 27    0.000E+00  delta-T from fabrication temperature: TEMPER(1 )
 28    0.000E+00  delta-T from fabrication temperature: TEMPER(2 )
 29    0.000E+00  delta-T from fabrication temperature: TEMPER(3 )
 30    1.000E-01  weight density of material: DENSTY(1 )
 31    1.000E-01  weight density of material: DENSTY(2 )
 32    1.000E-01  weight density of material: DENSTY(3 )

 PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    0.000E+00  pressure inside the inner membrane: PINNER(1 )
  2    6.000E+01  pressure between inner and outer membranes: PMIDDL(1 )
```

Item 18:

3   5.000E+00 pressure outside the outer membrane: POUTER(1)

```
 PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.000E+00  buckling from BIGBOSOR4 allowable: BUCKB4A(1 )
  2    1.000E+00  tension loss allowable (Use 1.0): TENLOSA(1 )
  3    1.000E+04  allowable stress in material 1: STRM1A(1 ,1 )
  4    1.000E+04  allowable stress in material 1: STRM1A(1 ,2 )
  5    1.000E+04  allowable stress in material 1: STRM1A(1 ,3 )
  6    1.000E+04  allowable stress in material 1: STRM1A(1 ,4 )
  7    1.000E+04  allowable stress in material 1: STRM1A(1 ,5 )
  8    1.000E+04  allowable for stress in material 2: STRM2A(1 ,1 )
  9    1.000E+04  allowable for stress in material 2: STRM2A(1 ,2 )
 10    1.000E+04  allowable for stress in material 2: STRM2A(1 ,3 )
 11    1.000E+04  allowable for stress in material 2: STRM2A(1 ,4 )
 12    1.000E+04  allowable for stress in material 2: STRM2A(1 ,5 )
 13    1.000E+04  allowable for stress in material 3: STRM3A(1 ,1 )
 14    1.000E+04  allowable for stress in material 3: STRM3A(1 ,2 )
 15    1.000E+04  allowable for stress in material 3: STRM3A(1 ,3 )
 16    1.000E+04  allowable for stress in material 3: STRM3A(1 ,4 )
 17    1.000E+04  allowable for stress in material 3: STRM3A(1 ,5 )


 PARAMETERS WHICH ARE FACTORS OF SAFETY
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
```

Item 19:

1   3.000E+00 buckling from BIGBOSOR4 factor of safety: BUCKB4F(1)

2   3.000E+00 tension loss factor of safety: TENLOSF(1)

```
  3    1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,1 )
  4    1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,2 )
  5    1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,3 )
  6    1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,4 )
  7    1.000E+00  factor of safety for stress in material 1: STRM1F(1 ,5 )
  8    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,1 )
  9    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,2 )
 10    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,3 )
 11    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,4 )
 12    1.000E+00  factor of safety for stress in material 2: STRM2F(1 ,5 )
```

```
13    1.000E+00  factor of safety for stress in material 3: STRM3F(1 ,1 )
14    1.000E+00  factor of safety for stress in material 3: STRM3F(1 ,2 )
15    1.000E+00  factor of safety for stress in material 3: STRM3F(1 ,3 )
16    1.000E+00  factor of safety for stress in material 3: STRM3F(1 ,4 )
17    1.000E+00  factor of safety for stress in material 3: STRM3F(1 ,5 )

   0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED



DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

try4.NAM = This file contains only the name of the case.
try4.OPM = Output data. Please list this file and inspect
           carefully before proceeding.
try4.OPP = Output file containing evolution of design and
           margins since the beginning of optimization cycles.
try4.CBL = Labelled common blocks for analysis.
           (This is an unformatted sequential file.)
try4.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 try4.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 try4.OPM FILE ****************
==================================================================
```

Table 10 The part of SUBROUTINE BEHX1 (which is contained in the behavior.balloon library) that is concerned with obtaining buckling load factors from a BIGBOSOR4 stability analysis in which the BIGBOSOR4 analysis index, INDIC = 1

```
========================================================================
C BEG DEC 2010
C  Next, solve the bifurcation buckling equations
C  with use of the INDIC = 1 strategy in BIGBOSOR4.
C  The vector, FTOTX, contains the solution of the
C  pre-buckling equilibrium equations for the balloon
C  loaded by PINNER, PMIDDL, and DELTAT, that is, the
C  loads in Load Set B, the "fixed" (non-eigenvalue)
C  loads. This is the starting vector for the Newton
C  iterations for the solution of the nonlinear
C  pre-buckling equilibrium equations for the balloon
C  loaded by PINNER, PMIDDL, DELTAT, and POUTER, that is,
C  the TOTAL loads on the balloon. The eigenvalue
C  problem is:
C
C     [A] + eigenvalue x [B] = 0
C
C  in which [A] is the stiffness matrix of the balloon
C  as loaded by Load Set B only, and [B] is the load-
C  geometric matrix of the balloon as loaded by the
C  difference: (TOTAL load) - (Load Set B).
C
C  The input file, *.ALL, for BIGBOSOR4 is generated
C  by the statement below:
C
C     CALL BOSDEC(1,24,ILOADX,INDIC)
C
C  and the bifurcation buckling eigenvalue problem is
C  solved via the stementa below:
C
C     CALL B4READ
C     CALL B4MAIN
C
C  Bifurcation buckling mode shapes are produced via
C  the following statement below:
C
C     IF (ITYPEX.EQ.2) CALL B4POST
C
C  SUBROUTINE B4POST generates the file, *.PLT2, in
C  which "*" denotes the end-user-selected specific
C  name for the case (e.g. "try4"). Plots of the
C  bifurcation buckling mode shapes are obtained
C  as follows:
C
C  cd /home/progs/work6       (go to a working directory
```

```
C                              for execution of BIGBOSOR4
C                              processors)
C
C  cp ../genoptcase/try4.PLT2 .  (get the *.PLT2 file)
C
C  bigbosor4log               (activate BIGBOSOR4 commands)
C
C  bosorplot                  (generate plots)
C
C END DEC 2010
      IFTOTS = IFTOT
      M22B4 = 2*M2B4
      CALL GASP(FTOTX,M22B4,3,IFTOT)
      CALL GASP(DUM1,DUM2,-2,DUM3)
C
      INDIC = 1
C BEG NOV 2010
      IF (IMODX.EQ.0) IABORT = 0
      IF (ISHAPE.EQ.1) THEN
        N0B = 1
        NMAXB = 1
        INCRB = 1
      ELSE
        N0B = 0
        NMAXB = 0
        INCRB = 1
C BEG DEC 2010
C  Perhaps comment out the following block because of the possible
C  existence of spurious modes and very low spurious eigenvalues:
        IF (ITYPEX.EQ.2) THEN
          NMAXB = 10*NMODUL
          INCRB = NMAXB/10
          IF (INCRB.LT.1) INCRB = 1
        ENDIF
C END DEC 2010
      ENDIF
      IF (IABORT.EQ.1) THEN
          WEIGHT = 10.E20
          TOTMAS = 10.E20
          GO TO 1000
      ENDIF
C END NOV 2010
      WRDCOL = '                                                   '
      CALL BOSDEC(1,24,ILOADX,INDIC)
C
      IF (ITYPEX.EQ.2) THEN
C      Get CASE.BEHX1 file for input for BIGBOSOR4...
C      CASE.BEHX1 is an input file for BIGBOSOR4 for behavior no. 1:
C      buckling load from BIGBSOSOR4
         I=INDEX(CASE,' ')
         IF(I.NE.0) THEN
            CASA=CASE(:I-1)//'.BEHX1'
         ELSE
            CASA=CASE//'.BEHX1'
```

```
         ENDIF
         OPEN(UNIT=61,FILE=CASA,STATUS='UNKNOWN')
         CALL BOSDEC(1,61,ILOADX,INDIC)
         CLOSE(UNIT=61)
         WRITE(IFILE,'(/,/,A,A,/,A)')
     1 ' BIGBOSOR4 input file for:',
     1 ' general buckling load',
     1   CASA
C BEG DEC 2010
C23456789012345678901234567890123456789012345678901234567890123456789012
         IF (ISHAPE.EQ.2)
     1   WRITE(IFILE,'(A,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A,/,A)')
     1 ' Ordinarily, the file called ',CASA,
     1 ' which contains valid input data for BIGBOSOR4,',
     1 ' would be used for an execution of BIGBOSOR4 independently',
     1 ' of the GENOPT environment. However, that BIGBOSOR4 execution',
     1 ' will probably fail in this case because of failure of the',
     1 ' Newton iterations for solution of the nonlinear pre-buckling',
     1 ' equilibrium equations corresponding to the application of the',
     1 ' "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and',
     1 ' PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not',
     1 ' presently have the capability to divide Load Set B into sub-',
     1 ' steps.'
C END DEC 2010
      ENDIF
C
      CALL B4READ
      IF (IMODX.EQ.0) THEN
         N0BX = N0B
         NMINBX = N0B
         NMAXBX = NMAXB
         INCRBX = INCRB
      ELSE
         NOBX = NWAV1
         NMINBX = NWAV1
         NMAXBX = NWAV1
         INCRBX = INCRB
      ENDIF
      REWIND IFILE9
      CALL STOCM1(IFILE9)
      CALL STOCM2(IFILE9)
      CALL B4MAIN
C BEG NOV 2010
      IF (ITYPEX.EQ.2) CALL B4POST
C END NOV 2010
      CALL GASP(DUM1,DUM2,-2,DUM3)
========================================================================
```

Table 11 The following is the difference between the version of addbosor4.src to be used with GENOPT, that is: /home/progs/bosdec/sources/addbosor4.src and the version of addbosor4.src that is part of the BIGBOSOR4 software, that is: /home/progs/bigbosor4/sources/addbosor4.src

==

```
The following list was obtained via the command:
diff /home/progs/bosdec/sources/addbosor4.src
/home/progs/bigbosor4/sources/addbosor4.src > addbosor4.diff
----------------------------------------------------------------------
1477,1480c1477
< C BEG OCT 2010
< C     ERR = 0.001
<       IF (ERR.NE.0.01) ERR = 0.001
< C END OCT 2010
---
>       ERR = 0.001
1736,1738c1733
< C BEG FEB 2010
< C     IF (IREST.NE.0) CALL GASP(DUM1,DUM2,-1,DUM3)
< C END FEB 2010
---
>       IF (IREST.NE.0) CALL GASP(DUM1,DUM2,-1,DUM3)
12714,12717d12708
< C BEG NOV 2010
<       COMMON/CODWRX/CODWRD
<       CHARACTER*20 CODWRD
< C END NOV 2010
12720,12723d12710
<       DOUBLE PRECISION FTOTX
<       COMMON/FPREBX/FMAXST(200),FTOTX(20000)
<       COMMON/IFPREB/IFTOTS
< C END OCT 2010
12783,12787d12769
< C BEG OCT 2010
<       IF (IFTOTS.NE.0) THEN
<          CALL MOVER(FTOTX,1,FTOT,1,M22)
<       ENDIF
< C END OCT 2010
12965,12972c12947
< C BEG OCT 2010
< C     CALL UNLOAD(V,HF,FM,NSEG1)
<       IABORT = 0
< C BEG NOV 2010
```

```
<       CALL UNLOAD(V,HF,FM,NSEG1,IABORT,CODWRD)
< C END NOV 2010
<       IF (IABORT.EQ.2) GO TO 340
< C END OCT 2010
---
>       CALL UNLOAD(V,HF,FM,NSEG1)
12999,13002c12974
<       IF (INDIC.NE.1) THEN
<          ITRSTP(ISTEP) = ITER
<          FMAXST(ISTEP) = FMAX
<       ENDIF
---
>       IF (INDIC.NE.1) ITRSTP(ISTEP) = ITER
13004,13011c12976,12977
<          IF (IFIX.EQ.1) THEN
<             ITRSTP(1) = ITER
<             FMAXST(1) = FMAX
<          ENDIF
<          IF (IFIX.EQ.0) THEN
<             ITRSTP(2) = ITER
<             FMAXST(2) = FMAX
<          ENDIF
---
>          IF (IFIX.EQ.1) ITRSTP(1) = ITER
>          IF (IFIX.EQ.0) ITRSTP(2) = ITER
13084,13090c13050
< C BEG OCT 2010
<       IF (IABORT.NE.2) THEN
<        WRDCOL= 'SHELL COLLAPSES AXISYMMETRICALLY AT P='//CNPRES
<       ELSE
<        WRDCOL= 'INITIAL LOADS TOO HIGH FOR THIS STRUCT'//CNPRES
<       ENDIF
< C END OCT 2010
---
>       WRDCOL = 'SHELL COLLAPSES AXISYMMETRICALLY AT P='//CNPRES
13097,13103c13057,13059
< C BEG OCT 2010
<       IF (IABORT.NE.2) THEN
<        CALL CONVRF(PSTEP(ISTEP),CNPRES)
<        WRDCOL= 'SHELL COLLAPSES AXISYMMETRICALLY AT P='//CNPRES
<        WRITE(IFILE4,'(A)') WRDCOL
<       ENDIF
< C END OCT 2010
---
>       CALL CONVRF(PSTEP(ISTEP),CNPRES)
>       WRDCOL = 'SHELL COLLAPSES AXISYMMETRICALLY AT P='//CNPRES
>       WRITE(IFILE4,'(A)') WRDCOL
13107,13108c13063
< C BEG NOV 2010
< 370   FORMAT(/,' NO CONVERGENCE IN PREBUCKLING ANALYSIS AFTER 20',
---
> 370   FORMAT(/,' NO CONVERGENCE IN PREBUCKLING ANALYSIS AFTER 10',
13110d13064
< C END NOV 2010
```

```
13199,13204c13153
< C BEG OCT 2010
< C     SUBROUTINE UNLOAD(V,HF,FM,K)
< C BEG NOV 2010
<       SUBROUTINE UNLOAD(V,HF,FM,K,IABORT,CODWRD)
< C END NOV 2010
< C END OCT 2010
---
>       SUBROUTINE UNLOAD(V,HF,FM,K)
13211,13221d13159
< C BEG NOV 2010
< C "CODWRD" introduced to be able to provide a special strategy
< C for the generic case, "BALLOON".
<       CHARACTER*20 CODWRD
< C END NOV 2010
< C BEG OCT 2010
<       COMMON/PSTEPX/PSTEP(200),ENDUVS(200)
<       COMMON/WRDCLX/WRDCOL
<       CHARACTER*45 WRDCOL
<       CHARACTER*7 CNPRES
< C END OCT 2010
13231,13241d13168
< C BEG NOV 2010
< C  If the code word is "BALLOON" we do not want to unload,
< C  and we want to set WRDCOL to "INITIAL..." and IABORT = 2
<       ILET = INDEX(CODWRD,'BALLOON')
<       IF (ILET.NE.0) THEN
<          CALL CONVRF(PSTEP(ISTEP),CNPRES)
<          WRDCOL = 'INITIAL LOADS TOO HIGH FOR THIS STRUCT'//CNPRES
<          IABORT = 2
<          RETURN
<       ENDIF
< C END NOV 2010
13250,13258c13177
< C BEG OCT 2010
<       CALL CONVRF(PSTEP(ISTEP),CNPRES)
< C     WRDCOL = 'SHELL COLLAPSES AXISYMMETRICALLY AT P='//CNPRES
<       WRDCOL = 'INITIAL LOADS TOO HIGH FOR THIS STRUCT'//CNPRES
<       WRITE(IFILE4,'(A)') WRDCOL
<       IABORT = 2
<       RETURN
< C     CALL ERREX
< C END OCT 2010
---
>       CALL ERREX
15408,15411c15327,15328
< C BEG NOV 2010
<       COMMON/N1N2FX/N1FIX(100,295),N2FIX(100,295)
<       COMMON/N1N2VR/N1VAR(100,295),N2VAR(100,295)
< C END NOV 2010
---
>       COMMON/N1N2FX/N1FIX(100,100),N2FIX(100,100)
>       COMMON/N1N2VR/N1VAR(100,100),N2VAR(100,100)
15572,15574c15489
```

```
< C BEG NOV 2010
<         IF (ISEG.LE.295) THEN
< C END NOV 2010
---
>         IF (ISEG.LE.100) THEN
========================================================================
```

Table 12 Optimum designs of spherical balloons with 35 modules (Material = polyethylene terephthalate)

===

PART 1a: SPHERICAL BALLOON WITH TRUSS-LIKE (SLANTED) WEBS AND POUTER = 5.0 psi, FACTORS OF SAFETY, BUCKB4F AND TENLOSF = 3.0

```
************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 2
 IWEBS  = 2
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL= 35
 The balloon has truss-like (slanted) webs (Fig. 2).


  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E+01 2.5280E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  2.75E+00 2.7500E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  3.45E+00 3.4910E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  2.00E-02 2.0920E-02  3.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  2.00E-02 2.3640E-02  3.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  2.00E-02 1.0300E-01  3.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  1.00E-02 1.1290E-02  3.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  2.00E-02 2.4630E-02  3.00E-01
thickness of each truss-core web: TFWEBS

 ******************** DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    8.252E+03  total weight of the spherical balloon: WEIGHT
 ******************** DESIGN OBJECTIVE *******************


 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
```

```
 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,6)=
  3.9769E+00  9.5702E+00  3.5145E+00  7.8362E+01  1.2085E+01  9.0361E+00

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,6)=
  3.7659E+00  5.3686E+00  2.8901E+00  4.5365E+00  4.4089E+00  3.5820E+00

 Buckling load factor corresponding to the initial loss of
 either meridional or circumferential tension, EIGMIN=  2.8901E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.6051E+00(     0)
        3.5298E+00(    35)
        3.4283E+00(    70)
        3.3879E+00(   105)
        3.4230E+00(   140)
        3.5253E+00(   175)
        3.6841E+00(   210)
        3.8060E+00(   245)
        3.8039E+00(   280)
        3.8034E+00(   315)
        3.8042E+00(   350)


 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1    1.293E-01  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -3.663E-02  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -2.943E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    5.169E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5    2.273E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    6.569E-01  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.985E-02  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.450E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00
----------------------------------------------------------------------
```

PART 1B: SPHERICAL BALLOON WITH TRUSS-LIKE (SLANTED) WEBS AND POUTER = 15.0 psi, FACTORS OF SAFETY, BUCKB4F AND TENLOSF = 1.0

```
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  1.5000E+01
 Factors of safety: BUCKB4F,TENLOSF=  1.0000E+00  1.0000E+00

 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,6)=
  1.2945E+00  3.2660E+00  1.1532E+00  2.6794E+01  4.0849E+00  2.9127E+00

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,6)=
  1.2809E+00  1.8359E+00  9.8997E-01  1.5811E+00  1.5273E+00  1.3336E+00


 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        1.1948E+00(     0)
        1.1760E+00(    35)
```

```
        1.1569E+00(    70)
        1.1487E+00(   105)
        1.1639E+00(   140)
        1.2009E+00(   175)
        1.2565E+00(   210)
        1.2918E+00(   245)
        1.2917E+00(   280)
        1.2919E+00(   315)
        1.2926E+00(   350)


 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE           DEFINITION
  1    1.487E-01  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  1.00
  2   -1.003E-02  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  1.00
  3    6.499E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    1.484E+00  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5    2.035E+00  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    4.851E+00  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.539E-01  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    3.642E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00
------------------------------------------------------------------------------
```

PART 2: SPHERICAL BALLOON WITH RADIAL WEBS AND POUTER = 5.0 psi, FACTORS OF SAFETY, BUCKB4F AND TENLOSF = 3.0

```
 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 2
 IWEBS  = 1
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL= 35
 The balloon has radial webs (Fig. 1).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************

STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E+01 2.8070E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  2.75E+00 2.7500E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  3.45E+00 3.8050E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  1.00E-02 2.4920E-02  3.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  1.00E-02 2.5930E-02  3.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  1.00E-02 9.5490E-02  3.00E-01
thickness of inner truss-core segment: TFINNR
```

```
   7   Y     N     N      0    0.00E+00  1.00E-02 3.5330E-02  3.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  1.00E-02 3.8890E-02  3.00E-01
thickness of each truss-core web: TFWEBS


 ******************** DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    8.295E+03  weight/length of the balloon: WEIGHT
 ******************** DESIGN OBJECTIVE *******************


 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00


 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=
  4.4168E+00  9.2776E+00  3.6790E+00  6.0051E+01  1.3294E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=
  4.1469E+00  5.5863E+00  2.8911E+00  4.0466E+00  4.3154E+00

 Buckling load factor corresponding to the initial loss of
 either meridional or circumferential tension, EIGMIN=  2.8911E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.7817E+00(     0)
        3.6856E+00(    35)
        3.5301E+00(    70)
        3.4460E+00(   105)
        3.4491E+00(   140)
        3.5258E+00(   175)
        3.6617E+00(   210)
        3.8473E+00(   245)
        4.0766E+00(   280)
        4.3288E+00(   315)
        4.3571E+00(   350)

 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1    2.606E-01  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -3.630E-02  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -3.219E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    3.819E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5    1.002E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    4.051E-01  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7   -2.404E-02  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.134E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00
==========================================================================
```

Table 13 Material properties of balloons fabricated of composite material (fictitious carbon fiber "cloth") which has high stress allowables that lead to much lighter balloons than those with weights plotted in Fig. 23. Compare Fig. 23 and Fig. 28.)

==

In this paper and in [1] it is assumed that each "shell" segment is fabricated with only one ply of material through the segment thickness. This ply is assumed to have "fibers" and a "fiber direction" as if it were a composite ply with fibers running in only one direction, despite the fact that in this study the ply actually has fibers running in two in-plane orthogonal directions (composite carbon “cloth”).

The "fibers" are assumed to be oriented in the direction of increasing arc length along a "shell" segment (**Figs.3 and 4**), called "meridional direction" in the text and in some of the definitions in this table.

In this particular case the material is a fictitious "cloth" in which the properties are the same "along the fibers" and "normal to the fibers" because, in the one layer through the thickness of each "shell" segment permitted by the "balloon" software, there are equal stiffnesses in the two orthogonal in-plane coordinate directions: meridional and circumferential.

NOTE: In the following list there exist out-of-plane shear stiffnesses, G13 and G23, defined by the GENOPT user and specified by the end user. However, note that BIGBSOSOR4 does not account for the effects of transverse shear deformation. Therefore, G13 and G23 play no role in the analysis and do not affect the results.

Some of the output listed near the end of the *.OPM file follows. Only the items relating to material properties are listed here. The array index i [e.g. EMOD1(i)], denotes the material number. **Figure 4** shows which parts of the complex balloon wall are fabricated with which of the three material types.

```
 PARAMETERS WHICH ARE ALWAYS FIXED.  NONE CAN BE DECISION VARIAB.
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  3    1.140E+07  elastic modulus, meridional direction: EMOD1(1 )
  4    1.140E+07  elastic modulus, meridional direction: EMOD1(2 )
  5    1.140E+07  elastic modulus, meridional direction: EMOD1(3 )
  6    1.140E+07  elastic modulus, circumferential direction: EMOD2(1 )
  7    1.140E+07  elastic modulus, circumferential direction: EMOD2(2 )
  8    1.140E+07  elastic modulus, circumferential direction: EMOD2(3 )
  9    6.790E+05  in-plane shear modulus: G12(1 )
 10    6.790E+05  in-plane shear modulus: G12(2 )
 11    6.790E+05  in-plane shear modulus: G12(3 )
 12    6.270E+05  out-of-plane (s,z) shear modulus: G13(1 )
 13    6.270E+05  out-of-plane (s,z) shear modulus: G13(2 )
 14    6.270E+05  out-of-plane (s,z) shear modulus: G13(3 )
```

```
 15    3.340E+05  out-of-plane (y,z) shear modulus: G23(1 )
 16    3.340E+05  out-of-plane (y,z) shear modulus: G23(2 )
 17    3.340E+05  out-of-plane (y,z) shear modulus: G23(3 )
 18    2.370E-02  Poisson ratio: NU(1 )
 19    2.370E-02  Poisson ratio: NU(2 )
 20    2.370E-02  Poisson ratio: NU(3 )
 21    1.000E-05  meridional coef. thermal expansion: ALPHA1(1 )
 22    1.000E-05  meridional coef. thermal expansion: ALPHA1(2 )
 23    1.000E-05  meridional coef. thermal expansion: ALPHA1(3 )
 24    1.000E-04  circumf.coef.thermal expansion: ALPHA2(1 )
 25    1.000E-04  circumf.coef.thermal expansion: ALPHA2(2 )
 26    1.000E-04  circumf.coef.thermal expansion: ALPHA2(3 )
 27    0.000E+00  delta-T from fabrication temperature: TEMPER(1 )
 28    0.000E+00  delta-T from fabrication temperature: TEMPER(2 )
 29    0.000E+00  delta-T from fabrication temperature: TEMPER(3 )
 30    5.700E-02  weight density of material: DENSTY(1 )
 31    5.700E-02  weight density of material: DENSTY(2 )
 32    5.700E-02  weight density of material: DENSTY(3 )
-----------------------------------------------------------------------

 Some definitions:
 STRMiA(1,j): i = material number; j = stress component number;
              The "1" in (1,j) means Load Set Number: ILOADX = 1
 STRMiA(1,1) = maximum allowable tensile stress along the fibers
 STRMiA(1,2) = maximum allowable compressive stress along the fibers
 STRMiA(1,3) = maximum allowable tensile stress normal to the fibers
 STRMiA(1,4) = maximum allowable compressive stress normal to the fibers
 STRMiA(1,5) = maximum allowable in-plane shear stress
---------------------------------------------------------------------
```

Some of the output listed near the end of the *.OPM file follows. Only the items relating to material properties are listed here.

```
 PARAMETERS WHICH ARE CLASSIFIED AS ALLOWABLES (e.g. max. stress)
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  3    7.560E+04  allowable for stress in material 1: STRM1A(1 ,1 )
  4    5.960E+04  allowable for stress in material 1: STRM1A(1 ,2 )
  5    7.560E+04  allowable for stress in material 1: STRM1A(1 ,3 )
  6    5.960E+04  allowable for stress in material 1: STRM1A(1 ,4 )
  7    6.290E+03  allowable for stress in material 1: STRM1A(1 ,5 )
  8    7.560E+04  allowable for stress in material 2: STRM2A(1 ,1 )
  9    5.960E+04  allowable for stress in material 2: STRM2A(1 ,2 )
 10    7.560E+04  allowable for stress in material 2: STRM2A(1 ,3 )
 11    5.960E+04  allowable for stress in material 2: STRM2A(1 ,4 )
 12    6.290E+03  allowable for stress in material 2: STRM2A(1 ,5 )
 13    7.560E+04  allowable for stress in material 3: STRM3A(1 ,1 )
 14    5.960E+04  allowable for stress in material 3: STRM3A(1 ,2 )
 15    7.560E+04  allowable for stress in material 3: STRM3A(1 ,3 )
 16    5.960E+04  allowable for stress in material 3: STRM3A(1 ,4 )
 17    6.290E+03  allowable for stress in material 3: STRM3A(1 ,5 )
========================================================================
```

Table 14 Optimized design of a spherical balloon made of fictitious carbon fiber cloth with 35 modules over 90 degrees of the meridian and with radial webs. This is an abridged version of the try7.OPM file generated with NPRINT = 2 and ITYPE = 2 (analysis of a fixed design).

```
==============================================================================
 STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  1.50E+01 2.1130E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  2.75E+00 2.7500E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  3.45E+00 3.4510E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  2.00E-03 3.0990E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  2.00E-03 3.2170E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  2.00E-03 6.8710E-03  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-03 4.2810E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  2.00E-03 4.9400E-03  2.00E-01
thickness of each truss-core web: TFWEBS

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        2.9541E+00(     0)  ← a real buckling mode (Fig. 29)
        3.5645E-01(    35)  ← a spurious buckling mode (Figs. 30,31)
        1.0988E+00(    70)  ← a spurious buckling mode
        2.8633E-01(   105)  ← a spurious buckling mode
        1.4390E-01(   140)  ← a spurious buckling mode
        3.4214E-01(   175)  ← a spurious buckling mode
        3.2825E-04(   210)  ← a spurious buckling mode
        2.2010E-02(   245)  ← a spurious buckling mode
        5.0503E-03(   280)  ← a spurious buckling mode
        4.8305E-01(   315)  ← a spurious buckling mode
        1.2113E+00(   350)  ← a spurious buckling mode


 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE           DEFINITION
  1   -1.530E-02  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -1.923E-02  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -3.910E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    9.089E-02  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
```

```
  5   -6.164E-04  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    6.952E-02  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.264E-02  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.382E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

 ******************* DESIGN OBJECTIVE *******************
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    4.522E+02  weight of the balloon: WEIGHT
 ******************* DESIGN OBJECTIVE *******************
======================================================================
```

Table 15 Optimized design of a spherical balloon made of carbon fiber cloth with 50 modules over 90 degrees of the meridian and with radial webs. This is an abridged version of the try7.OPM file generated with NPRINT = 2 and ITYPE = 2 (analysis of a fixed design).

```
=========================================================================
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     N     N      0    0.00E+00  1.50E+01 2.0680E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  1.90E+00 1.9000E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  2.40E+00 2.4470E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  2.00E-03 2.2800E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  2.00E-03 2.3840E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  2.00E-03 7.8820E-03  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  2.00E-03 3.7420E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  2.00E-03 3.4300E-03  2.00E-01
thickness of each truss-core web: TFWEBS


  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 2
 IWEBS  = 1
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL= 50
 The balloon has radial webs (Fig. 1).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *****************************************************


 BIGBOSOR4 input file for: pre-buckling state of the balloon, Load Set B
try7.LOADB
```

Total weight of the spherical balloon from BIGBOSOR4, 2 x TOTMAS=
4.2150E+02

Newton iterations required to solve the nonlinear
axisymmetric pre-buckling equilibrium state for the
"fixed" loads, PINNER= 0.0000E+00, PMIDDL= 6.0000E+01, DELTAT=
0.0000E+00

LOAD STEP	Newton iterations	Maximum displacement	
1	7	1.341529E-02	
2	7	2.047000E-01	
3	3	4.472704E-01	
4	2	6.929482E-01	
5	2	9.410489E-01	
6	2	1.192203E+00	
7	2	1.446907E+00	
8	2	1.706016E+00	
9	2	1.970408E+00	
10	2	2.240976E+00	
11	**2**	**2.518623E+00**	**←The axisymmetrically deformed balloon is shown in Fig.33a.**

BIGBOSOR4 input file for: general buckling load
try7.BEHX1
Ordinarily, the file called try7.BEHX1
which contains valid input data for BIGBOSOR4,
would be used for an execution of BIGBOSOR4 independently
of the GENOPT environment. However, that BIGBOSOR4 execution
will probably fail in this case because of failure of the
Newton iterations for solution of the nonlinear pre-buckling
equilibrium equations corresponding to the application of the
"fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
presently have the capability to divide Load Set B into sub-
steps.

(FN1MAX(ISEG),ISEG=1,5)=
4.0875E+02 1.5693E+02 8.9064E+02 1.1534E+02 2.7658E+02
(FN2MAX(ISEG),ISEG=1,5)=
2.8766E+02 2.0110E+02 7.3612E+02 1.8736E+02 1.4505E+02

LOSS OF **MERIDIONAL** TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=
3.2852E+00 8.4514E+00 **2.9874E+00** 1.1605E+02 1.4552E+01

LOSS OF **CIRCUMFERENTIAL** TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=
3.7188E+00 3.7781E+00 **3.0465E+00** 3.1052E+00 **3.0400E+00**

Buckling load factor corresponding to the initial loss of either meridional or circumferential tension, EIGMIN= 2.9874E+00

BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
3.0028E+00(0) ← real buckling mode
6.8044E-01(50) ← spurious buckling mode
5.0880E-01(100) ← spurious buckling mode

```
       5.6127E-02(   150)  ← spurious buckling mode
       6.7558E-02(   200)  ← spurious buckling mode
       2.2700E-01(   250)  ← spurious buckling mode
       2.1296E-01(   300)  ← spurious buckling mode
       7.0326E-02(   350)  ← spurious buckling mode
       3.8505E-01(   400)  ← spurious buckling mode
       3.9400E-01(   450)  ← spurious buckling mode
       3.9079E-01(   500)  ← spurious buckling mode
Critical buckling load factor, BUCKB4=  5.6127E-02 ←spurious buckling
Critical number of circumferential full-waves, NWVCRT=  150

MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS
                "fixed"       "total"
              Load Step 1   Load Step 2
Seg.J  Node I  N1FIX(I,J)    N1VAR(I,J)
 226       5   4.08735E+02   2.84716E+02
  32      28   1.56925E+02   1.38894E+02
  78       5   8.90637E+02   5.97135E+02
 244      14   1.15334E+02   1.15002E+02
  25       5   2.76575E+02   2.58653E+02

MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS
                "fixed"       "total"
              Load Step 1   Load Step 2
Seg.J  Node I  N2FIX(I,J)    N2VAR(I,J)
  21       5   2.87659E+02   2.12859E+02
  22      29   2.01101E+02   1.48157E+02 ← end of red curve, Fig.39
  23       5   7.36119E+02   5.08258E+02
  34       5   1.87357E+02   1.35636E+02 ← beginning of red curve, Fig.36
 240      29   1.45053E+02   1.08884E+02

MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION
                              "fixed"       "total"
                            Load Step 1   Load Step 2
Seg.J  Node I  EIGEN1(I,J)    N1FIX(I,J)    N1VAR(I,J)
 106       5   3.28555E+00   4.00312E+02   2.78472E+02
  22      29   8.45141E+00   1.56189E+02   1.37708E+02
 233       5   2.98766E+00   8.59577E+02   5.71868E+02
  49      29   1.16055E+02   1.12342E+02   1.11374E+02
 160      29   1.45537E+01   2.48164E+02   2.31112E+02

MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION
                              "fixed"       "total"
                            Load Step 1   Load Step 2
Seg.J  Node I  EIGEN2(I,J)    N2FIX(I,J)    N2VAR(I,J)
  46      16   3.71884E+00   2.56258E+02   1.87350E+02
  32      29   3.77807E+00   1.95227E+02   1.43554E+02
 248      16   3.04668E+00   2.94411E+02   1.97778E+02
 249      16   3.10541E+00   8.18931E+01   5.55220E+01
  55       7   3.04000E+00   5.47408E+01   3.67340E+01

PREBUCKLING MEMBRANE STRESSES COMPUTED FROM
N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:
```

```
 MAXIMUM PREBUCKLING MERIDIONAL MEMBRANE STRESSES
                "fixed"       "total"
              Load Step 1   Load Step 2
 Seg.J  Node I STRS1F(I,J)   STRS1V(I,J)
  226      5   1.09229E+05   7.60866E+04
   32     28   6.58244E+04   5.82607E+04
   78      5   1.12996E+05   7.57594E+04
  244     14   5.05852E+04   5.04394E+04
   25      5   8.06342E+04   7.54091E+04

 MAXIMUM PREBUCKLING CIRCUMFERENTIAL MEMBRANE STRESSES
                "fixed"       "total"
              Load Step 1   Load Step 2
 Seg.J  Node I STRS2F(I,J)   STRS2V(I,J)
   21      5   7.68731E+04   5.68838E+04
   22     29   8.43546E+04   6.21465E+04
   23      5   9.33924E+04   6.44833E+04
   34      5   8.21742E+04   5.94893E+04
  240     29   4.22895E+04   3.17446E+04

 Behavior number, General buckling load factor:

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=  1
 Maximum displacement,                         FMAX=  2.5130E+00
 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=  2
 Maximum displacement,                         FMAX=  1.7134E+00

    1        3.002842      buckling load factor from BIGBOSOR4: BUCKB4(1 )
    2        2.987430      load factor for tension loss: TENLOS(1 )

  BEHAVIOR OVER J =  stress component number

 ************************************************************
 ****** MIN.STRESS CONSTRAINTS INCLUDING BENDING STRESS ******
 Bending stresses are printed here only for your information.
 Bending stresses are NOT included in the computation of the
 stress constraints or the stress margins, which are obtained
 from the maximum stress resultants divided by the "shell"
 segment wall thickness. Therefore, the stress margins printed
 below are probably unconservative, especially at "shell"
 segment junctions where there are probably large, very local
 bending stress concentrations. In fabricating the balloon,
 reinforce the seams at "shell" junctions to avoid failure.


 BIGBOSOR4 input file for: stress components in materials 1,2,3
try7.BEHX3
 Ordinarily, the file called try7.BEHX3
 which contains valid input data for BIGBOSOR4,
```

would be used for an execution of BIGBOSOR4 independently of the GENOPT environment. However, that BIGBOSOR4 execution will probably fail in this case because of failure of the Newton iterations for solution of the nonlinear pre-buckling equilibrium equations corresponding to the application of the "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not presently have the capability to divide Load Set B into sub-steps.

```
 Minimum stress constraints in the entire structure at the last load step
(from BIGBOSOR4):
  1  3.8978E-02 fiber tension : matl=1 ,  A , seg=24, node=33, layer=1 ,z= 0.00
  2  3.2328E-02 fiber compres.: matl=1 ,  A , seg=24, node=33, layer=1 ,z= 0.00
  3  3.8436E-01 transv tension: matl=1 ,  A , seg=4 , node=1 , layer=1 ,z= 0.00
  4  6.3042E-01 transv compres: matl=1 ,  A , seg=4 , node=1 , layer=1 ,z= 0.00
  5  4.7610E-01 fiber tension : matl=2 ,  A , seg=111, node=33, layer=1 ,z= 0.00
  6  4.8772E+00 fiber compres.: matl=2 ,  A , seg=106, node=33, layer=1 ,z= 0.00
  7  1.0862E+00 transv tension: matl=2 ,  A , seg=8 , node=2 , layer=1 ,z= 0.00
  8  2.0664E-01 fiber tension : matl=3 ,  A , seg=110, node=1 , layer=1 ,z= 0.00
  9  2.7546E-01 fiber compres.: matl=3 ,  A , seg=110, node=1 , layer=1 ,z= 0.00
 10  1.0785E+00 transv tension: matl=3 ,  A , seg=5 , node=1 , layer=1 ,z= 0.00

 FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
    fiber tension  fiber compres  transv tension transv compres in-plane shear
  or effect.stress
 Material 1 stress: STRC1(ILOADX,J),J=1,5)=
     1.9395E+06     1.8436E+06     1.9669E+05     9.4540E+04     0.0000E+00
 Material 2 stress: STRC2(ILOADX,J),J=1,5)=
     1.5879E+05     1.2220E+04     6.9598E+04     0.0000E+00     0.0000E+00
 Material 3 stress: STRC3(ILOADX,J),J=1,5)=
     3.6585E+05     2.1636E+05     7.0096E+04     0.0000E+00     0.0000E+00

 ********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM
 STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********
 *************************************************************
```

The maximum stresses from membrane theory (no bending) follow. It is these much smaller stress components that are used to compute the stress margins listed below and that are used as constraints during optimization cycles.

```
    3        58260.75      stress component in material 1: STRM1(1 ,1 )
    4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
    5        62146.48      stress component in material 1: STRM1(1 ,3 )
    6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
    7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
    8        76086.57      stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10        64483.34      stress component in material 2: STRM2(1 ,3 )
   11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

  BEHAVIOR OVER J =  stress component number
```

```
  13        75409.15      stress component in material 3: STRM3(1 ,1 )
  14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
  15        31744.60      stress component in material 3: STRM3(1 ,3 )
  16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
  17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

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

BEH.   CURRENT
NO.     VALUE           DEFINITION
 1    3.003E+00    buckling load factor from BIGBOSOR4: BUCKB4(1 )
 2    2.987E+00    load factor for tension loss: TENLOS(1 )
 3    5.826E+04    stress component in material 1: STRM1(1 ,1 )
 4    1.000E-10    stress component in material 1: STRM1(1 ,2 )
 5    6.215E+04    stress component in material 1: STRM1(1 ,3 )
 6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
 7    1.000E-10    stress component in material 1: STRM1(1 ,5 )
 8    7.609E+04    stress component in material 2: STRM2(1 ,1 )
 9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
10    6.448E+04    stress component in material 2: STRM2(1 ,3 )
11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
13    7.541E+04    stress component in material 3: STRM3(1 ,1 )
14    1.000E-10    stress component in material 3: STRM3(1 ,2 )
15    3.174E+04    stress component in material 3: STRM3(1 ,3 )
16    1.000E-10    stress component in material 3: STRM3(1 ,4 )
17    1.000E-10    stress component in material 3: STRM3(1 ,5 )

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


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

MARGIN CURRENT
NO.   VALUE   DEFINITION

```
 1    9.475E-04  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
 2   -4.190E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
 3    2.976E-01  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
 4    2.165E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
 5   -6.395E-03  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
 6    1.724E-01  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
 7    2.531E-03  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
 8    1.382E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

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

VAR.   CURRENT
```

```
 NO.     VALUE            DEFINITION
  1    4.215E+02  weight/length of the balloon: WEIGHT

(NOTE: Although the definition of the objective is:
 "weight/length of the balloon"
 the objective, 421.5, is actually the total weight of the
 spherical balloon.)
 *************                          ************
 ******************** DESIGN OBJECTIVE *******************
====================================================================
```

Table 16 List of the try7.OPM file for the optimized spherical balloon with 15 modules and radial webs. Material = carbon fiber cloth. Each segment of the model has 31 nodal points, that is, NODSEG = 31 in the "balloon" software, SUBROUTINE BOSDEC (Table 7).

```
======================================================================
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     N     N      0    0.00E+00  1.50E+01 2.2640E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  6.30E+00 6.3000E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  7.95E+00 7.9500E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  2.00E-03 7.0790E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  2.00E-03 7.4410E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  2.00E-03 9.9900E-03  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-03 2.5670E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  2.00E-03 1.1690E-02  2.00E-01
thickness of each truss-core web: TFWEBS

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 2
 IWEBS  = 1
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL= 15
 The balloon has radial webs (Fig. 1).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************


 BIGBOSOR4 input file for: pre-buckling state of the balloon, Load Set B
try7.LOADB

 Total weight of the spherical balloon from BIGBOSOR4, 2 x TOTMAS=
6.2791E+02

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
```

```
 "fixed" loads, PINNER=  0.0000E+00, PMIDDL=  6.0000E+01, DELTAT=
0.0000E+00
 LOAD STEP   Newton iterations  Maximum displacement
     1             5              1.635163E-02
     2             9              1.891117E-01
     3             3              3.674872E-01
     4             2              5.670297E-01
     5             2              7.911859E-01
     6             2              1.017532E+00
     7             2              1.242395E+00
     8             2              1.465994E+00
     9             2              1.688615E+00
    10             2              1.910556E+00
    11             2              2.132104E+00


 BIGBOSOR4 input file for: general buckling load
try7.BEHX1
 Ordinarily, the file called try7.BEHX1
 which contains valid input data for BIGBOSOR4,
 would be used for an execution of BIGBOSOR4 independently
 of the GENOPT environment. However, that BIGBOSOR4 execution
 will probably fail in this case because of failure of the
 Newton iterations for solution of the nonlinear pre-buckling
 equilibrium equations corresponding to the application of the
 "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
 PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
 presently have the capability to divide Load Set B into sub-
 steps.

 (FN1MAX(ISEG),ISEG=1,5)=
  2.7260E+02  6.1338E+02  1.0828E+03  5.5398E+02  9.4962E+02
 (FN2MAX(ISEG),ISEG=1,5)=
  2.3680E+02  3.8847E+02  9.9534E+02  3.6560E+02  4.7766E+02

 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=
  3.3035E+00  1.0337E+01  3.0365E+00  6.1425E+01  1.3725E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=
  3.9937E+00  5.1841E+00  2.9786E+00  3.8246E+00  3.1979E+00

 Buckling load factor corresponding to the initial loss of
 either meridional or circumferential tension, EIGMIN=  2.9786E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.0573E+00(     0)
        3.0438E+00(    15) [eigenvalue(number of circumferential waves)]
        3.0294E+00(    30)
        3.0216E+00(    45)   (These are all real modes;
        3.0245E+00(    60)    no spurious modes in this
        3.0336E+00(    75)    particular model which has
        3.0474E+00(    90)    only 15 modules.)
        3.0604E+00(   105)
        3.0694E+00(   120)
```

```
       3.0783E+00(   135)
       3.0824E+00(   150)
Critical buckling load factor, BUCKB4=  3.0216E+00
Critical number of circumferential full-waves, NWVCRT=   45

MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS
                "fixed"       "total"
              Load Step 1   Load Step 2
Seg.J  Node I  N1FIX(I,J)    N1VAR(I,J)
  71      5   2.72595E+02   1.91957E+02
   7      5   6.13375E+02   5.69613E+02
   8      5   1.08282E+03   7.64249E+02
   9      5   5.53976E+02   5.50206E+02
  10      5   9.49624E+02   8.81993E+02

MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS
                "fixed"       "total"
              Load Step 1   Load Step 2
Seg.J  Node I  N2FIX(I,J)    N2VAR(I,J)
   1      5   2.36802E+02   2.03036E+02
  12     29   3.88471E+02   3.19015E+02
   3      5   9.95341E+02   7.13230E+02
  24      5   3.65602E+02   2.90163E+02
  70     29   4.77663E+02   3.86045E+02

MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION
                              "fixed"       "total"
                            Load Step 1   Load Step 2
Seg.J  Node I  EIGEN1(I,J)    N1FIX(I,J)    N1VAR(I,J)
  31      5   3.30347E+00   2.51100E+02   1.75089E+02
  12     29   1.03372E+01   4.48718E+02   4.05310E+02
  73      5   3.03652E+00   9.70047E+02   6.50587E+02
  44     29   6.14247E+01   3.81893E+02   3.75676E+02
  40     29   1.37253E+01   8.38502E+02   7.77410E+02

MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION
                              "fixed"       "total"
                            Load Step 1   Load Step 2
Seg.J  Node I  EIGEN2(I,J)    N2FIX(I,J)    N2VAR(I,J)
  21     16   3.99374E+00   1.00145E+02   7.50693E+01
  22     10   5.18409E+00   3.77112E+02   3.04368E+02
  13     13   2.97860E+00   7.17128E+02   4.76368E+02
  74     20   3.82461E+00   2.37354E+02   1.75294E+02
  15      6   3.19790E+00   2.22107E+02   1.52653E+02

PREBUCKLING MEMBRANE STRESSES COMPUTED FROM
N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:

MAXIMUM PREBUCKLING MERIDIONAL MEMBRANE STRESSES
                "fixed"       "total"
              Load Step 1   Load Step 2
Seg.J  Node I STRS1F(I,J)   STRS1V(I,J)
  71      5   1.06192E+05   7.47788E+04
   7      5   8.24318E+04   7.65506E+04
```

```
   8      5   1.08390E+05   7.65014E+04
   9      5   7.82563E+04   7.77236E+04
  10      5   8.12339E+04   7.54485E+04

 MAXIMUM PREBUCKLING CIRCUMFERENTIAL MEMBRANE STRESSES
                "fixed"       "total"
               Load Step 1   Load Step 2
 Seg.J  Node I STRS2F(I,J)   STRS2V(I,J)
   1      5   9.22487E+04   7.90948E+04
  12     29   5.22069E+04   4.28726E+04
   3      5   9.96337E+04   7.13944E+04
  24      5   5.16460E+04   4.09893E+04
  70     29   4.08609E+04   3.30235E+04

 Behavior number, General buckling load factor:

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=  1
 Maximum displacement,                         FMAX=  2.1277E+00
 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=  2
 Maximum displacement,                         FMAX=  1.4296E+00

   1        3.057343      buckling load factor from BIGBOSOR4: BUCKB4(1 )
   2        2.978578      load factor for tension loss: TENLOS(1 )

  BEHAVIOR OVER J =  stress component number

 ************************************************************
 ****** MIN.STRESS CONSTRAINTS INCLUDING BENDING STRESS ******
 Bending stresses are printed here only for your information.
 Bending stresses are NOT included in the computation of the
 stress constraints or the stress margins, which are obtained
 from the maximum stress resultants divided by the "shell"
 segment wall thickness. Therefore, the stress margins printed
 below are probably unconservative, especially at "shell"
 segment junctions where there are probably large, very local
 bending stress concentrations. In fabricating the balloon,
 reinforce the seams at "shell" junctions to avoid failure.


 BIGBOSOR4 input file for: stress components in materials 1,2,3
try7.BEHX3
 Ordinarily, the file called try7.BEHX3
 which contains valid input data for BIGBOSOR4,
 would be used for an execution of BIGBOSOR4 independently
 of the GENOPT environment. However, that BIGBOSOR4 execution
 will probably fail in this case because of failure of the
 Newton iterations for solution of the nonlinear pre-buckling
 equilibrium equations corresponding to the application of the
 "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
 PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
```

presently have the capability to divide Load Set B into sub-
steps.

```
 Minimum stress constraints in the entire structure at the last load step
(from BIGBOSOR4):
  1  1.3426E-01 fiber tension : matl=1 ,  A , seg=19, node=33, layer=1 ,z= 0.00
  2  1.2907E-01 fiber compres.: matl=1 ,  A , seg=19, node=33, layer=1 ,z= 0.00
  3  8.3211E-01 transv tension: matl=1 ,  A , seg=7 , node=2 , layer=1 ,z= 0.00
  4  5.4427E+00 transv compres: matl=1 ,  A , seg=4 , node=1 , layer=1 ,z= 0.00
  5  1.2470E-01 fiber tension : matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
  6  1.2171E-01 fiber compres.: matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
  7  8.2563E-01 transv tension: matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
  8  2.8372E-01 fiber tension : matl=3 ,  A , seg=20, node=1 , layer=1 ,z=-0.01
  9  5.1707E-01 fiber compres.: matl=3 ,  A , seg=20, node=1 , layer=1 ,z= 0.01
 10  9.4692E-01 transv tension: matl=3 ,  A , seg=5 , node=33, layer=1 ,z= 0.01

 FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
    fiber tension  fiber compres  transv tension transv compres in-plane shear
  or effect.stress
 Material 1 stress: STRC1(ILOADX,J),J=1,5)=
     5.6307E+05     4.6176E+05     9.0853E+04     1.0951E+04     0.0000E+00
 Material 2 stress: STRC2(ILOADX,J),J=1,5)=
     6.0626E+05     4.8969E+05     9.1567E+04     0.0000E+00     0.0000E+00
 Material 3 stress: STRC3(ILOADX,J),J=1,5)=
     2.6646E+05     1.1526E+05     7.9838E+04     0.0000E+00     0.0000E+00

 ********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM
 STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********
 ************************************************************

 The maximum stresses from membrane theory (no bending)
 follow. It is these much smaller stress components that are
 used to compute the stress margins listed below and that are
 used as constraints during optimization cycles.
    3         77723.62      stress component in material 1: STRM1(1 ,1 )
    4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
    5         42872.62      stress component in material 1: STRM1(1 ,3 )
    6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
    7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
    8         76501.39      stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10         79094.80      stress component in material 2: STRM2(1 ,3 )
   11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

  BEHAVIOR OVER J =  stress component number
   13         75448.51      stress component in material 3: STRM3(1 ,1 )
   14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
   15         33023.52      stress component in material 3: STRM3(1 ,3 )
   16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
   17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

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

```
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    3.057E+00    buckling load factor from BIGBOSOR4: BUCKB4(1 )
  2    2.979E+00    load factor for tension loss: TENLOS(1 )
  3    7.772E+04    stress component in material 1: STRM1(1 ,1 )
  4    1.000E-10    stress component in material 1: STRM1(1 ,2 )
  5    4.287E+04    stress component in material 1: STRM1(1 ,3 )
  6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
  7    1.000E-10    stress component in material 1: STRM1(1 ,5 )
  8    7.650E+04    stress component in material 2: STRM2(1 ,1 )
  9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10    7.909E+04    stress component in material 2: STRM2(1 ,3 )
 11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
 12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
 13    7.545E+04    stress component in material 3: STRM3(1 ,1 )
 14    1.000E-10    stress component in material 3: STRM3(1 ,2 )
 15    3.302E+04    stress component in material 3: STRM3(1 ,3 )
 16    1.000E-10    stress component in material 3: STRM3(1 ,4 )
 17    1.000E-10    stress component in material 3: STRM3(1 ,5 )

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

 ***** RESULTS FOR LOAD SET NO.  1  ******
 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE             DEFINITION
  1    1.911E-02  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -7.141E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -2.732E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    7.634E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5   -1.178E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6   -4.418E-02  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.008E-03  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.289E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

******************* DESIGN OBJECTIVE ******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    6.279E+02  weight/length of the balloon: WEIGHT

(NOTE: Although the definition of the objective is:
 "weight/length of the balloon"
 the objective, 627.9, is actually the total weight of the
 spherical balloon.)
******************* DESIGN OBJECTIVE ******************
==================================================================
```

Table 17 List of the try7.OPM file for the optimized spherical balloon with 15 modules and radial webs. Material = carbon fiber cloth. Each segment of the model has 97 nodal points, that is, NODSEG = 97 in the "balloon" software, SUBROUTINE BOSDEC (Table 7).

```
==========================================================================
STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.   0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER
DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  1.50E+01 2.2640E+01  3.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  6.30E+00 6.3000E+00  1.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  7.95E+00 7.9500E+00  1.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  2.00E-03 7.0790E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  2.00E-03 7.4410E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  2.00E-03 9.9900E-03  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-03 2.5670E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  2.00E-03 1.1690E-02  2.00E-01
thickness of each truss-core web: TFWEBS


  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 2
 IWEBS  = 1
 Inner radius, RADIUS =  1.2000E+02
 The balloon is spherical.
 Number of modules,NMODUL= 15
 The balloon has radial webs (Fig. 1).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 ******************************************************


 BIGBOSOR4 input file for: pre-buckling state of the balloon, Load Set B
try7.LOADB

 Total weight of the spherical balloon from BIGBOSOR4, 2 x  TOTMAS=
6.2791E+02

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
```

```
 "fixed" loads, PINNER=  0.0000E+00, PMIDDL=  6.0000E+01, DELTAT=
0.0000E+00
 LOAD STEP   Newton iterations  Maximum displacement
     1             5              1.512678E-02
     2             9              1.865579E-01
     3             3              3.710006E-01
     4             2              5.887370E-01
     5             2              8.168145E-01
     6             2              1.042462E+00
     7             2              1.265392E+00
     8             2              1.485724E+00
     9             2              1.703629E+00
    10             2              1.919287E+00
    11             2              2.132866E+00


 BIGBOSOR4 input file for: general buckling load
try7.BEHX1
 Ordinarily, the file called try7.BEHX1
 which contains valid input data for BIGBOSOR4,
 would be used for an execution of BIGBOSOR4 independently
 of the GENOPT environment. However, that BIGBOSOR4 execution
 will probably fail in this case because of failure of the
 Newton iterations for solution of the nonlinear pre-buckling
 equilibrium equations corresponding to the application of the
 "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
 PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
 presently have the capability to divide Load Set B into sub-
 steps.

 (FN1MAX(ISEG),ISEG=1,5)=
  2.6858E+02  6.5556E+02  1.0669E+03  5.7310E+02  9.5595E+02
 (FN2MAX(ISEG),ISEG=1,5)=
  2.1620E+02  4.8805E+02  9.4200E+02  4.4864E+02  6.1876E+02

 LOSS OF    MERIDIONAL   TENSION: (EIG1MN(1,ISEG),ISEG=1,5)=
  3.3240E+00  1.0610E+01  3.0395E+00  4.4809E+01  1.3607E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIG2MN(1,ISEG),ISEG=1,5)=
  4.0903E+00  5.1445E+00  3.0221E+00  3.7367E+00  3.1336E+00

 Buckling load factor corresponding to the initial loss of
 either meridional or circumferential tension, EIGMIN=  3.0221E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        3.0584E+00(     0)
        3.0580E+00(    15)
        3.0577E+00(    30)
        3.0584E+00(    45)   (All of these buckling modes are real.
        3.0606E+00(    60)    There are no spurious modes in this
        3.0636E+00(    75)    model, which has only 15 modules.)
        3.0669E+00(    90)
        3.0706E+00(   105)
        3.0743E+00(   120)
```

```
       3.0782E+00(   135)
       3.0821E+00(   150)
Critical buckling load factor, BUCKB4=  3.0577E+00
Critical number of circumferential full-waves, NWVCRT=   30
```

MAXIMUM PREBUCKLING MERIDIONAL STRESS RESULTANTS

Seg.J	Node I	"fixed" Load Step 1 N1FIX(I,J)	"total" Load Step 2 N1VAR(I,J)
71	5	2.68578E+02	1.89988E+02
7	5	6.55563E+02	6.08971E+02
8	5	1.06686E+03	7.57668E+02
9	5	5.73101E+02	5.69499E+02
10	5	9.55948E+02	8.90088E+02

MAXIMUM PREBUCKLING CIRCUMFERENTIAL STRESS RESULTANTS

Seg.J	Node I	"fixed" Load Step 1 N2FIX(I,J)	"total" Load Step 2 N2VAR(I,J)
1	5	2.16205E+02	1.86925E+02
2	95	4.88054E+02	4.16052E+02
3	5	9.41997E+02	6.78339E+02
19	5	4.48644E+02	3.37069E+02
15	5	6.18765E+02	4.43056E+02

MINIMUM EIGENVALUE FOR LOSS OF MERIDIONAL TENSION

Seg.J	Node I	EIGEN1(I,J)	"fixed" Load Step 1 N1FIX(I,J)	"total" Load Step 2 N1VAR(I,J)
26	5	3.32405E+00	2.42672E+02	1.69667E+02
12	95	1.06105E+01	4.43649E+02	4.01837E+02
73	5	3.03951E+00	9.53803E+02	6.40002E+02
34	95	4.48085E+01	3.81720E+02	3.73201E+02
40	95	1.36068E+01	8.34947E+02	7.73584E+02

MINIMUM EIGENVALUE FOR LOSS OF CIRCUMFERENTIAL TENSION

Seg.J	Node I	EIGEN2(I,J)	"fixed" Load Step 1 N2FIX(I,J)	"total" Load Step 2 N2VAR(I,J)
21	45	4.09058E+00	1.01353E+02	7.65758E+01
17	31	5.14453E+00	3.72838E+02	3.00365E+02
8	31	3.02211E+00	7.23123E+02	4.83845E+02
74	54	3.73681E+00	2.42890E+02	1.77891E+02
10	12	3.13363E+00	1.98802E+02	1.35361E+02

PREBUCKLING MEMBRANE STRESSES COMPUTED FROM
N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:

MAXIMUM PREBUCKLING MERIDIONAL MEMBRANE STRESSES

Seg.J	Node I	"fixed" Load Step 1 STRS1F(I,J)	"total" Load Step 2 STRS1V(I,J)
71	5	1.04627E+05	7.40116E+04
7	5	8.81015E+04	8.18400E+04

```
   8      5   1.06792E+05   7.58427E+04
   9      5   8.09579E+04   8.04490E+04
  10      5   8.17748E+04   7.61409E+04

 MAXIMUM PREBUCKLING CIRCUMFERENTIAL MEMBRANE STRESSES
                 "fixed"       "total"
               Load Step 1   Load Step 2
 Seg.J  Node I STRS2F(I,J)   STRS2V(I,J)
   1      5   8.42247E+04   7.28184E+04
   2     95   6.55898E+04   5.59135E+04
   3      5   9.42940E+04   6.79018E+04
  19      5   6.33767E+04   4.76153E+04
  15      5   5.29311E+04   3.79004E+04

 Behavior number, General buckling load factor:

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=  1
 Maximum displacement,                         FMAX=  2.1286E+00
 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=  2
 Maximum displacement,                         FMAX=  1.4381E+00

   1        3.058383      buckling load factor from BIGBOSOR4: BUCKB4(1 )
   2        3.022104      load factor for tension loss: TENLOS(1 )

  BEHAVIOR OVER J =  stress component number

 ************************************************************
 ****** MIN.STRESS CONSTRAINTS INCLUDING BENDING STRESS ******
 Bending stresses are printed here only for your information.
 Bending stresses are NOT included in the computation of the
 stress constraints or the stress margins, which are obtained
 from the maximum stress resultants divided by the "shell"
 segment wall thickness. Therefore, the stress margins printed
 below are probably unconservative, especially at "shell"
 segment junctions where there are probably large, very local
 bending stress concentrations. In fabricating the balloon,
 reinforce the seams at "shell" junctions to avoid failure.


 BIGBOSOR4 input file for: stress components in materials 1,2,3
try7.BEHX3
 Ordinarily, the file called try7.BEHX3
 which contains valid input data for BIGBOSOR4,
 would be used for an execution of BIGBOSOR4 independently
 of the GENOPT environment. However, that BIGBOSOR4 execution
 will probably fail in this case because of failure of the
 Newton iterations for solution of the nonlinear pre-buckling
 equilibrium equations corresponding to the application of the
 "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
 PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
```

presently have the capability to divide Load Set B into sub-steps.

Minimum stress constraints in the entire structure at the last load step (from BIGBOSOR4):

```
 1  2.7605E-01 fiber tension : matl=1 ,  A , seg=7 , node=1 , layer=1 ,z= 0.00
 2  4.0178E-01 fiber compres.: matl=1 ,  A , seg=9 , node=99, layer=1 ,z= 0.00
 3  9.7401E-01 transv tension: matl=1 ,  A , seg=7 , node=1 , layer=1 ,z= 0.00
 4  2.2756E-01 fiber tension : matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
 5  2.5704E-01 fiber compres.: matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
 6  9.5772E-01 transv tension: matl=2 ,  A , seg=6 , node=1 , layer=1 ,z= 0.00
 7  5.4538E-01 fiber tension : matl=3 ,  A , seg=10, node=2 , layer=1 ,z= 0.01
 8  1.0365E+00 transv tension: matl=3 ,  A , seg=5 , node=99, layer=1 ,z=-0.01
 9  8.0113E-01 transv tension: matl=3 ,  A , seg=5 , node=1 , layer=1 ,z= 0.01

FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
   fiber tension  fiber compres  transv tension transv compres in-plane shear
 or effect.stress
Material 1 stress: STRC1(ILOADX,J),J=1,5)=
    2.7386E+05     1.4834E+05     7.7618E+04     0.0000E+00     0.0000E+00
Material 2 stress: STRC2(ILOADX,J),J=1,5)=
    3.3221E+05     2.3187E+05     7.8938E+04     0.0000E+00     0.0000E+00
Material 3 stress: STRC3(ILOADX,J),J=1,5)=
    1.3862E+05     0.0000E+00     9.4367E+04     0.0000E+00     0.0000E+00
```

********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********
****

The maximum stresses from membrane theory (no bending) follow. It is these much smaller stress components that are used to compute the stress margins listed below and that are used as constraints during optimization cycles.

```
   3        81839.95      stress component in material 1: STRM1(1 ,1 )
   4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
   5        55913.46      stress component in material 1: STRM1(1 ,3 )
   6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
   7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

 BEHAVIOR OVER J =  stress component number
   8        75842.68      stress component in material 2: STRM2(1 ,1 )
   9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
  10        72818.38      stress component in material 2: STRM2(1 ,3 )
  11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
  12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

 BEHAVIOR OVER J =  stress component number
  13        76140.95      stress component in material 3: STRM3(1 ,1 )
  14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
  15        37900.42      stress component in material 3: STRM3(1 ,3 )
  16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
  17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )
```

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

```
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    3.058E+00    buckling load factor from BIGBOSOR4: BUCKB4(1 )
  2    3.022E+00    load factor for tension loss: TENLOS(1 )
  3    8.184E+04    stress component in material 1: STRM1(1 ,1 )
  4    1.000E-10    stress component in material 1: STRM1(1 ,2 )
  5    5.591E+04    stress component in material 1: STRM1(1 ,3 )
  6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
  7    1.000E-10    stress component in material 1: STRM1(1 ,5 )
  8    7.584E+04    stress component in material 2: STRM2(1 ,1 )
  9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10    7.282E+04    stress component in material 2: STRM2(1 ,3 )
 11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
 12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
 13    7.614E+04    stress component in material 3: STRM3(1 ,1 )
 14    1.000E-10    stress component in material 3: STRM3(1 ,2 )
 15    3.790E+04    stress component in material 3: STRM3(1 ,3 )
 16    1.000E-10    stress component in material 3: STRM3(1 ,4 )
 17    1.000E-10    stress component in material 3: STRM3(1 ,5 )

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

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

 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1    1.946E-02  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2    7.368E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -7.625E-02  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    3.521E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5   -3.200E-03  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    3.820E-02  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7   -7.105E-03  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    9.947E-01  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
 *************                            ***********
    CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    6.279E+02  weight/length of the balloon: WEIGHT
```

(NOTE: Although the definition of the objective is:
"weight/length of the balloon"
the objective, 627.9, is actually the total weight of the
spherical balloon.)

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

Table 18 Input data for the GENOPT processor, DECIDE, for the case in which the lower bounds of the thicknesses has been reduced from 0.002 inch to 0.001 inch and two inequality constraints that involve RINNER and ROUTER have been introduced

```
==================================================================================
      n         $ Do you want a tutorial session and tutorial output?
         1      $ Choose a decision variable (1,2,3,...)
   15.00000     $ Lower bound of variable no.(  1)
   30.00000     $ Upper bound of variable no.(  1)
      y         $ Do you want especially to restrict variable no.(  1)
   0.500000     $ Maximum permitted change in variable no.(  1)
      y         $ Any more decision variables (Y or N) ?
         2      $ Choose a decision variable (1,2,3,...)
   1.885000     $ Lower bound of variable no.(  2)
        10      $ Upper bound of variable no.(  2)
      y         $ Do you want especially to restrict variable no.(  2)
  0.2000000     $ Maximum permitted change in variable no.(  2)
      y         $ Any more decision variables (Y or N) ?
         3      $ Choose a decision variable (1,2,3,...)
    2.13000     $ Lower bound of variable no.(  3)
        10      $ Upper bound of variable no.(  3)
      y         $ Do you want especially to restrict variable no.(  3)
  0.2000000     $ Maximum permitted change in variable no.(  3)
      y         $ Any more decision variables (Y or N) ?
         4      $ Choose a decision variable (1,2,3,...)
  0.0100000E-01 $ Lower bound of variable no.(  4)
  0.2000000     $ Upper bound of variable no.(  4)
      n         $ Do you want especially to restrict variable no.(  4)
      y         $ Any more decision variables (Y or N) ?
         5      $ Choose a decision variable (1,2,3,...)
  0.0100000E-01 $ Lower bound of variable no.(  5)
  0.2000000     $ Upper bound of variable no.(  5)
      n         $ Do you want especially to restrict variable no.(  5)
      y         $ Any more decision variables (Y or N) ?
         6      $ Choose a decision variable (1,2,3,...)
  0.0100000E-01 $ Lower bound of variable no.(  6)
  0.2000000     $ Upper bound of variable no.(  6)
      n         $ Do you want especially to restrict variable no.(  6)
      y         $ Any more decision variables (Y or N) ?
         7      $ Choose a decision variable (1,2,3,...)
  0.0100000E-01 $ Lower bound of variable no.(  7)
  0.2000000     $ Upper bound of variable no.(  7)
      n         $ Do you want especially to restrict variable no.(  7)
      y         $ Any more decision variables (Y or N) ?
         8      $ Choose a decision variable (1,2,3,...)
  0.0100000E-01 $ Lower bound of variable no.(  8)
  0.2000000     $ Upper bound of variable no.(  8)
      n         $ Do you want especially to restrict variable no.(  8)
      n         $ Any more decision variables (Y or N) ?
      n         $ Any 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,..?
```

```
      1       $ Identify the type of inequality expression (1 or 2)
  2.885000    $ Give a value to the constant, C0
      2       $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000    $ Choose a value for the coefficient, C1
      1       $ Choose a value for the power, D1
    n         $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
    y         $ Are there any more inequality expressions?
      1       $ Identify the type of inequality expression (1 or 2)
  2.885000    $ Give a value to the constant, C0
      1       $ Choose a variable from the list above (1, 2, 3,...)
 1.570800E-02 $ 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 +...
      3       $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000    $ Choose a value for the coefficient, Cn
      1       $ Choose a value for the power, Dn
    n         $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
    n         $ Are there any more inequality expressions?
    y         $ Any escape variables (Y or N) ?
    y         $ Want to have escape variables chosen by default?
=================================================================================
```

Table 19 Optimum design obtained when Table 18 is used as the input data for the GENOPT processor, DECIDE

```
==========================================================================
STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER   NAMES
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1    Y     N     N      0    0.00E+00  1.50E+01 2.0520E+01  3.00E+01 HEIGHT
   2    Y     N     N      0    0.00E+00  1.88E+00 1.8850E+00  1.00E+01 RINNER
   3    Y     N     N      0    0.00E+00  2.13E+00 2.4310E+00  1.00E+01 ROUTER
   4    Y     N     N      0    0.00E+00  1.00E-03 1.8000E-03  2.00E-01 TINNER
   5    Y     N     N      0    0.00E+00  1.00E-03 1.9260E-03  2.00E-01 TOUTER
   6    Y     N     N      0    0.00E+00  1.00E-03 7.8870E-03  2.00E-01 TFINNR
   7    Y     N     N      0    0.00E+00  1.00E-03 4.0670E-03  2.00E-01 TFOUTR
   8    Y     N     N      0    0.00E+00  1.00E-03 3.3960E-03  2.00E-01 TFWEBS

MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE           DEFINITION
  1    NOT APPLY  1.- (2.88-1.00*V(2))
  2    2.237E-01  1.- (2.88+0.02*V(1)-1.00*V(3))
  3    1.544E-03  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  4   -3.522E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  5    3.090E-03  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  6    2.195E-03  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  7   -3.364E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  8    1.217E-01  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  9   -2.387E-04  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
 10    1.338E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    4.089E+02  weight/length of the balloon: WEIGHT

(NOTE: Although the definition of the objective is:
 "weight/length of the balloon"
 the objective, 408.9, is actually the total weight of the
 spherical balloon, not the weight/length.)
==========================================================================
```

Table 20 The try7.OPM file: Optimum design of the cylindrical balloon made of carbon fiber cloth. The cylindrical balloon has 40 modules over 90 degrees of circumference and has truss-like (slanted) webs.

```
===========================================================================
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     N     N      0    0.00E+00  3.50E+01 4.3810E+01  5.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  2.40E+00 2.6400E+00  2.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  3.40E+00 3.4880E+00  2.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     N     N      0    0.00E+00  2.00E-03 2.3260E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     N     N      0    0.00E+00  2.00E-03 2.5990E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     N     N      0    0.00E+00  2.00E-03 2.1750E-02  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     N     N      0    0.00E+00  2.00E-03 2.0000E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     N     N      0    0.00E+00  2.00E-03 2.3880E-03  2.00E-01
thickness of each truss-core web: TFWEBS

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 1
 IWEBS  = 2
 Inner radius, RADIUS =  1.2000E+02
 The balloon is cylindrical.
 Number of modules,NMODUL= 40
 The balloon has truss-like (slanted) webs (Fig. 2).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************

 BIGBOSOR4 input file for: pre-buckling state of the balloon, Load Set B
try7.LOADB

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads, PINNER=  0.0000E+00, PMIDDL=  6.0000E+01, DELTAT= -
3.5690E+01
 LOAD STEP   Newton iterations  Maximum displacement
     1             3              2.671639E-03
     2             5              1.361178E-01
     3             3              2.708641E-01
```

```
     4              5              4.084680E-01
     5              3              5.478896E-01
     6              3              6.904929E-01
     7              3              8.361416E-01
     8              3              9.850521E-01
     9              3              1.137438E+00
    10              2              1.293513E+00
    11              2              1.453483E+00

 BIGBOSOR4 input file for: general buckling load
try7.BEHX1

 LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,6)=
  3.4550E+00  1.0718E+01  2.9814E+00 -1.3663E+02  1.1957E+01  1.1998E+01

 LOSS OF CIRCUMFERENTIAL TENSION: (EIGEN2(1,ISEG),ISEG=1,6)=
  5.7487E+01  2.3234E+02  4.7742E+01 -3.6676E+03  2.6855E+02  2.7034E+02

 Buckling load factor corresponding to the initial loss of
 meridional tension, EIGMIN=  2.9814E+00

 Changes in temperature required to create 2 total axial loads:

  1. Change in temperature required to create the axial thermal
     strain that generates the axial tension due to closing the
     two ends of the pressurized volume (PMIDDL=  6.0000E+01)
     between the inner and outer walls of the balloon in
     Load Step No. 1:                                DELTAT= -3.5690E+01

  2. Change in temperature required to simulate the Poisson
     axial expansion caused by the application of the outer
     pressure, POUTER =  5.0000E+00 in Load Step No. 2:  DELT=  0.0000E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
        2.9094E+00(     1)
 Critical buckling load factor, BUCKB4=  2.9094E+00
 Critical number of axial half-waves, NWVCRT=    1

 Differences in the resultants along the axis of the prismatic
 balloon for each segment, J, of the first module:
 [N2VAR(J) for the total load] - [N2FIX(J) for the fixed load]=
 N2DIFF(J),J=1,6)= -1.5060E+00 -4.7714E-01 -1.9771E+01  2.6802E-02 -
3.7865E-01 -3.7608E-01
 N2VAR(J) (total load) are the resultants from Load Step No. 2.
 N2FIX(J) (fixed load) are the resultants from Load Step No. 1.
 NOTE: The stresses used as behavioral constraints are
       computed from N2VAR(J)/thickness(J). These stresses are
       lower than those computed from N2FIX(J)/thickness(J).

 PREBUCKLING STRESS RESULTANTS IN THE FIRST MODULE
          "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I  N1FIX(I,J)   N2FIX(I,J)   N1VAR(I,J)   N2VAR(I,J)
    1      1   2.1955E+02   8.6577E+01   1.5600E+02   8.5071E+01
    2      1   2.1578E+02   1.1086E+02   1.9565E+02   1.1038E+02
```

```
   3      1   2.4871E+03   9.4388E+02   1.6529E+03   9.2411E+02
   4      1   1.5452E+02   9.8300E+01   1.5565E+02   9.8326E+01
   5      1   1.9103E+02   1.0169E+02   1.7505E+02   1.0131E+02
   6      1   1.9038E+02   1.0167E+02   1.7452E+02   1.0130E+02

 PREBUCKLING MEMBRANE STRESSES IN THE FIRST MODULE COMPUTED FROM
 N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:
           "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I STRS1F(I,J)  STRS2F(I,J)  STRS1V(I,J)  STRS2V(I,J)
   1      1   1.0977E+05   4.3288E+04   7.8001E+04   4.2535E+04
   2      1   8.3026E+04   4.2655E+04   7.5280E+04   4.2471E+04
   3      1   1.1435E+05   4.3397E+04   7.5994E+04   4.2488E+04
   4      1   6.6433E+04   4.2261E+04   6.6919E+04   4.2273E+04
   5      1   7.9996E+04   4.2583E+04   7.3305E+04   4.2424E+04
   6      1   7.9725E+04   4.2576E+04   7.3080E+04   4.2419E+04

 Behavior number, General buckling load factor:

 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 "fixed" loads (PINNER, PMIDDL, DELTAT):       ITER=  1
 Maximum displacement,                         FMAX=  1.4502E+00
 Newton iterations required to solve the nonlinear
 axisymmetric pre-buckling equilibrium state for the
 total loads (PINNER, PMIDDL, DELTAT, POUTER): ITER=  3
 Maximum displacement,                         FMAX=  1.0214E+00

   1        2.909379      buckling load factor from BIGBOSOR4: BUCKB4(1 )
   2        2.981382      load factor for tension loss: TENLOS(1 )

  BEHAVIOR OVER J =  stress component number

 BIGBOSOR4 input file for: stress components in materials 1,2,3
try7.BEHX3
 Ordinarily, the file called try7.BEHX3
 which contains valid input data for BIGBOSOR4,
 would be used for an execution of BIGBOSOR4 independently
 of the GENOPT environment. However, that BIGBOSOR4 execution
 will probably fail in this case because of failure of the
 Newton iterations for solution of the nonlinear pre-buckling
 equilibrium equations corresponding to the application of the
 "fixed" loads (non-eigenvalue loads: Load Set B), PINNER and
 PMIDDL and DELTAT (if any DELTAT exists). BIGBOSOR4 does not
 presently have the capability to divide Load Set B into sub-
 steps.

 Minimum stress constraints in the entire structure at the last load step
(from BIGBOSOR4):
  1  1.5239E-01 fiber tension : matl=1 ,  A , seg=134, node=33, layer=1 ,z= 0.00
  2  1.7370E-01 fiber compres.: matl=1 ,  A , seg=134, node=33, layer=1 ,z= 0.00
  3  1.4415E+00 transv tension: matl=1 ,  A , seg=134, node=33, layer=1 ,z= 0.00
  4  9.6922E-01 fiber tension : matl=2 ,  A , seg=1 , node=33, layer=1 ,z= 0.00
  5  1.7773E+00 transv tension: matl=2 ,  A , seg=241, node=33, layer=1 ,z= 0.00
  6  1.0250E+00 fiber tension : matl=3 ,  A , seg=59, node=1 , layer=1 ,z= 0.00
```

```
 7  1.7816E+00 transv tension: matl=3 ,  A , seg=198, node=33, layer=1 ,z= 0.00

FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
   fiber tension  fiber compres  transv tension transv compres in-plane shear
 or effect.stress
Material 1 stress: STRC1(ILOADX,J),J=1,5)=
    4.9608E+05     3.4312E+05     5.2444E+04     0.0000E+00     0.0000E+00
Material 2 stress: STRC2(ILOADX,J),J=1,5)=
    7.8001E+04     0.0000E+00     4.2535E+04     0.0000E+00     0.0000E+00
Material 3 stress: STRC3(ILOADX,J),J=1,5)=
    7.3753E+04     0.0000E+00     4.2435E+04     0.0000E+00     0.0000E+00

Changes in temperature required to create 2 total axial loads:

  1. Change in temperature required to create the axial thermal
     strain that generates the axial tension due to closing the
     two ends of the pressurized volume (PMIDDL=  6.0000E+01)
     between the inner and outer walls of the balloon in
     Load Step No. 1:                                DELTAT= -3.5690E+01

  2. Change in temperature required to simulate the Poisson
     axial expansion caused by the application of the outer
     pressure, POUTER =  5.0000E+00 in Load Step No. 2:  DELT=  3.3237E-01

********* END OF PRINTOUT OF STRESS CONSTRAINTS AND MAXIMUM
STRESSES INCLUDING BENDING OPTAINED FROM BIGBOSOR4 *********
*************************************************************

The maximum stresses from membrane theory (no bending)
follow. It is these much smaller stress components that are
used to compute the stress margins listed below and that are
used as constraints during optimization cycles.
   3        75279.67      stress component in material 1: STRM1(1 ,1 )
   4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
   5        42470.92      stress component in material 1: STRM1(1 ,3 )
   6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
   7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

 BEHAVIOR OVER J =  stress component number
   8        78000.84      stress component in material 2: STRM2(1 ,1 )
   9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
  10        42535.41      stress component in material 2: STRM2(1 ,3 )
  11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
  12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

 BEHAVIOR OVER J =  stress component number
  13        73305.19      stress component in material 3: STRM3(1 ,1 )
  14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
  15        42424.12      stress component in material 3: STRM3(1 ,3 )
  16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
  17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

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

```
 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    2.909E+00    buckling load factor from BIGBOSOR4: BUCKB4(1 )
  2    2.981E+00    load factor for tension loss: TENLOS(1 )
  3    7.528E+04    stress component in material 1: STRM1(1 ,1 )
  4    1.000E-10    stress component in material 1: STRM1(1 ,2 )
  5    4.247E+04    stress component in material 1: STRM1(1 ,3 )
  6    1.000E-10    stress component in material 1: STRM1(1 ,4 )
  7    1.000E-10    stress component in material 1: STRM1(1 ,5 )
  8    7.800E+04    stress component in material 2: STRM2(1 ,1 )
  9    1.000E-10    stress component in material 2: STRM2(1 ,2 )
 10    4.254E+04    stress component in material 2: STRM2(1 ,3 )
 11    1.000E-10    stress component in material 2: STRM2(1 ,4 )
 12    1.000E-10    stress component in material 2: STRM2(1 ,5 )
 13    7.331E+04    stress component in material 3: STRM3(1 ,1 )
 14    1.000E-10    stress component in material 3: STRM3(1 ,2 )
 15    4.242E+04    stress component in material 3: STRM3(1 ,3 )
 16    1.000E-10    stress component in material 3: STRM3(1 ,4 )
 17    1.000E-10    stress component in material 3: STRM3(1 ,5 )

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

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

 MARGIN CURRENT
 NO.     VALUE             DEFINITION
  1   -3.021E-02  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -6.206E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3    4.255E-03  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    7.800E-01  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5   -3.078E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    7.773E-01  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    3.130E-02  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    7.820E-01  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    3.282E+00  weight/length of the balloon: WEIGHT
******************** DESIGN OBJECTIVE *******************
***********  ALL 1 LOAD CASES PROCESSED ***********
==================================================================
```

Table 21 List of the try7.OPM file for the optimized cylindrical balloon with 15 modules and radial webs. Material = carbon fiber cloth. Each segment of the model has 31 nodal points, that is, NODSEG = 31 in the "balloon" software, SUBROUTINE BOSDEC (Table 7).

```
==========================================================================
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     N     N      0    0.00E+00  4.00E+01 4.6630E+01  5.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  6.30E+00 6.3000E+00  2.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  9.05E+00 9.0500E+00  2.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  2.00E-03 5.8460E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  2.00E-03 6.6480E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  2.00E-03 1.9180E-02  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  2.00E-03 5.3910E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  2.00E-03 6.0830E-03  2.00E-01
thickness of each truss-core web: TFWEBS

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 1
 IWEBS  = 2
 Inner radius, RADIUS =  1.2000E+02
 The balloon is cylindrical.
 Number of modules,NMODUL= 15
 The balloon has truss-like (slanted) webs (Fig. 2).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************

LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,6)=
  3.6265E+00  1.1301E+01  2.9985E+00 -3.2423E+03  1.3252E+01  1.3385E+01

 Buckling load factor corresponding to the initial loss of
 meridional tension, EIGMIN=  2.9985E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
       2.9889E+00(     1)
```

```
 Critical buckling load factor, BUCKB4=  2.9889E+00
 Critical number of axial half-waves, NWVCRT=    1

***********************************************************
 NOTE: The eigenvalue, 2.9889, corresponds to general buckling.
 With this 31-node model general buckling corresponds to the
 lowest eigenvalue. The lowest local buckling eigenvalue is
 3.xxxx.
***********************************************************


PREBUCKLING STRESS RESULTANTS IN THE FIRST MODULE
           "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I  N1FIX(I,J)   N2FIX(I,J)   N1VAR(I,J)   N2VAR(I,J)
    1      1   5.6203E+02   2.0575E+02   4.0705E+02   2.0208E+02
    2      1   5.5239E+02   2.5039E+02   5.0351E+02   2.4923E+02
    3      1   2.1292E+03   7.3509E+02   1.4191E+03   7.1826E+02
    4      1   3.7778E+02   2.1762E+02   3.7790E+02   2.1763E+02
    5      1   4.9727E+02   2.2892E+02   4.5975E+02   2.2803E+02
    6      1   4.9551E+02   2.2887E+02   4.5849E+02   2.2800E+02

 PREBUCKLING MEMBRANE STRESSES IN THE FIRST MODULE COMPUTED FROM
 N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:
           "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I STRS1F(I,J)  STRS2F(I,J)  STRS1V(I,J)  STRS2V(I,J)
    1      1   1.0425E+05   3.8166E+04   7.5506E+04   3.7484E+04
    2      1   8.3092E+04   3.7664E+04   7.5739E+04   3.7490E+04
    3      1   1.1101E+05   3.8326E+04   7.3989E+04   3.7448E+04
    4      1   6.4623E+04   3.7226E+04   6.4643E+04   3.7227E+04
    5      1   8.1747E+04   3.7632E+04   7.5579E+04   3.7486E+04
    6      1   8.1459E+04   3.7625E+04   7.5373E+04   3.7481E+04

 Behavior number, buckling load factors:
    1        2.988862      buckling load factor from BIGBOSOR4: BUCKB4(1 )
    2        2.998502      load factor for tension loss: TENLOS(1 )

Minimum stress constraints in the entire structure at the last load step
(from BIGBOSOR4):
  1  2.7592E-01 fiber tension : matl=1 ,  A , seg=56, node=33, layer=1 ,z= 0.00
  2  4.8946E-01 fiber compres.: matl=1 ,  A , seg=56, node=33, layer=1 ,z= 0.00
  3  1.7920E+00 transv tension: matl=1 ,  A , seg=56, node=33, layer=1 ,z= 0.00
  4  1.0012E+00 fiber tension : matl=2 ,  A , seg=1 , node=33, layer=1 ,z= 0.00
  5  2.0168E+00 transv tension: matl=2 ,  A , seg=91, node=33, layer=1 ,z= 0.00
  6  9.9600E-01 fiber tension : matl=3 ,  A , seg=78, node=33, layer=1 ,z= 0.00
  7  2.0163E+00 transv tension: matl=3 ,  A , seg=78, node=33, layer=1 ,z= 0.00

 FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
    fiber tension  fiber compres  transv tension transv compres in-plane shear
  or effect.stress
 Material 1 stress: STRC1(ILOADX,J),J=1,5)=
    2.7399E+05     1.2177E+05     4.2188E+04     0.0000E+00     0.0000E+00
 Material 2 stress: STRC2(ILOADX,J),J=1,5)=
    7.5506E+04     0.0000E+00     3.7484E+04     0.0000E+00     0.0000E+00
 Material 3 stress: STRC3(ILOADX,J),J=1,5)=
    7.5904E+04     0.0000E+00     3.7494E+04     0.0000E+00     0.0000E+00
```

```
 The maximum stresses from membrane theory (no bending)
 follow. It is these much smaller stress components that are
 used to compute the stress margins listed below and that are
 used as constraints during optimization cycles.
    3        75738.86      stress component in material 1: STRM1(1 ,1 )
    4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
    5        37489.72      stress component in material 1: STRM1(1 ,3 )
    6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
    7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
    8        75505.91      stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10        37484.20      stress component in material 2: STRM2(1 ,3 )
   11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

  BEHAVIOR OVER J =  stress component number
   13        75578.90      stress component in material 3: STRM3(1 ,1 )
   14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
   15        37485.93      stress component in material 3: STRM3(1 ,3 )
   16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
   17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

  ***** RESULTS FOR LOAD SET NO.  1  ******
 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
 MARGIN CURRENT
 NO.     VALUE            DEFINITION
  1   -3.713E-03  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2   -4.993E-04  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3   -1.833E-03  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    1.017E+00  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5    1.246E-03  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    1.017E+00  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.792E-04  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.017E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
VAR.   CURRENT
 NO.     VALUE             DEFINITION
  1    4.021E+00  weight/length of the balloon: WEIGHT
******************** DESIGN OBJECTIVE *******************
***********  ALL 1 LOAD CASES PROCESSED ***********
======================================================================
```

Table 22 List of the try7.OPM file for the optimized cylindrical balloon with 15 modules and radial webs. Material = carbon fiber cloth. Each segment of the model has 97 nodal points, that is, NODSEG = 97 in the "balloon" software, SUBROUTINE BOSDEC (Table 7).

```
==========================================================================
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     N     N      0    0.00E+00  4.00E+01 4.6630E+01  5.00E+01
height from inner to outer membranes: HEIGHT
   2   Y     N     N      0    0.00E+00  6.30E+00 6.3000E+00  2.00E+01
radius of curvature of inner membrane: RINNER
   3   Y     N     N      0    0.00E+00  9.05E+00 9.0500E+00  2.00E+01
radius of curvature of outer membrane: ROUTER
   4   Y     Y     N      0    0.00E+00  2.00E-03 5.8460E-03  2.00E-01
thickness of the inner curved membrane: TINNER
   5   Y     Y     N      0    0.00E+00  2.00E-03 6.6480E-03  2.00E-01
thickness of the outer curved membrane: TOUTER
   6   Y     Y     N      0    0.00E+00  2.00E-03 1.9180E-02  2.00E-01
thickness of inner truss-core segment: TFINNR
   7   Y     Y     N      0    0.00E+00  2.00E-03 5.3910E-03  2.00E-01
thickness of the outer truss segment: TFOUTR
   8   Y     Y     N      0    0.00E+00  2.00E-03 6.0830E-03  2.00E-01
thickness of each truss-core web: TFWEBS

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

 ************** TYPE OF BALLOON AND WEBS ***************
 ISHAPE = 1
 IWEBS  = 2
 Inner radius, RADIUS =  1.2000E+02
 The balloon is cylindrical.
 Number of modules,NMODUL= 15
 The balloon has truss-like (slanted) webs (Fig. 2).
 Pressures: PINNER,PMIDDL,POUTER=  0.0000E+00  6.0000E+01  5.0000E+00
 Factors of safety: BUCKB4F,TENLOSF=  3.0000E+00  3.0000E+00
 *******************************************************

LOSS OF    MERIDIONAL   TENSION: (EIGEN1(1,ISEG),ISEG=1,6)=
  3.6770E+00  1.1551E+01  3.0092E+00  3.3049E+02  1.3352E+01  1.3375E+01

 Buckling load factor corresponding to the initial loss of
 meridional tension, EIGMIN=  3.0092E+00

 BUCKLING LOAD FACTORS AND MODES FROM BIGBOSOR4 (BEHX1)
       3.0098E+00(     1)
```

```
 Critical buckling load factor, BUCKB4=  3.0098E+00
 Critical number of axial half-waves, NWVCRT=    1

***********************************************************
 NOTE: The eigenvalue, 3.0098, corresponds to local buckling.
 With this 97-node model we could not find general buckling.
 The general buckling eigenvalue must be greater than 3.0192,
 which corresponds to the 50th buckling mode, all of which
 are local buckling modes.
***********************************************************

 PREBUCKLING STRESS RESULTANTS IN THE FIRST MODULE
          "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I  N1FIX(I,J)   N2FIX(I,J)   N1VAR(I,J)   N2VAR(I,J)
    1      1   5.3560E+02   2.0512E+02   3.8994E+02   2.0167E+02
    2      1   5.4833E+02   2.5029E+02   5.0086E+02   2.4917E+02
    3      1   2.0354E+03   7.3286E+02   1.3590E+03   7.1683E+02
    4      1   3.8110E+02   2.1770E+02   3.7995E+02   2.1768E+02
    5      1   4.9593E+02   2.2888E+02   4.5879E+02   2.2800E+02
    6      1   4.9564E+02   2.2888E+02   4.5859E+02   2.2800E+02

 PREBUCKLING MEMBRANE STRESSES IN THE FIRST MODULE COMPUTED FROM
 N1FIX/thickness, N2FIX/thickness, N1VAR/thickness, N2VAR/thickness:
          "fixed" from Load Step No. 1 total from Load Step No. 2
 Seg.J  Node I STRS1F(I,J)  STRS2F(I,J)  STRS1V(I,J)  STRS2V(I,J)
    1      1   9.9351E+04   3.8049E+04   7.2331E+04   3.7409E+04
    2      1   8.2480E+04   3.7649E+04   7.5340E+04   3.7480E+04
    3      1   1.0612E+05   3.8210E+04   7.0857E+04   3.7374E+04
    4      1   6.5191E+04   3.7240E+04   6.4993E+04   3.7235E+04
    5      1   8.1528E+04   3.7627E+04   7.5421E+04   3.7482E+04
    6      1   8.1480E+04   3.7626E+04   7.5388E+04   3.7481E+04

 Behavior number, General buckling load factor:
    1        3.009818      buckling load factor from BIGBOSOR4: BUCKB4(1 )
    2        3.009218      load factor for tension loss: TENLOS(1 )

Minimum stress constraints in the entire structure at the last load step
(from BIGBOSOR4):
  1  5.1735E-01 fiber tension : matl=1 ,  A , seg=56, node=98, layer=1 ,z= 0.00
  2  1.5583E+01 fiber compres.: matl=1 ,  A , seg=40, node=2 , layer=1 ,z= 0.00
  3  1.9306E+00 transv tension: matl=1 ,  A , seg=68, node=98, layer=1 ,z= 0.00
  4  1.0452E+00 fiber tension : matl=2 ,  A , seg=1 , node=99, layer=1 ,z= 0.00
  5  2.0209E+00 transv tension: matl=2 ,  A , seg=91, node=99, layer=1 ,z= 0.00
  6  9.9974E-01 fiber tension : matl=3 ,  A , seg=84, node=99, layer=1 ,z= 0.00
  7  2.0167E+00 transv tension: matl=3 ,  A , seg=84, node=99, layer=1 ,z= 0.00

 FIVE STRESS COMPONENTS (including bending) FOR MATL i, STRCi(ILOADX,J), J=1,5:
    fiber tension  fiber compres  transv tension transv compres in-plane shear
  or effect.stress
 Material 1 stress: STRC1(ILOADX,J),J=1,5)=
     1.4613E+05     3.8246E+03     3.9158E+04     0.0000E+00     0.0000E+00
 Material 2 stress: STRC2(ILOADX,J),J=1,5)=
     7.2331E+04     0.0000E+00     3.7409E+04     0.0000E+00     0.0000E+00
 Material 3 stress: STRC3(ILOADX,J),J=1,5)=
     7.5619E+04     0.0000E+00     3.7487E+04     0.0000E+00     0.0000E+00
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The maximum stresses from membrane theory (no bending)
 follow. It is these much smaller stress components that are
 used to compute the stress margins listed below and that are
 used as constraints during optimization cycles.
    3        75339.93      stress component in material 1: STRM1(1 ,1 )
    4       0.1000000E-09  stress component in material 1: STRM1(1 ,2 )
    5        37480.27      stress component in material 1: STRM1(1 ,3 )
    6       0.1000000E-09  stress component in material 1: STRM1(1 ,4 )
    7       0.1000000E-09  stress component in material 1: STRM1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
    8        72331.46      stress component in material 2: STRM2(1 ,1 )
    9       0.1000000E-09  stress component in material 2: STRM2(1 ,2 )
   10        37408.96      stress component in material 2: STRM2(1 ,3 )
   11       0.1000000E-09  stress component in material 2: STRM2(1 ,4 )
   12       0.1000000E-09  stress component in material 2: STRM2(1 ,5 )

  BEHAVIOR OVER J =  stress component number
   13        75421.29      stress component in material 3: STRM3(1 ,1 )
   14       0.1000000E-09  stress component in material 3: STRM3(1 ,2 )
   15        37482.19      stress component in material 3: STRM3(1 ,3 )
   16       0.1000000E-09  stress component in material 3: STRM3(1 ,4 )
   17       0.1000000E-09  stress component in material 3: STRM3(1 ,5 )

MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
MARGIN CURRENT
 NO.     VALUE           DEFINITION
  1    3.273E-03  (BUCKB4(1 )/BUCKB4A(1 )) / BUCKB4F(1 )-1; F.S.=  3.00
  2    3.073E-03  (TENLOS(1 )/TENLOSA(1 )) / TENLOSF(1 )-1; F.S.=  3.00
  3    3.452E-03  (STRM1A(1 ,1 )/STRM1(1 ,1 )) / STRM1F(1 ,1 )-1; F.S.=  1.00
  4    1.017E+00  (STRM1A(1 ,3 )/STRM1(1 ,3 )) / STRM1F(1 ,3 )-1; F.S.=  1.00
  5    4.519E-02  (STRM2A(1 ,1 )/STRM2(1 ,1 )) / STRM2F(1 ,1 )-1; F.S.=  1.00
  6    1.021E+00  (STRM2A(1 ,3 )/STRM2(1 ,3 )) / STRM2F(1 ,3 )-1; F.S.=  1.00
  7    2.370E-03  (STRM3A(1 ,1 )/STRM3(1 ,1 )) / STRM3F(1 ,1 )-1; F.S.=  1.00
  8    1.017E+00  (STRM3A(1 ,3 )/STRM3(1 ,3 )) / STRM3F(1 ,3 )-1; F.S.=  1.00

******************** DESIGN OBJECTIVE *******************
CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    4.021E+00  weight/length of the balloon: WEIGHT
******************** DESIGN OBJECTIVE *******************
***********  ALL 1 LOAD CASES PROCESSED ***********
======================================================================
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