Tables that go with the "tank2/oneskirt" tank/skirt system

Table 1 Glossary of variables used in the generic case, "tank2" (This is part of the tank2.DEF file, created automatically by the GENOPT processor, GENTEXT, with use of information, variable names and one-line definitions provided by the GENOPT user.)

```
C==============================================================
C  ARRAY  NUMBER OF         PROMPT
C    ?   (ROWS,COLS)  ROLE  NUMBER   NAME                  DEFINITION OF VARIABLE
C                          (tank2.PRO)
C==============================================================
C    n   (    0,    0)    2      10   GRAV     = acceleration of gravity
C    n   (    0,    0)    2      20   DIAVEH   = diameter of launch vehicle
C    n   (    0,    0)    2      30   AFTDIA   = diameter of the aft dome of the tank
C    n   (    0,    0)    2      35   AFTHI    = height of the aft dome of the tank
C    n   (    0,    0)    2      40   FWDDIA   = diameter of the forward dome of the tank
C    n   (    0,    0)    2      45   FWDHI    = height of the forward dome of the tank
C    n   (    0,    0)    2      50   FLTANK   = axial dist. from aft dome apex to fwd dome apex
C    n   (    0,    0)    2      55   ZAPEX    = global axial coordinate of the aft dome apex
C    n   (    0,    0)    2      60   DENPRP   = weight density of the propellant
C    n   (    0,    0)    2      65   ZCG      = global axial coordinate of the tank cg
C    n   (    0,    0)    1      70   THKAFT   = thickness of the tank aft dome skin
C    n   (    0,    0)    1      75   THKMID   = thickness of the tank cylinder skin
C    n   (    0,    0)    1      80   THKFWD   = thickness of the forward tank dome skin
C    n   (    0,    0)    1      90   STRSPC   = spacing of the tank orthogrid stringers
C    n   (    0,    0)    1      95   RNGSPC   = spacing of the tank orthogrid rings
C    n   (    0,    0)    1     100   STRTHK   = thickness of the tank orthogrid stringers
C    n   (    0,    0)    1     105   STRHI    = height of the tank orthogrid stringers
C    n   (    0,    0)    1     110   RNGTHK   = thickness of the tank orthogrid rings
C    n   (    0,    0)    1     115   RNGHI    = height of the tank orthogrid rings
C    n   (    0,    0)    2     125   ETANK    = Young's modulus of the cold tank material
C    n   (    0,    0)    2     130   NUTANK   = Poisson's ratio of the tank material
C    n   (    0,    0)    2     135   DENTNK   = mass density of the tank material
C    n   (    0,    0)    2     140   ALTNK    = coef.thermal expansion of tank material
C    n   (    0,    0)    2     150   IAXIS    = tank is vertical (1) or horizontal (2)
C    n   (    0,    0)    2     160   IZTANK   = skirt support ring number in ZTANK(IZTANK)
C    y   (    2,    0)    1     165   ZTANK    = global axial coordinate of tank support ring
C    y   (    2,    0)    1     170   ZGRND    = global axial coordinate of "ground"
C    y   (    2,    0)    2     180   RNGTYP   = propellant tank reinforcement type
C    n   (    0,    0)    2     190   IDUBAXL  = propellant tank reinforcement type number in
DUBAXL(IDUBAXL)
C    y   (    2,    0)    1     195   DUBAXL   = axial length of the propellant tank doubler
C    y   (    2,    0)    1     200   DUBTHK   = max.thickness of the propellant tank doubler
C    y   (    2,    0)    1     210   TRNGTH   = thickness of the tank reinforcement ring
C    y   (    2,    0)    1     215   TRNGHI   = height of the tank reinforcement ring
C    y   (    2,    0)    2     220   TRNGE    = hoop modulus of the tank ring
C    y   (    2,    0)    2     225   ALRNGT   = coef.of thermal expansion of the tank ring
C    n   (    0,    0)    2     235   ISKRTYP  = skirt type number in SKRTYP(ISKRTYP)
C    y   (    2,    0)    2     240   SKRTYP   = skirt type index
C    y   (    2,    0)    1     250   LNGTNK1  = tank-end length of one-layered skirt part
C    y   (    2,    0)    1     255   THKTNK1  = tank-end thickness of tapered skirt part
C    y   (    2,    0)    1     260   LNGTNK2  = tank-end length of tapered prongs
C    y   (    2,    0)    1     265   THKTNK2  = tank-end thickness of one tapered prong
C    y   (    2,    0)    1     270   LNGVEH1  = "ground" end length of one-layered skirt part
C    y   (    2,    0)    1     275   THKVEH1  = "ground"-end thickness of tapered skirt part
C    y   (    2,    0)    1     280   LNGVEH2  = "ground"-end length of tapered prongs
C    y   (    2,    0)    1     285   THKVEH2  = "ground"-end thickness of one tapered prong
```

```
C    y   (   2,    0)    2      300   WALTYP   = type of wall constructions in skirt type SKRTYP
C    n   (   0,    0)    2      310   ITHICK   = thickness index in THICK(ITHICK)
C    y   (  15,    0)    1      315   THICK    = thickness of a lamina
C    y   (  15,    0)    1      320   ANGLE    = layup angle
C    y   (  15,    0)    2      325   MATTYP   = Material type
C    n   (   0,    0)    2      335   JLAYTYP  = wall type number in LAYTYP(ILAYTYP,JLAYTYP)
C    n   (   0,    0)    2      340   ILAYTYP  = layer number in LAYTYP(ILAYTYP,JLAYTYP)
C    y   (  90,    2)    2      345   LAYTYP   = layer type index
C    n   (   0,    0)    2      355   IE1      = material type in E1(IE1)
C    y   (   2,    0)    2      360   E1       = modulus in the fiber direction
C    y   (   2,    0)    2      365   E2       = modulus transverse to fibers
C    y   (   2,    0)    2      370   G12      = in-plane shear modulus
C    y   (   2,    0)    2      375   NU       = small Poisson's ratio
C    y   (   2,    0)    2      380   G13      = x-z out-of-plane shear modulus
C    y   (   2,    0)    2      385   G23      = y-z out-of-plane shear modulus
C    y   (   2,    0)    2      390   ALPHA1   = coef.of thermal expansion along fibers
C    y   (   2,    0)    2      395   ALPHA2   = coef.of thermal expan.transverse to fibers
C    y   (   2,    0)    2      400   TEMTUR   = curing delta temperature (positive)
C    y   (   2,    0)    2      405   COND1    = conductivity along the fibers
C    y   (   2,    0)    2      410   COND2    = conductivity transverse to fibers
C    y   (   2,    0)    2      415   DENSTY   = weight density of the material
C    n   (   0,    0)    2      425   WGT      = objective=WGT*(empty tank mass) +(1-
WGT)*(conductance)
C    n   (   0,    0)    2      430   TNKNRM   = normalizing empty tank mass
C    n   (   0,    0)    2      435   CONNRM   = normalizing total skirt conductance
C    n   (   0,    0)    2      445   IPHASE   = IPHASE=1=launch phase; IPHASE=2=orbital phase
C    n   (   0,    0)    2      455   NCASES   = Number of load cases (number of environments)  in
PRESS(NCASES)
C    y   (  20,    0)    3      460   PRESS    = propellant tank ullage pressure
C    y   (  20,    0)    3      465   GAXIAL   = quasi-static axial g-loading
C    y   (  20,    0)    3      470   GLATRL   = quasi-static lateral g-loading
C    y   (  20,    0)    3      475   TNKCOOL  = propellant tank cool-down from cryogen
C    n   (   0,    0)    2      485   JFREQ    = vibration mode type in FREQ(NCASES,JFREQ)
C    y   (  20,    4)    4      490   FREQ     = free vibration frequency (cps)
C    y   (  20,    4)    5      495   FREQA    = minimum allowable frequency (cps)
C    y   (  20,    4)    6      500   FREQF    = factor of safety for freqency
C    n   (   0,    0)    2      510   JSTRES1  = stress component number in STRES1(NCASES,JSTRES1)
C    y   (  20,    6)    4      515   STRES1   = maximum stress in material 1
C    y   (  20,    6)    5      520   STRES1A  = maximum allowable stress in material 1
C    y   (  20,    6)    6      525   STRES1F  = factor of safety for stress, matl 1
C    y   (  20,    6)    4      530   STRES2   = maximum stress in material 2
C    y   (  20,    6)    5      535   STRES2A  = maximum allowable stress in material 2
C    y   (  20,    6)    6      540   STRES2F  = factor of safety for stress, matl 2
C    n   (   0,    0)    2      550   JSHLBUK  = skirt number (1 for aft skirt) in
SHLBUK(NCASES,JSHLBUK)
C    y   (  20,    2)    4      555   SHLBUK   = buckling of skirt as a shell
C    y   (  20,    2)    5      560   SHLBUKA  = allowable for shell buckling of skirt
C    y   (  20,    2)    6      565   SHLBUKF  = factor of safety for shell buckling of skirt
C    y   (  20,    2)    4      570   FORCE    = launch-hold force in a skirt
C    y   (  20,    2)    5      575   FORCEA   = maximum allowable launch-hold force in skirt
C    y   (  20,    2)    6      580   FORCEF   = factor of safety for launch-hold force
C    y   (  20,    2)    4      585   TNKSTR   = maximum stress in the propellant tank
C    y   (  20,    2)    5      590   TNKSTRA  = allowable for propellant tank stress
C    y   (  20,    2)    6      595   TNKSTRF  = factor of safety for tank stress
C    y   (  20,    2)    4      600   TNKBUK   = propellant tank buckling load factor
C    y   (  20,    2)    5      605   TNKBUKA  = allowable for propellant tank buckling
C    y   (  20,    2)    6      610   TNKBUKF  = factor of safety for tank buckling
C    n   (   0,    0)    7      620   CONDCT   = WGTxTOTMAS/TNKNRM +(1-WGT)xCONDCT/CONNRM
C===============================================================
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Table 2 The file, test.PRO, generated automatically by GENOPT using the variable names, one-line definitions, and "help" paragraphs supplied by the GENOPT user during his/her interactive GENTEXT session.
(This text will be seen by the End user. Therefore, it should be as free of jargon as possible.)

```
==========================================================================
   5.0
       This is a computer program that uses GENOPT and BIGBOSOR4
       to find the optimum design of advanced laminated composite
       skirts that support the
       propellant tank. The tank is carried by a booster that
       imparts a certain ultimate peak axial acceleration and a
       certain ultimate peak lateral acceleration. The minimum free
       vibration frequency must be greater than some specified
       value. The tank is assumed to be either cylindrical with
       domed ends. It is made of isotropic material.
       It may have locally thickened regions and stiffening rings
       to handle the concentrated loads applied by the skirts.

       The three parts of the propellant tank (1. aft dome, 2.
       cylindrical middle, 3. forward dome) have internal orthogrid
       stiffening that is "smeared out" in all the BIGBOSOR4 models.
       In the BIGBOSOR4 models the smeared orthogrid stiffeners are
       treated as an orthotropic layer of constant thickness. The
       tank wall is modeled as consisting of three layers:
       Innermost layer: smeared orthogrid of thickness equal to
       the height of the orthogrid stiffeners and stiffness and
       density equal to the tank wall material "E" & "rho" multiplied
       by (orthogrid stiffener thickness)/(stiffener spacing)
       Middle layer: constant thickness that may differ in each
       of the three parts of the propellant tank
       Outer layer: variable thickness that represents tapered
       doublers attached to the outer wall of the propellant tank
       centered on axial locations where supporting skirts are
       attached to external rings that are part of the tank.
       The BIGBOSOR4 shell wall type, NWALL = 9, is used in order
       to simulate this three-layered construction. NWALL = 9 is
       the BIGBOSOR4 option for a laminated composite wall in
       which one or more of the layers may have thickness that
       varies along the meridian.

       In the free vibration BIGBOSOR4 model the mass of the fluid
       in the tank is "lumped" into the constant-thickness middle
       layer of the three-layered orthotropic wall. For the
```

cylindrical part of the propellant tank the "effective"
wall skin density, rho(add), to be added to the material
density is obtained from the relationship:
(cylindrical tank volume)xrho(propellant) =
(volume occupied by shell wall skin)xrho(add)
or, for a cylindrical shell:
pi x r^2 x L x rho(propellant) = 2 x pi x r x L x t x rho(add)
which leads to rho(add) = 0.5 x r/t x rho(propellant)
For a spherical dome, we have:
(4/3) x pi x r^3 x rho(propellant) = 4 x pi x r^2 x t x rho(add)
which leads to rho(add) = 0.333 x r/t x rho(propellant)

There are laminated composite skirts attached to the tank
at one or two axial locations.

10.1 acceleration of gravity: GRAV
10.2
Example: 386.4 inches/sec^2

15.0
There are many variables with role types 1 and 2 (role type 1
means a decision variable candidate; role type 2 means a
constant that is not an environmental variable such as a load
and that is not a behavioral variable, an allowable, or a
factor of safety.

The role type 1 and role type 2 variables are organized
as follows:
1. The launch vehicle diameter: DIAVEH

2. The propellant tank dimensions and properties:
AFTDIA = diameter of the aft dome of the tank
AFTHI = height of the aft dome of the tank
FWDDIA = diameter of the forward dome of the tank
FWDHI = height of the forward dome of the tank
FLTANK = axial distance from the aft dome apex to the
forward dome apex
ZAPEX = global axial coordinate of the aft dome apex
DENPRP = weight density of the propellant
ZCG   = global axial coordinate of the tank center of gravity
THKAFT = thickness of the tank aft dome skin
THKMID = thickness of the tank cylinder skin
THKFWD = thickness of the forward tank dome skin
STRSPC = spacing of the internal tank orthogrid stringers
RNGSPC = spacing of the internal tank orthogrid rings
STRTHK = thickness of the tank orthogrid stringers
STRHI = height of the tank orthogrid stringers

```
RNGTHK = thickness of the tank orthogrid rings
RNGHI  = height of the tank orthogrid rings
ETANK  = Young's modulus of the cold tank
NUTANK = Poisson's ratio of the tank material
DENTNK = mass density of the tank material
ALTNK  = coefficient of thermal expansion of the tank material

3. Orientation of the propellant tank in the launch vehicle:
IAXIS  = 1 means tank is vertical; 2 means tank is horizontal

4. Propellant tank support rings:
IZTANK = tank skirt support ring number
ZTANK  = global axial coordinate of a tank support ring
ZGRND  = global axial coordinate of "ground" (launch vehicle)
for skirt attached at ZTANK

5. Dimensions of skirt types:
SKRTYP = index for the type of skirt
LNGTNK1 = tank-end length of one-layered skirt part
THKTNK1  = tank-end thickness of tapered skirt part
LNGTNK2  = tank-end length of tapered prongs
THKTNK2  = tank-end thickness of one tapered prong
LNGVEH1  = "ground" end length of one-layered skirt part
THKVEH1  = "ground"-end thickness of tapered skirt part
LNGVEH2  = "ground"-end length of tapered prongs
THKVEH2  = "ground"-end thickness of one tapered prong

6. Properties of the propellant tank reinforcement
corresponding to each tank reinforcement type:
RNGTYP = propellant tank reinforcement type
IDUBAXL= reinforcement type number
DUBAXL = axial length of the propellant tank tapered doubler
that is centered on each propellant tank support ring
DUBTHK = maximum thickness of the tapered propellant tank doubler
TRNGTH = thickness of the propellant tank support ring
TRNGHI = height of the propellant tank support ring
TRNGE  = hoop modulus of the propellant tank support ring
ALRNGT = coefficient of thermal expansion of the tank ring

7. Properties of the walls of the composite skirts:
JWALTYP= 1 means launch skirt; 2 means orbital skirt
IWALTYP= skirt wall type number
WALTYP = type of laminated composite skirt wall
ITHICK = index for type of unidirectional composite ply
THICK  = thickness of lamina of type ITHICK
ANGLE  = layup angle of lamina of type ITHICK
MATTYP = material type of lamina of type ITHICK
JLAYTYP= wall type number
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ILAYTYP= layer number
LAYTYP = layer type index for layer number ILAYTYP and
wall type number JLAYTYP

8. Properties of composite material of which the launch skirts
are fabricated:
IE1 = material type number
E1 = modulus in the fiber direction in material type IE1
E2 = modulus transverse to fibers in material type IE1
G12 = in-plane shear modulus of material type IE1
NU = minor Poisson ratio of material type IE1
G13 = x-z out-of-plane shear modulus in material type IE1
G23 = y-z out-of-plane shear modulus in material type IE1
ALPHA1 = coefficient of thermal expansion along fibers
ALPHA2 = coefficient of thermal expansion transverse to fibers
TEMTUR = curing delta temperature in material type IE1
COND1 = conductivity along the fibers in material type IE1
COND2 = conductivity transverse to fibers in material IE1
DENSTY = weight density of material type IE1

9. Elements that are used in the expression for the objective:
WGT = weighting coefficient used in the expression for
the objective:
objective = WGTx(normalized empty tank mass)
+ (1-WGT)x(normalized total skirt conductance)
TNKNRM = normalizing empty tank mass
CONNRM = normalizing total skirt conductance

10. Mission phase index:
IPHASE = 1 means launch phase of the mission
IPHASE = 2 means orbital phase of the mission

20.1 diameter of launch vehicle: DIAVEH
20.2

Diameter of the launch vehicle
The launch vehicle must have a larger diameter than the
propellant tank, of course, because it carries the propellant
tank. The propellant tank end of the skirts are located on
the tank reference surface at the axial attachment
point of a ring the centroidal diameter of which is
equal to the diameter of the aft dome plus 2 x ECCR,
in which ECCR is the radial eccentricity of the
support ring attached to the propellant tank.

25.0

The supported mass, what is called here "the tank", is assumed
to have domed ends with elliptical cross sections. You will be

asked to provide the height and diameter of each of the two domed ends.
Next, you will be asked to provide the diameter of the aft dome of the tank.

30.1 diameter of the aft dome of the tank: AFTDIA
30.2
This is the length of the major axis of the ellipsoidal dome.

35.1 height of the aft dome of the tank: AFTHI
35.2
This is the length of the semi-minor axis of the ellipsoidal dome.

40.1 diameter of the forward dome of the tank: FWDDIA
40.2
This is the length of the major axis of the ellipsoidal dome.
In most cases FWDDIA will be equal to AFTDIA and the middle part of the tank connecting the aft and forward domes will be cylindrical.

45.1 height of the forward dome of the tank: FWDHI
45.2
This is the length of the semi-minor axis of the ellipsoidal dome.

50.1 axial dist. from aft dome apex to fwd dome apex: FLTANK
50.2
FLTANK is needed in order to determine if the attachment points of the skirts to the tank are located within the aft or forward domes. NOTE: So far in this study it is assumed that no skirts are attached to either end dome of the propellant tank. All skirts are attached to the cylindrical part of the propellant tank.

55.1 global axial coordinate of the aft dome apex: ZAPEX
55.2
This quantity is needed in order to determine if the attachment points of the skirts to the tank are located within the aft or forward domes of the tank.

60.1 weight density of the propellant: DENPRP
60.2
e.g. weight density of aluminum is 0.1 lb/in^3
Examples: LH2 = 4.43 lb/ft^3 = 0.00256366 lb/in^3
LOX = 71.3 lb/ft^3 = 0.0412616 lb/in^3

65.1 global axial coordinate of the tank cg: ZCG
65.2
"cg" = center of gravity

70.1 thickness of the tank aft dome skin: THKAFT
70.2
The thickness is assumed to be constant. It is the middle layer of the BIGBOSOR4 three-layered NWALL=9 model of the tank wall, in which the inner layer represents the smeared orthogrid stiffeners and the outer layer represents the tapered doublers. The middle layer of thickness THKAFT is the layer into which is "lumped" the propellant mass.

75.1 thickness of the tank cylinder skin: THKMID
75.2
This thickness is constant. This is the thickness into which is "lumped" the propellant mass.

80.1 thickness of the forward tank dome skin: THKFWD
80.2
This thickness is constant. This is the thickness into which is "lumped" the propellant mass.

85.0
All three parts of the tank wall (domes & cyl.) are stiffened internally in what is called an "orthogrid" style. There are internal rings and stringers of rectangular cross sections. The orthogrid stiffeners are "smeared out" in all the models used in this study. The "smeared" orthogrid is modeled as the innermost layer of the tank wall in the BIGBOSOR4 model. The decision variable candidates associated with this internal smeared grid stiffening are:
1. STRSPC = spacing of the stringers (axial stiffeners)
2. RNGSPC = spacing of the rings
3. STRTHK = stringer thickness (dimension parallel to skin)
4. STRHI = stringer height (dimension normal to skin)
5. RNGTHK = ring thickness (dimension parallel to skin)
6. RNGHI = ring height (dimension normal to skin)

RNGHI should be equal to STRHI.

This internal orthogrid is smeared out in models of the propellant tank. The smeared orthogrid is treated as the innermost layer (layer 1) of the propellant tank wall. The properties of the propellant tank wall are formatted in the NWALL = 9 option of BIGBOSOR4. NWALL = 9 means "layered orthotropic wall in which one or more of the layers has thickness that varies along the meridian". The thickness of the smeared orthogrid layer is equal to the height of the orthogrid stringers and rings, and the "effective" moduli, E1 and E1, and density are equal to the stiffness and density of the material muliplied by (stiffener thickness)/(stiffener height).

NOTE: There are two types of rings that enter this model:
1. The internal rings that are part of the orthogrid stiffening, and
2. The external rings to which the support skirts are attached. Please don't get them confused!

90.1 spacing of the tank orthogrid stringers: STRSPC
90.2
"Stringers" are meridionally oriented stiffeners. the spacing is in the circumferential direction. The fact that in the two domes the circumferential spacing of meridional stiffeners varies from base to apex of a dome is ignored. In the model the internal orthogrid is smeared and the spacing at the equator of the dome is used for the entire dome. A dome could possibly be fabricated in which this is approximately true.

95.1 spacing of the tank orthogrid rings: RNGSPC
95.2
The orthogrid is smeared out in all models and is treated as if it were Layer No. 1 in a two-layered orthotropic tank (NWALL = 9 in BIGBOSOR4 jargon).

100.1 thickness of the tank orthogrid stringers: STRTHK
100.2
This is the dimension measured parallel to the tank skin.

105.1 height of the tank orthogrid stringers: STRHI
105.2
This is the dimension measured normal to the tank skin. It is the dimension from the inner surface of the tank skin to the tip of the stringer

110.1 thickness of the tank orthogrid rings: RNGTHK
110.2
This is the dimension of the internal ring stiffener measured parallel to the tank skin. NOTE: the "tank ring" we are referring to here is one of the regularly spaced internal rings that form part of the internal orthogrid stiffening on the cylindrical part of the propellant tank, not one of the external rings to which the support skirts are attached.

115.1 height of the tank orthogrid rings: RNGHI
115.2
Note that here we are referring to part of the orthogrid

stiffening inside the wall of the propellant tank, not one of the external rings to which the support skirts are attached. RNGHI should be equal to STRHI.

120.0

Next, you will be asked to provide the material properties of the propellant tank. Use the material properties that are appropriate when the tank is filled with cryogen.

125.1 Young's modulus of the cold tank material: ETANK
125.2

Make sure to use the properties that hold for the propellant tank in its cold condition, that is, after it has been filled with cryogen.

130.1 Poisson's ratio of the tank material: NUTANK
130.2

Example: 0.3 for aluminum.

135.1 mass density of the tank material: DENTNK
135.2

For example, aluminum has DENTNK = 0.00025 lb/in^3

140.1 coef.thermal expansion of tank material: ALTNK
140.2

What is wanted here is the average coefficient of thermal axial expansion between the bottom & top propellant tank support rings. The thermal axial contraction between these rings is included in the stress and buckling analyses of the supporting skirts. Units of ALTNK are "per degree xxx". The temperature difference between the portion of the propellant tank between the two tank support rings must afterward be given in units consistent with the coefficient of thermal axial expansion, of course.

145.0

Next, you will be asked whether the propellant tank is oriented axially or lying on its side in the launch vehicle. This orientation is specified by the value of an integer, IAXIS, being 1 or 2:
IAXIS = 1 means that the axis of the propellant tank is aligned with the axis of the launch vehicle.
IAXIS = 2 means that the axis of the propellant tank is oriented 90 degrees from the axis of the launch vehicle.

150.1 tank is vertical (1) or horizontal (2): IAXIS

150.2

IAXIS = 1 means that the axis of the propellant tank is aligned with the axis of the launch vehicle.
IAXIS = 2 means that the axis of the propellant tank is oriented at 90 degrees with respect to the axis of the launch vehicle.

155.0

The tank is assumed to be supported by up to 2 skirts, one attached at the aft end of the cylindrical part of the propellant tank and the other attached at the forward end of the cylindrical part of the propellant tank.

For each tank support skirts you will be asked to provide the following input data:
1. The axial locations and properties of the structural rings to which the propellant-tank-ends of the skirts are attached. These rings are part of the propellant tank.
2. The axial lengths of tapered doublers added to the propellant tank wall that are centered on the line of attachment of the propellant tank support ring to the tank shell.
3. The maximum thicknesses of these tapered reinforcing doublers.
4. Thermal expansion coefficients of the tank and the tank support rings.
5. Lengths and thicknesses pertaining to two short parts of each skirt nearest the propellant tank.
6. Lengths and thicknesses pertaining to two short parts of each skirt nearest the launch vehicle ("ground").
7. For each supporting skirt:
7.1 number of layers through the skirt thickness
7.2 layer type indicator for each layer
7.3 For each new layer type;
7.3.1 thickness
7.3.2 winding (layup) angle
7.3.3 material type indicator
8. Material properties for each material type. The skirts are fabricated of laminated composite material.

Next, you will see the prompt:
"Number IZTANK of rows in the array ZTANK: IZTANK"
Want is wanted is the number of axial locations at which skirts are to be attached to the propellant tank.
With long propellant tanks IZTANK should probably be 2
With spherical or ellipsoidal tanks a choice of IZTANK = 1 is probably best.

160.1 Number IZTANK of rows in the array ZTANK: IZTANK

165.1 global axial coordinate of tank support ring: ZTANK
165.2
Must be a positive number. Use the attachment line of the
tank support ring to the tank as the reference measure, not
the ring centroidal axis.
NOTE: IF THERE IS ONLY ONE SKIRT, PUT ZTANK
AT AN AXIAL STATION NEAR THE LOCATION OF THE TANK C.G.
ANOTHER NOTE: Do not put the ring exactly at the apex of the
tank dome. If the ring is in the dome make sure that it is
some distance from the dome apex. If it is at the apex a
singularity will occur and the computations will be meaningless.

170.1 global axial coordinate of "ground": ZGRND
170.2
This is the global axial coordinate of the end of a skirt
that is connected to "ground", that is, the end of a skirt
that is connected to the launch vehicle, which is assumed
to be rigid in this study..

175.0
Next, you will be asked to provide the propellant tank
reinforcement type. A given propellant tank reinforcement
type is associated with the following "bundle" of properties:
1. the doubler length and max. thickness: DUBAXL and DUBTHK
2. the ring cross section properties: ring thickness (TRNGTH),
ring height (TRNGHI), ring elastic modulus (TRNGE), and
ring coefficient of thermal expansion (ALRNGT).

180.1 propellant tank reinforcement type: RNGTYP
180.2
The propellant tank reinforcement type is associated with
the bundle of tapered doubler and discrete ring properties.

185.0
Next, you will be asked to provide the axial lengths of doublers
associated with each propellant tank support ring. The propellant
tank end of each skirtt is associated not only with a propellant
tank support ring but also with a region in the neighborhood
of this ring where the propellant tank is thicker than elswhere
because of a tapered doubler added to the outside of the
propellant tank skin.

You will next see the following prompt:
"Number IDUBAXL of rows in the array DUBAXL: IDUBAXL"
What is wanted is the number of different reinforcement types.
In most cases IDUBAXL should probably be 1

190.1 Number IDUBAXL of rows in the array DUBAXL: IDUBAXL
195.1 axial length of the propellant tank doubler: DUBAXL
195.2

This is the axial length of the axisymmetric doubler

200.1 max.thickness of the propellant tank doubler: DUBTHK
200.2

The tapered doubler is centered at the axial location of the propellant tank support ring with which it is associated. The maximum thickness, DUBTHK, of the tapered doubler occurs at the same axial location as the external discrete ring. This is the additional thickness to be added to the nominal tank thickness that exists in regions remote from each propellant tank support ring. In axial regions where tapered doublers exist the BIGBOSOR4 tank wall model has three layers: innermost layer = smeared orthogrid; middle layer = tank skin of thickness, THKAFT or THKMID or THKFWD; outermost layer = tapered doubler.

205.0

Next, you will be asked to provide properties of the external rings near which the propellant tank end of the support skirts are attached. You will be asked for the following:
TRNGTH = thickness of the propellant tank support ring
TRNGHI = height of the propellant tank support ring
You must provide these two properties of the propellant tank support rings for each propellant tank reinforcement type. The propellant tank support rings have rectangular cross sections.
TRNGE = elastic modulus of the propellant tank support ring
ALRNGT = coefficient of thermal expansion of the ring

210.1 thickness of the tank reinforcement ring: TRNGTH
210.2

This ring is part of the propellant tank reinforcement The propellant tank end of the skirt is attached to the tank reference surface at the ring attachment point. TRNGTH is the dimension of the ring measured parallel to the tank skin. The ring is attached to the outer surface of the tank skin. (Not the outer surface of the doubler, but the outer surface of the part of the tank skin of thickness THKMID.)

215.1 height of the tank reinforcement ring: TRNGHI
215.2

TRNGHI is the dimension of the ring measured normal to the tank skin.

220.1 hoop modulus of the tank ring: TRNGE
220.2
The hoop modulus is the stiffness/area of the tank support ring in units, for example, of lb/in**2.

225.1 coef.of thermal expansion of the tank ring: ALRNGT
225.2
What is wanted here is the coefficient of thermal radial expansion of the propellant tank support ring. The thermal radial contraction of each propellant tank support ring is included in the stress and buckling analyses of the supporting skirts. Units of ALRNGT are "per degree xxx". Use consistent units for this quantity and the temperature difference you will be asked for below.

230.0
Next, you will be asked to provide some properties of the skirts that support the propellant tank. etc.

235.1 Number ISKRTYP of rows in the array SKRTYP: ISKRTYP
240.1 skirt type index: SKRTYP
240.2
There can be 1 or 2 skirt types. If there are 2 skirt types skirt type 1 is the aft skirt and skirt type 2 is the forward skirt.

245.0
Next, you will be asked to provide variables that pertain to each type of skirt:
1. length of one-layered section of the end of the skirt that is attached to the propellant tank.
2. thickness of the one-layered tank-end section where the skirt is attached to the propellant tank
3. length of the multi-layed section of the tank-end of the skirt in which there exist exterior metal "prongs" that enclose the laminated composite skirt wall.
4. thickness of the tapered "prongs" at the tank-end junction between the one-layered tank-end section and the multi-layered tank-end section of the skirt.
5. length of the one-layered section of the end of the skirt that is attached to "ground".
6. thickness of the one-layered "ground"-end section where the skirt is attached to "ground".

7. length of the multi-layered section of the "ground"-end of the skirt in which there exist exterior metal "prongs" that enclose the "ground"-end laminated composite skirt wall.
8. thickness of the tapered "pprongs" at the "ground"-end junction between the one-layered "ground"-end seciotn and the multi-layered "ground"-end section of the skirt.

250.1 tank-end length of one-layered skirt part: LNGTNK1
250.2
explain

255.1 tank-end thickness of tapered skirt part: THKTNK1
255.2
explain

260.1 tank-end length of tapered prongs: LNGTNK2
260.2
explain

265.1 tank-end thickness of one tapered prong: THKTNK2
265.2
explain

270.1 "ground" end length of one-layered skirt part: LNGVEH1
270.2
explain

275.1 "ground"-end thickness of tapered skirt part: THKVEH1
275.2
explain

280.1 "ground"-end length of tapered prongs: LNGVEH2
280.2
explain

285.1 "ground"-end thickness of one tapered prong: THKVEH2
285.2
explain

290.0
Next, you will be asked to provide some properties of the skirts that support the propellant tank. etc.

295.0
Next, you will be asked to provide an index for the type of wall construction (type of composite laminate)

associated with the skirt type, SKRTYP.
Skirts at different propellant tank rings may have
different composite layups, that is, different wall types.

300.1 type of wall constructions in skirt type SKRTYP: WALTYP
300.2
Probably the skirts at different axial levels will have
different wall types, that is, different composite layups.

305.0
Next, you will be asked to provide thickness types,
layup angle types, and material types. These quantities
are the "building blocks" of the laminated composite walls
that form the skirts.
THICK = thickness corresponding to a layer index
ANGLE = layup angle corresponding to a layer index
MATTYP = material type corresponding to a layer index.
THICK, ANGLE, and MATTYP form a triad that corresponds
to a given layer index.
The layer indices are stored in a matrix, LAYTYP(i,j),
in which i = the layer number in a laminate and j = a
wall type number.

You will next see the prompt:
"Number ITHICK of rows in the array THICK: ITHICK"
What is wanted is the number of different layer indices
that point to a unique triad, (THICK,ANGLE,MATTYP). For
example, suppose you have a laminated composite wall with
ply layup given by [0,+45,-45,90,90,-45,+45,0]total. In
this example ITHICK = 4 (4 unique triads) because each of
the first four layers in the symmetric 8-layered laminate
has a different layup angle. You would provide the following:
ITHICK = 4
THICK(i), i=1,4 = 0.01, 0.01, 0.01, 0.01 (for example, and
to be provided by you one datum at a time)
ANGLE(i), i=1.4 = 0., 45., -45., 90. (one datum at a time)
MATTYP(i),i=1,4 = 1, 1, 1, 1 (one datum at a time)

310.1 Number ITHICK of rows in the array THICK: ITHICK
315.1 thickness of a lamina: THICK
315.2
It is possible to have multiple adjacent plies of the same
thickness type (same thickness index).

320.1 layup angle: ANGLE
320.2
Please provide the layup angle in degrees

325.1 Material type: MATTYP
325.2
Thickness, Layup angle, and Material type form a triad that corresponds to a layer type, or a layer index. Composite laminated walls consist of a group of layer types. The thickness and layup angle of the layer type can be selected by the user as decision variables. They are called "decision variable candidates".

330.0
Next, you will be asked to provide a matrix of layer types corresponding to each wall type.
LAYTYP(ILAYTYP,JLAYTYP) = layer type(layer no., walltype no.)
Suppose you have the following laminate stacking sequence:
[0,+45,-45,90,90,-45,+45,0]total. Then, for wall type no. 1
you would want LAYTYP(i,1) to be as follows:
LAYTYP(i,1), i=1,8 = 1, 2, 3, 4, 4, 3, 2, 1

You will next see the two prompts:
"Number JLAYTYP of columns in the array, LAYTYP: JLAYTYP"
"Number ILAYTYP of rows in this column of LAYTYP: ILAYTYP"
JLAYTYP is the number of wall types and ILAYTYP is the number of layers in the laminate.
Following the prompts for JLAYTYP and ILAYTYP, you will be prompted to provide the layer types, LAYTYP. Corresponding to the example of the laminate with 8 layers, you would provide:
LAYTYP(i,1), i=1,8 = 1, 2, 3, 4, 4, 3, 2, 1
one datum at a time.

335.1 Number JLAYTYP of columns in the array, LAYTYP: JLAYTYP
340.1 Number ILAYTYP of rows in this column of LAYTYP: ILAYTYP
345.1 layer type index: LAYTYP
345.2
For example, LAYTYP(7,3) is the layer index for layer number 7 wall type number 3. The integer, LAYTYP(i,j) points to a specific triad: thickness, layup angle, material type.

350.0
Next, you will be asked to supply material properties for an orthotropic ply of composite material. You will be asked to provide the following for each material type:

E1 = modulus in the fiber direction
E2 = modulus transverse to fibers in the plane of the layey
G12 = in-plane shear modulus

NU = Poisson's ratio: NU = NU12 = NU21 x E2/E1
NOTE: The NU you provide is the smallest of the two if
E1 > E2. This is a bit unusual, so BEWARE!
G13 = transverse shear modulus for shear in a plane normal
to the fibers
G23 = transverse shear modulus for shear in a plane parallel
to the fibers.

For an isotropic material just use E1 = E2; G12 = E1/[2(1+NU)]
G13 = G23 = G12

ALPHA1 = coefficient of thermal expansion along fibers
ALPHA2 = coefficient of thermal expansion transverse to fibers
TEMTUR = residual stress temperature (curing delta temperature)
COND1 = thermal conductivity along fibers
COND2 = thermal conductivity transverse to fibers

You will next see the prompt:
"Number IE1   of rows in the array E1: IE1"
What is wanted is the number of different material types.
In the example given above in which there is an 8-layered
symmetric laminate, there is only one material type, that is,
MATTYP(i), i=1,4 = 1, 1, 1, 1 In this example you would
provide IE1 = 1

355.1 Number IE1   of rows in the array E1: IE1
360.1 modulus in the fiber direction: E1
365.1 modulus transverse to fibers: E2
370.1 in-plane shear modulus: G12
375.1 small Poisson's ratio: NU
375.2
This is unusual, so BEWARE! NU is the small Poisson's
ratio if E1 > E2, which is almost always the case.
NU = NU12 = NU21 x E2/E1

380.1 x-z out-of-plane shear modulus: G13
380.2
Ths is the transverse shear modulus governing shear stiffness
normal to the laminate in a plane normal to the fibers. For
unidirectional tape you might use a value equal to or close
to the in-plane shear modulus, G12.

385.1 y-z out-of-plane shear modulus: G23
385.2
This is the transverse shear modulus governing shear stiffness
normal to the laminate in a plane parallel to the fibers. For
unidirectional tape you might use a value equal or close to
the in-plane shear modulus, G12.

390.1 coef.of thermal expansion along fibers: ALPHA1
395.1 coef.of thermal expan.transverse to fibers: ALPHA2
400.1 curing delta temperature (positive): TEMTUR
400.2
This is the temperature difference between the temperature
at which the material sets and the ambient (room) temperature,
that is, the temperature difference that gives rise to residual
stresses from curing the composite laminate. Use TEMTUR = 0
if you wish to neglect the effect of curing residual stresses.

405.1 conductivity along the fibers: COND1
405.2
This is the conductivity along the fibers in a unidirectional
ply of a composite laminate.

410.1 conductivity transverse to fibers: COND2
410.2
This is the conductivity transverse to the fibers in a
unidirectional
ply that is a layer in a composite laminate.

415.1 weight density of the material: DENSTY
415.2
e.g. aluminum = 0.1 lb/in^3
many composite materials have DENSTY = 0.057 lb/in^3

420.0
Next, you will be asked to provide a variable
called "WGT". This variable plays a role in the definition
of the objective:
OBJECTIVE = WGT*(normalized empty tank mass)
+ (1.0 - WGT)*(normalized conductance of support system)
After you provite WGT you will be asked to provide the
normalizing values of empty tank mass and total
conductance of all the supporting skirts.

425.1 objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
425.2
WGT is a "weighting" variable by means of which the
objective is defined.
In general, the objective is defined as:
OBJECTIVE = WGT*(normalized empty tank mass)
+(1.-WGT)*(normalized total skirt conductance)
If WGT = 0.0 the objective is given by:
OBJECTIVE = (total skirt conductance)
You will next be asked to provide two variables:

```
      1. TNKNRM = the normalizing quantity for empty tank mass
      2. CONNRM = the normalizing quantity for total skirt conductance
      With WGT > 0.0 the objective will be as follows:
      OBJECTIVE = WGT*(empty tank mass)/TNKNRM
      +(1.-WGT)*(total skirt conductance)/CONNRM

430.1 normalizing empty tank mass: TNKNRM
430.2
      In general, the objective is defined as:
      OBJECTIVE = WGT*(normalized empty tank mass)
      +(1.-WGT)*(normalized total skirt conductance)
      If WGT = 0.0 the objective is given by:
      OBJECTIVE = (total skirt conductance)
      You will next be asked to provide two variables:
      1. TNKNRM = the normalizing quantity for empty tank mass
      2. CONNRM = the normalizing quantity for total skirt conductance
      With WGT > 0.0 the objective will be as follows:
      OBJECTIVE = WGT*(empty tank mass)/TNKNRM
      +(1.-WGT)*(total skirt conductance)/CONNRM

435.1 normalizing total skirt conductance: CONNRM
435.2
      In general, the objective is defined as:
      OBJECTIVE = WGT*(normalized empty tank mass)
      +(1.-WGT)*(normalized total skirt conductance)
      If WGT = 0.0 the objective is given by:
      OBJECTIVE = (total skirt conductance)
      You will next be asked to provide the variable:
      CONNRM = the normalizing quantity for total skirt conductance
      With WGT > 0.0 the objective will be as follows:
      OBJECTIVE = WGT*(empty tank mass)/TNKNRM
      +(1.-WGT)*(total skirt conductance)/CONNRM


440.0
      Next, provide the index for mission phase:
      IPHASE = 1 means launch phase
      IPHASE = 2 means orbital phase
      In the orbital phase the conductance is lower than in the
      launch phase because the heat must flow through both the
      launch skirt and the inner orbital skirt assembly in series.

445.1 IPHASE=1=launch phase; IPHASE=2=orbital phase: IPHASE
445.2
      help for IPHASE


450.0
```

Next, provide the environment seen by the filled propellant tank. This environment has the following components:
1. ullage pressure, PRESS, in the propellant tank
2. quasi-static axial g-loading in gees, GAXIAL
3. quasi-static lateral g-loading in gees, GLATRL
4. propellant tank cool-down in the launch-hold condition
5. launch vehicle temperature in the launch-hold condition
6. average cool-down of each skirt in the launch-hold condition and during launch
7. propellant tank cool-down in the orbital condition
8. launch vehicle temperature in the orbital condition
9. average cool-down of each skirt in the orbital condition

You will next see the following prompt:
"Number NCASES of load cases (environments): NCASES"
Each case corresponds to a "bundle" of loads: ullage pressure, PRESS, axial g-loading, GAXIAL, lateral g-loading, GLATRL, and propellant tank cool-down delta temperature, TNKCOOL. It is probably best to optimize with NCASES = 2
For example, in Load Case 1 you might have:
PRESS = 24, GAXIAL = 10., GLATRL = 0., TNKCOOL = -200
In load Case 2 you might have:
PRESS = 24, GAXIAL = 0., GLATRL = 10., TNKCOOL = -200

455.1 Number NCASES of load cases (environments): NCASES
460.1 propellant tank ullage pressure: PRESS
460.2
The propellant tank is internally pressurized in addition to the pressure head provided by the propellant.

465.1 quasi-static axial g-loading: GAXIAL
465.2
Provide the ultimate axial g-loading to be seen by the propellant tank.

470.1 quasi-static lateral g-loading: GLATRL
470.2
Provide the ultimate resultant lateral g-loading to be seen by the propellant tank.

475.1 propellant tank cool-down from cryogen: TNKCOOL
475.2
This is the temperature decrease after the tank has been filled with cryogen.

480.0
The responses (behaviors) include the following:

1. four vibration modes and frequencies:
a. axial vibration
b. rolling vibration
c. lateral-pitching vibration mode 1
d. lateral-pitching vibration mode 2

2. maximum stress components in the composite laminates:
a. maximum tensile stress along the fibers of a ply
b. maximum compressive stress along the fibers of a ply
c. maximum tensile stress transverse to the fibers in a ply
d. maximum compressive stress transverse to the fibers in a ply
e. maximum in-plane shear stress in a ply
f. maximum vonMises effective stress if the material is isotropic

3. shell buckling of a skirt
4. force in a skirt in the launch-hold condition
5. maximum effective stress in the propellant tank
6. buckling of the propellant tank

You will next see the prompt:
"Number JFREQ of columns in the array, FREQ: JFREQ"
JFREQ is the number of free vibration frequencies to be computed for the tank/skirt system. In this study JFREQ is must always be equal to 4 There are two free vibration modes corresponding to n = 0 circumferential waves: one corresponding to rolling and the other corresponding to axial translation of the skirt-supported propellant tank. There are two free vibration modes corresponding to n = 1 circumferential wave: both corresponding to a combination of lateral translation and pitching of the propellant tank.

485.1 Number JFREQ of columns in the array, FREQ: JFREQ
490.0 free vibration frequency (cps): FREQ
490.2

Four vibration modes are important:
1. axial vibration [axisymmetric (n=0) vibration mode]
2. rolling vibration [axisymmetric (n=0) vibration mode]
3. lateral-pitching mode 1 (vibration with n = 1 circ. wave)
4. lateral-pitching mode 2 (vibration with n = 1 circ. wave)

495.1 minimum allowable frequency (cps): FREQA
495.2

Typically the minimum allowable frequency during the launch phase of the mission is significantly higher than the minimum allowable frequency in orbit.

500.1 factor of safety for freqency: FREQF
500.2

One suggestion would be a factor of safety of something like 1.2.

505.0

Next, you will be asked to provide behavioral variables relating to stress in the laminated composite skirts. For a unidirectional composite ply there are 5 stress components that are important:
1. tensile stress along fibers
2. compressive stress along fibers
3. tensile stress transverse to fibers
4. compressive stress transverse to fibers
5. in-plane shear stress

The ply can fail if the allowable stress for any one or more of these stress components is exceeded.

You will next see the prompt:
"Number JSTRES1 of columns in the array, STRES1: JSTRES1"
What is wanted is the number of stress components, which must always be 5 in this GENOPT application. Enter "5" when you are presented with this prompting phrase.

510.1 Number JSTRES1 of columns in the array, STRES1: JSTRES1
515.0 maximum stress in material 1: STRES1
515.2

The six possible stress components are:
1. tensile stress along fibers
2. compressive stress along fibers
3. tensile stress transverse to fibers
4. compressive stress transverse to fibers
5. in-plane shear stress
6. vonMises effective stress (in isotropic material)

520.1 maximum allowable stress in material 1: STRES1A
525.1 factor of safety for stress, matl 1: STRES1F
525.2

Generally use a factor of safety between 1.0 and 1.5.

530.0 maximum stress in material 2: STRES2
530.2

In an analogous manner to the behavior, STRES1, there are six component of stress in the array, STRES2. The only difference here is that we are concerned with material type 2 instead of material type 1.

535.1 maximum allowable stress in material 2: STRES2A
540.1 factor of safety for stress, matl 2: STRES2F

540.2

Generally use a factor of safety between 1.0 and 1.5.

545.0

Next, you will be asked to provide a behavioral variable relating to buckling of the laminated composite skirts.

You will next see the prompt:
"Number JSHLBUK of columns in the array, SHLBUK: JSHLBUK"
What is wanted is the number of skirt supports.

550.1 Number JSHLBUK of columns in the array, SHLBUK: JSHLBUK
555.0 buckling of skirt as a shell: SHLBUK
555.2

The shell buckling mode of the skirt may be a short-axial-wavelength mode. The critical shell buckling mode usually has multiple waves around the circumference of the skirt.

560.1 allowable for shell buckling of skirt: SHLBUKA
560.2

Always set SHLBUKA = 1.0

565.1 factor of safety for shell buckling of skirt: SHLBUKF
565.2

Generally use a factor of safety of about 2.0 in order to account for the inevitable presence of initial imperfections in the skirt.

570.0 launch-hold force in a skirt: FORCE
570.2

During lauch-hold a compound skirt, that is, a skirt that has both a launch wall and a "folded" orbital wall, has a "disconnect" feature (a gap) that must remain open during the launch-hold phase and during the orbital phase of a mission. If FORCE is less than the allowable force, then this gap remains open, and the conductance of heat into the propellant tank from the launch vehicle remains small.

575.1 maximum allowable launch-hold force in skirt: FORCEA
575.2

Consult the maker of "disconnect" skirts for what the maximum allowable launch-hold/orbital FORCE should be.

580.1 factor of safety for launch-hold force: FORCEF
580.2

Generally use a factor of safety between 1.0 and 1.5.

585.0 maximum stress in the propellant tank: TNKSTR
585.2
It is assumed here that the propellant tank is made of
isotropic material with a single layer in the shell wall.

590.1 allowable for propellant tank stress: TNKSTRA
590.2
Conult the experts for what this maximum allowable stress
should be.

595.1 factor of safety for tank stress: TNKSTRF
595.2
Use a factor of safety between 1.0 and 2.0

600.0 propellant tank buckling load factor: TNKBUK
600.2
The propellant tank can buckle in various ways:
1. Buckling of the internally pressurized ellipsoidal
dome at the bottom of the propellant tank
2. Buckling due to local compressive membrane stresses in
the neighborhoods of where the skirts "poke at" the
propellant tank.

605.1 allowable for propellant tank buckling: TNKBUKA
605.2
Always set TNKBUKA = 1.0

610.1 factor of safety for tank buckling: TNKBUKF
610.2
Generally use a factor of safety between 1.0 and 1.2

615.0
In this study the objective is a weighted average of the
normalized empty tank mass and the normalized total conductance:
objective = WGTxTOTMAS/TNKNRM +(1-WGT)xCONDCT/CONNRM
in which TOTMAS is the empty tank mass, TNKNRM is a user-
provided normalizing empty tank mass, CONDCT is the total
conductance of heat into the propellant tank and CONNRM is
the normalizing total conductance.
This compound objective is to be minimized subject to the
responses (behaviors) identified previously.

620.0 WGTxTOTMAS/TNKNRM +(1-WGT)xCONDCT/CONNRM: CONDCT
999.0 DUMMY ENTRY TO MARK END OF FILE

Table 3 Input data for the GENOPT processor, BEGIN (oneskirt.BEG file) (These input data are provided by the End user for the specific case called “test”)

```
================================================================================
      N         $ Do you want a tutorial session and tutorial output?
   386.4000     $ acceleration of gravity: GRAV
      300       $ diameter of launch vehicle: DIAVEH
      200       $ diameter of the aft dome of the tank: AFTDIA
       50       $ height of the aft dome of the tank: AFTHI
      200       $ diameter of the forward dome of the tank: FWDDIA
       50       $ height of the forward dome of the tank: FWDHI
      400       $ axial dist. from aft dome apex to fwd dome apex: FLTANK
      100       $ global axial coordinate of the aft dome apex: ZAPEX
  0.2560000E-02 $ weight density of the propellant: DENPRP
      300       $ global axial coordinate of the tank cg: ZCG
  0.1000000     $ thickness of the tank aft dome skin: THKAFT
  0.1000000     $ thickness of the tank cylinder skin: THKMID
  0.1000000     $ thickness of the forward tank dome skin: THKFWD
       10       $ spacing of the tank orthogrid stringers: STRSPC
       10       $ spacing of the tank orthogrid rings: RNGSPC
  0.5000000     $ thickness of the tank orthogrid stringers: STRTHK
        1       $ height of the tank orthogrid stringers: STRHI
  0.5000000     $ thickness of the tank orthogrid rings: RNGTHK
        1       $ height of the tank orthogrid rings: RNGHI
  0.1000000E+08 $ Young's modulus of the cold tank material: ETANK
  0.3000000     $ Poisson's ratio of the tank material: NUTANK
  0.2500000E-03 $ mass density of the tank material: DENTNK
  0.1000000E-04 $ coef.thermal expansion of tank material: ALTNK
        1       $ tank is vertical (1) or horizontal (2): IAXIS
        1       $ Number IZTANK  of rows in the array  ZTANK: IZTANK
      300       $ global axial coordinate of tank support ring: ZTANK(  1)
       50       $ global axial coordinate of "ground": ZGRND(  1)
        1       $ propellant tank reinforcement type: RNGTYP(  1)
        1       $ Number IDUBAXL of rows in the array  DUBAXL: IDUBAXL
       30       $ axial length of the propellant tank doubler: DUBAXL(  1)
  0.1000000     $ max.thickness of the propellant tank doubler: DUBTHK(  1)
  0.2000000     $ thickness of the tank reinforcement ring: TRNGTH(  1)
   1.000000     $ height of the tank reinforcement ring: TRNGHI(  1)
  0.1000000E+08 $ hoop modulus of the tank ring: TRNGE(  1)
  0.1000000E-04 $ coef.of thermal expansion of the tank ring: ALRNGT(  1)
        1       $ Number ISKRTYP of rows in the array  SKRTYP: ISKRTYP
        1       $ skirt type index: SKRTYP(  1)
        5       $ tank-end length of one-layered skirt part: LNGTNK1(  1)
  0.2500000     $ tank-end thickness of tapered skirt part: THKTNK1(  1)
        5       $ tank-end length of tapered prongs: LNGTNK2(  1)
  0.5000000E-01 $ tank-end thickness of one tapered prong: THKTNK2(  1)
        5       $ "ground" end length of one-layered skirt part: LNGVEH1(  1)
  0.2500000     $ "ground"-end thickness of tapered skirt part: THKVEH1(  1)
        5       $ "ground"-end length of tapered prongs: LNGVEH2(  1)
```

```
0.5000000E-01 $ "ground"-end thickness of one tapered prong: TNKVEH2(  1)
       1      $ type of wall constructions in skirt type SKRTYP: WALTYP(  1)
       6      $ Number ITHICK  of rows in the array  THICK: ITHICK
0.3000000E-01 $ thickness of a lamina: THICK(  1)
0.3000000E-01 $ thickness of a lamina: THICK(  2)
0.3000000E-01 $ thickness of a lamina: THICK(  3)
0.3000000E-01 $ thickness of a lamina: THICK(  4)
0.3000000E-01 $ thickness of a lamina: THICK(  5)
0.3000000E-01 $ thickness of a lamina: THICK(  6)
      45      $ layup angle: ANGLE(  1)
     -45      $ layup angle: ANGLE(  2)
      45      $ layup angle: ANGLE(  3)
     -45      $ layup angle: ANGLE(  4)
      45      $ layup angle: ANGLE(  5)
     -45      $ layup angle: ANGLE(  6)
       1      $ Material type: MATTYP(  1)
       1      $ Material type: MATTYP(  2)
       1      $ Material type: MATTYP(  3)
       1      $ Material type: MATTYP(  4)
       1      $ Material type: MATTYP(  5)
       1      $ Material type: MATTYP(  6)
       1      $ Number JLAYTYP of columns in the array, LAYTYP: JLAYTYP
      12      $ Number ILAYTYP of rows in this column of LAYTYP: ILAYTYP
       1      $ layer type index: LAYTYP(  1,  1)
       2      $ layer type index: LAYTYP(  2,  1)
       3      $ layer type index: LAYTYP(  3,  1)
       4      $ layer type index: LAYTYP(  4,  1)
       5      $ layer type index: LAYTYP(  5,  1)
       6      $ layer type index: LAYTYP(  6,  1)
       6      $ layer type index: LAYTYP(  7,  1)
       5      $ layer type index: LAYTYP(  8,  1)
       4      $ layer type index: LAYTYP(  9,  1)
       3      $ layer type index: LAYTYP( 10,  1)
       2      $ layer type index: LAYTYP( 11,  1)
       1      $ layer type index: LAYTYP( 12,  1)
       1      $ Number IE1     of rows in the array  E1: IE1
0.2100000E+08 $ modulus in the fiber direction: E1(  1)
 1600000.     $ modulus transverse to fibers: E2(  1)
 679000.0     $ in-plane shear modulus: G12(  1)
0.2300000E-01 $ small Poisson's ratio: NU(  1)
 627000.0     $ x-z out-of-plane shear modulus: G13(  1)
 334000.0     $ y-z out-of-plane shear modulus: G23(  1)
0.1000000E-05 $ coef.of thermal expansion along fibers: ALPHA1(  1)
0.1000000E-04 $ coef.of thermal expan.transverse to fibers: ALPHA2(  1)
     170      $ curing delta temperature (positive): TEMTUR(  1)
0.7270000E-02 $ conductivity along the fibers: COND1(  1)
0.4370000E-02 $ conductivity transverse to fibers: COND2(  1)
0.5700000E-01 $ weight density of the material: DENSTY(  1)
0.5000000     $ objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
 10.00000     $ normalizing empty tank mass: TNKNRM
0.2000000E-02 $ normalizing total skirt conductance: CONNRM
       1      $ IPHASE=1=launch phase; IPHASE=2=orbital phase: IPHASE
       2      $ Number NCASES  of load cases (environments): NCASES
```

```
      25       $ propellant tank ullage pressure: PRESS(  1)
      25       $ propellant tank ullage pressure: PRESS(  2)
      10       $ quasi-static axial g-loading: GAXIAL(  1)
       0       $ quasi-static axial g-loading: GAXIAL(  2)
       0       $ quasi-static lateral g-loading: GLATRL(  1)
      10       $ quasi-static lateral g-loading: GLATRL(  2)
    -200       $ propellant tank cool-down from cryogen: TNKCOOL(  1)
    -200       $ propellant tank cool-down from cryogen: TNKCOOL(  2)
       4       $ Number JFREQ   of columns in the array, FREQ: JFREQ
      10       $ minimum allowable frequency (cps): FREQA(  1,  1)
      10       $ minimum allowable frequency (cps): FREQA(  2,  1)
      10       $ minimum allowable frequency (cps): FREQA(  1,  2)
      10       $ minimum allowable frequency (cps): FREQA(  2,  2)
      10       $ minimum allowable frequency (cps): FREQA(  1,  3)
      10       $ minimum allowable frequency (cps): FREQA(  2,  3)
      10       $ minimum allowable frequency (cps): FREQA(  1,  4)
      10       $ minimum allowable frequency (cps): FREQA(  2,  4)
  1.200000     $ factor of safety for freqency: FREQF(  1,  1)
  1.200000     $ factor of safety for freqency: FREQF(  2,  1)
  1.200000     $ factor of safety for freqency: FREQF(  1,  2)
  1.200000     $ factor of safety for freqency: FREQF(  2,  2)
  1.200000     $ factor of safety for freqency: FREQF(  1,  3)
  1.200000     $ factor of safety for freqency: FREQF(  2,  3)
  1.200000     $ factor of safety for freqency: FREQF(  1,  4)
  1.200000     $ factor of safety for freqency: FREQF(  2,  4)
       5       $ Number JSTRES1 of columns in the array, STRES1: JSTRES1
   140571      $ maximum allowable stress in material 1: STRES1A(  1,  1)
   140571      $ maximum allowable stress in material 1: STRES1A(  2,  1)
   104714      $ maximum allowable stress in material 1: STRES1A(  1,  2)
   104714      $ maximum allowable stress in material 1: STRES1A(  2,  2)
    10557      $ maximum allowable stress in material 1: STRES1A(  1,  3)
    10557      $ maximum allowable stress in material 1: STRES1A(  2,  3)
    14529      $ maximum allowable stress in material 1: STRES1A(  1,  4)
    14529      $ maximum allowable stress in material 1: STRES1A(  2,  4)
     6290      $ maximum allowable stress in material 1: STRES1A(  1,  5)
     6290      $ maximum allowable stress in material 1: STRES1A(  2,  5)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  1,  1)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  2,  1)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  1,  2)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  2,  2)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  1,  3)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  2,  3)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  1,  4)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  2,  4)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  1,  5)
  1.500000     $ factor of safety for stress, matl 1: STRES1F(  2,  5)
   140571      $ maximum allowable stress in material 2: STRES2A(  1,  1)
   140571      $ maximum allowable stress in material 2: STRES2A(  2,  1)
   104714      $ maximum allowable stress in material 2: STRES2A(  1,  2)
   104714      $ maximum allowable stress in material 2: STRES2A(  2,  2)
    10557      $ maximum allowable stress in material 2: STRES2A(  1,  3)
    10557      $ maximum allowable stress in material 2: STRES2A(  2,  3)
    14529      $ maximum allowable stress in material 2: STRES2A(  1,  4)
```

```
   14529      $ maximum allowable stress in material 2: STRES2A(  2,  4)
    6290      $ maximum allowable stress in material 2: STRES2A(  1,  5)
    6290      $ maximum allowable stress in material 2: STRES2A(  2,  5)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  1,  1)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  2,  1)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  1,  2)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  2,  2)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  1,  3)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  2,  3)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  1,  4)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  2,  4)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  1,  5)
  1.500000    $ factor of safety for stress, matl 2: STRES2F(  2,  5)
       2      $ Number JSHLBUK of columns in the array, SHLBUK: JSHLBUK
       1      $ allowable for shell buckling of skirt: SHLBUKA(  1,  1)
       1      $ allowable for shell buckling of skirt: SHLBUKA(  2,  1)
       1      $ allowable for shell buckling of skirt: SHLBUKA(  1,  2)
       1      $ allowable for shell buckling of skirt: SHLBUKA(  2,  2)
       2      $ factor of safety for shell buckling of skirt: SHLBUKF(  1,  1)
       2      $ factor of safety for shell buckling of skirt: SHLBUKF(  2,  1)
       2      $ factor of safety for shell buckling of skirt: SHLBUKF(  1,  2)
       2      $ factor of safety for shell buckling of skirt: SHLBUKF(  2,  2)
   15000      $ maximum allowable launch-hold force in skirt: FORCEA(  1,  1)
   15000      $ maximum allowable launch-hold force in skirt: FORCEA(  2,  1)
   15000      $ maximum allowable launch-hold force in skirt: FORCEA(  1,  2)
   15000      $ maximum allowable launch-hold force in skirt: FORCEA(  2,  2)
       1      $ factor of safety for launch-hold force: FORCEF(  1,  1)
       1      $ factor of safety for launch-hold force: FORCEF(  2,  1)
       1      $ factor of safety for launch-hold force: FORCEF(  1,  2)
       1      $ factor of safety for launch-hold force: FORCEF(  2,  2)
   50000      $ allowable for propellant tank stress: TNKSTRA(  1,  1)
   50000      $ allowable for propellant tank stress: TNKSTRA(  2,  1)
   50000      $ allowable for propellant tank stress: TNKSTRA(  1,  2)
   50000      $ allowable for propellant tank stress: TNKSTRA(  2,  2)
       1      $ factor of safety for tank stress: TNKSTRF(  1,  1)
       1      $ factor of safety for tank stress: TNKSTRF(  2,  1)
       1      $ factor of safety for tank stress: TNKSTRF(  1,  2)
       1      $ factor of safety for tank stress: TNKSTRF(  2,  2)
       1      $ allowable for propellant tank buckling: TNKBUKA(  1,  1)
       1      $ allowable for propellant tank buckling: TNKBUKA(  2,  1)
       1      $ allowable for propellant tank buckling: TNKBUKA(  1,  2)
       1      $ allowable for propellant tank buckling: TNKBUKA(  2,  2)
       1      $ factor of safety for tank buckling: TNKBUKF(  1,  1)
       1      $ factor of safety for tank buckling: TNKBUKF(  2,  1)
       1      $ factor of safety for tank buckling: TNKBUKF(  1,  2)
       1      $ factor of safety for tank buckling: TNKBUKF(  2,  2)
```

Table 4 Input data for the GENOPT processor, DECIDE (oneskirt.DEC file) (These data are provided by the End user for the specific case, "oneskirt")

```
===========================================================
N         $ Do you want a tutorial session and tutorial output?
        1      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.(  1)
  0.2000000     $ Upper bound of variable no.(  1)
     N          $ Do you want especially to restrict variable no.(  1)
     Y          $ Any more decision variables (Y or N) ?
        2      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.(  2)
  0.2000000     $ Upper bound of variable no.(  2)
     N          $ Do you want especially to restrict variable no.(  2)
     Y          $ Any more decision variables (Y or N) ?
        3      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.(  3)
  0.2000000     $ Upper bound of variable no.(  3)
     N          $ Do you want especially to restrict variable no.(  3)
     Y          $ Any more decision variables (Y or N) ?
        4      $ Choose a decision variable (1,2,3,...)
   3.000000     $ Lower bound of variable no.(  4)
   10.00000     $ Upper bound of variable no.(  4)
     N          $ Do you want especially to restrict variable no.(  4)
     Y          $ Any more decision variables (Y or N) ?
        6      $ Choose a decision variable (1,2,3,...)
  0.1000000     $ Lower bound of variable no.(  6)
   1.000000     $ 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,...)
  0.2000000     $ Lower bound of variable no.(  7)
   1.000000     $ Upper bound of variable no.(  7)
     N          $ Do you want especially to restrict variable no.(  7)
     Y          $ Any more decision variables (Y or N) ?
       11      $ Choose a decision variable (1,2,3,...)
       20      $ Lower bound of variable no.( 11)
   290.0000     $ Upper bound of variable no.( 11)
     N          $ Do you want especially to restrict variable no.( 11)
     Y          $ Any more decision variables (Y or N) ?
       13      $ Choose a decision variable (1,2,3,...)
  0.2000000E-01 $ Lower bound of variable no.( 13)
   2.000000     $ Upper bound of variable no.( 13)
     N          $ Do you want especially to restrict variable no.( 13)
     Y          $ Any more decision variables (Y or N) ?
       14      $ Choose a decision variable (1,2,3,...)
```

```
0.5000000E-01 $ Lower bound of variable no.( 14)
 2.000000     $ Upper bound of variable no.( 14)
    N         $ Do you want especially to restrict variable no.( 14)
    Y         $ Any more decision variables (Y or N) ?
      16      $ Choose a decision variable (1,2,3,...)
 2.000000     $ Lower bound of variable no.( 16)
 10.00000     $ Upper bound of variable no.( 16)
    N         $ Do you want especially to restrict variable no.( 16)
    Y         $ Any more decision variables (Y or N) ?
      17      $ Choose a decision variable (1,2,3,...)
0.5000000E-01 $ Lower bound of variable no.( 17)
 1.000000     $ Upper bound of variable no.( 17)
    N         $ Do you want especially to restrict variable no.( 17)
    Y         $ Any more decision variables (Y or N) ?
      18      $ Choose a decision variable (1,2,3,...)
 2.000000     $ Lower bound of variable no.( 18)
 10.00000     $ Upper bound of variable no.( 18)
    N         $ Do you want especially to restrict variable no.( 18)
    Y         $ Any more decision variables (Y or N) ?
      19      $ Choose a decision variable (1,2,3,...)
0.3000000E-01 $ Lower bound of variable no.( 19)
0.3000000     $ Upper bound of variable no.( 19)
    N         $ Do you want especially to restrict variable no.( 19)
    Y         $ Any more decision variables (Y or N) ?
      20      $ Choose a decision variable (1,2,3,...)
 2.000000     $ Lower bound of variable no.( 20)
 10.00000     $ Upper bound of variable no.( 20)
    N         $ Do you want especially to restrict variable no.( 20)
    Y         $ Any more decision variables (Y or N) ?
      21      $ Choose a decision variable (1,2,3,...)
0.5000000E-01 $ Lower bound of variable no.( 21)
 1.000000     $ Upper bound of variable no.( 21)
    N         $ Do you want especially to restrict variable no.( 21)
    Y         $ Any more decision variables (Y or N) ?
      22      $ Choose a decision variable (1,2,3,...)
       2      $ Lower bound of variable no.( 22)
      10      $ Upper bound of variable no.( 22)
    N         $ Do you want especially to restrict variable no.( 22)
    Y         $ Any more decision variables (Y or N) ?
      23      $ Choose a decision variable (1,2,3,...)
0.3000000E-01 $ Lower bound of variable no.( 23)
0.3000000     $ Upper bound of variable no.( 23)
    N         $ Do you want especially to restrict variable no.( 23)
    Y         $ Any more decision variables (Y or N) ?
      24      $ Choose a decision variable (1,2,3,...)
0.5000000E-02 $ Lower bound of variable no.( 24)
0.1000000     $ Upper bound of variable no.( 24)
    N         $ Do you want especially to restrict variable no.( 24)
```

```
Y          $ Any more decision variables (Y or N) ?
  30       $ Choose a decision variable (1,2,3,...)
  10       $ Lower bound of variable no.( 30)
  80       $ Upper bound of variable no.( 30)
Y          $ Do you want especially to restrict variable no.( 30)
   2       $ Maximum permitted change in variable no.( 30)
Y          $ Any more decision variables (Y or N) ?
  32       $ Choose a decision variable (1,2,3,...)
  10       $ Lower bound of variable no.( 32)
  80       $ Upper bound of variable no.( 32)
Y          $ Do you want especially to restrict variable no.( 32)
   2       $ Maximum permitted change in variable no.( 32)
Y          $ Any more decision variables (Y or N) ?
  34       $ Choose a decision variable (1,2,3,...)
  10       $ Lower bound of variable no.( 34)
  80       $ Upper bound of variable no.( 34)
Y          $ Do you want especially to restrict variable no.( 34)
   2       $ Maximum permitted change in variable no.( 34)
N          $ Any more decision variables (Y or N) ?
Y          $ Any linked variables (Y or N) ?
   5       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
   4       $ To which variable is this variable linked?
   1       $ Assign a value to the linking coefficient, C(j)
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
Y          $ Any more linked variables (Y or N) ?
   8       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
   6       $ To which variable is this variable linked?
   1       $ Assign a value to the linking coefficient, C(j)
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
Y          $ Any more linked variables (Y or N) ?
   9       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
   7       $ To which variable is this variable linked?
   1       $ Assign a value to the linking coefficient, C(j)
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
Y          $ Any more linked variables (Y or N) ?
  15       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
  14       $ To which variable is this variable linked?
   5       $ Assign a value to the linking coefficient, C(j)
```

```
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  25      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  24      $ To which variable is this variable linked?
   1      $ Assign a value to the linking coefficient, C(j)
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  26      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  24      $ To which variable is this variable linked?
   1      $ Assign a value to the linking coefficient, C(j)
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  27      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  24      $ To which variable is this variable linked?
   1      $ Assign a value to the linking coefficient, C(j)
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  28      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  24      $ To which variable is this variable linked?
   1      $ Assign a value to the linking coefficient, C(j)
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  29      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  24      $ To which variable is this variable linked?
   1      $ Assign a value to the linking coefficient, C(j)
   1      $ To what power is the decision variable raised?
N         $ Any other decision variables in the linking expression?
N         $ Any constant C0 in the linking expression?
Y         $ Any more linked variables (Y or N) ?
  31      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  30      $ To which variable is this variable linked?
  -1      $ Assign a value to the linking coefficient, C(j)
```

```
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
Y          $ Any more linked variables (Y or N) ?
  33       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
  32       $ To which variable is this variable linked?
  -1       $ Assign a value to the linking coefficient, C(j)
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
Y          $ Any more linked variables (Y or N) ?
  35       $ Choose a linked variable (1,2,3,...)
   1       $ Choose type of linking (1=polynomial; 2=user-defined)
  34       $ To which variable is this variable linked?
  -1       $ Assign a value to the linking coefficient, C(j)
   1       $ To what power is the decision variable raised?
N          $ Any other decision variables in the linking expression?
N          $ Any constant C0 in the linking expression?
N          $ Any more linked variables (Y or N) ?
N          $ Any inequality relations among variables? (type H)
Y          $ Any escape variables (Y or N) ?
Y          $ Want to have escape variables chosen by default?
```

Table 5 Input data for the GENOPT processor, MAINSETUP (oneskirt.OPT file) (These data are provided by the End user)

```
==============================================================
      N         $ Do you want a tutorial session and tutorial output?
         0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
         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
      N         $ Do you want default (RATIO=10) for initial move limit jump?
   1000000.     $ Provide a value for the "move limit jump" ratio, RATIO
      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)
==============================================================================
```

Table 6 Output from the GENOPT processor, OPTIMIZE, for a fixed, optimized design. The specific case is called "oneskirt" (long propellant tank with one supporting skirt. (oneskirt.OPM file)

```
==========================================================================
      N         $ Do you want a tutorial session and tutorial output?
         0      $ Choose an analysis you DON'T want (1, 2,..), IBEHAV
         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
      N         $ Do you want default (RATIO=10) for initial move limit jump?
   1000000.     $ Provide a value for the "move limit jump" ratio, RATIO
      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  oneskirt.OPT  FILE ***********
 ************ AUGUST, 2010 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  oneskirt.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 oneskirt.  Results are stored in the file  oneskirt.OPM.
 Please inspect oneskirt.OPM before doing more design iterations.
 ************************************************************




 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.   0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER       DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E-02 1.2510E-01  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 6.4820E-02  2.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 7.4940E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 5.4320E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   N     N     Y      4    1.00E+00  0.00E+00 5.4320E+00  0.00E+00  spacing of the
tank orthogrid rings: RNGSPC
   6   Y     N     N      0    0.00E+00  1.00E-01 5.2020E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
```

```
   7   Y     N     N      0    0.00E+00  2.00E-01 2.0000E-01  1.00E+00  height of the
tank orthogrid stringers: STRHI
   8   N     N     Y      6    1.00E+00  0.00E+00 5.2020E-01  0.00E+00  thickness of the
tank orthogrid rings: RNGTHK
   9   N     N     Y      7    1.00E+00  0.00E+00 2.0000E-01  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 3.0000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   Y     N     N      0    0.00E+00  2.00E+01 9.0450E+01  2.90E+02  global axial
coordinate of "ground": ZGRND(1 )
  12   N     N     N      0    0.00E+00  0.00E+00 3.0000E+01  0.00E+00  axial length of
the propellant tank doubler: DUBAXL(1 )
  13   Y     N     N      0    0.00E+00  2.00E-02 7.6930E-02  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  14   Y     N     N      0    0.00E+00  5.00E-02 5.4450E-02  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  15   N     N     Y     14    5.00E+00  0.00E+00 2.7230E-01  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
  16   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  tank-end length
of one-layered skirt part: LNGTNK1(1 )
  17   Y     N     N      0    0.00E+00  5.00E-02 1.5320E-01  1.00E+00  tank-end
thickness of tapered skirt part: THKTNK1(1 )
  18   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  tank-end length
of tapered prongs: LNGTNK2(1 )
  19   Y     N     N      0    0.00E+00  3.00E-02 3.1270E-02  3.00E-01  tank-end
thickness of one tapered prong: THKTNK2(1 )
  20   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  "ground" end
length of one-layered skirt part: LNGVEH1(1
  21   Y     N     N      0    0.00E+00  5.00E-02 1.9510E-01  1.00E+00  "ground"-end
thickness of tapered skirt part: THKVEH1(1 )
  22   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  "ground"-end
length of tapered prongs: LNGVEH2(1 )
  23   Y     Y     N      0    0.00E+00  3.00E-02 4.2190E-02  3.00E-01  "ground"-end
thickness of one tapered prong: THKVEH2(1 )
  24   Y     Y     N      0    0.00E+00  5.00E-03 8.7980E-03  1.00E-01  thickness of a
lamina: THICK(1 )
  25   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  26   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  27   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(4 )
  28   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  29   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  30   Y     N     N      0    0.00E+00  1.00E+01 3.3740E+01  8.00E+01  layup angle:
ANGLE(1 )
  31   N     N     Y     30   -1.00E+00  0.00E+00-3.3740E+01  0.00E+00  layup angle:
ANGLE(2 )
  32   Y     N     N      0    0.00E+00  1.00E+01 7.6350E+01  8.00E+01  layup angle:
ANGLE(3 )
  33   N     N     Y     32   -1.00E+00  0.00E+00-7.6350E+01  0.00E+00  layup angle:
ANGLE(4 )
  34   Y     N     N      0    0.00E+00  1.00E+01 2.4830E+01  8.00E+01  layup angle:
ANGLE(5 )
  35   N     N     Y     34   -1.00E+00  0.00E+00-2.4830E+01  0.00E+00  layup angle:
ANGLE(6 )
```

```
  BEHAVIOR FOR  1 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1

  BEHAVIOR OVER J =  vibration mode type

 CHAPTER 6: Free vibration analysis-BEHX1x, x=1,2; x=load case)
 This is a BIGBOSOR4 model of the propellant tank with skirts.
 There is no loading. The mass of the
 propellant is "lumped" into the middle wall of the three-
 layered wall (inner layer = smeared orthogrid; middle layer=
 propellant tank wall of constant thickness; outer layer=
 tapered doubler centered on the global axial coordinate where
 the skirts (AFT and FORWARD) attached to the tank.


 BIGBOSOR4 input file for: free vibration frequencies for Load Case 1
oneskirt.BEHX11

 FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
  2.0796E+01(n= 0 circ.waves)  2.6236E+01(n= 0 circ.waves)
  1.1988E+01(n= 1 circ.waves)  1.4294E+01(n= 1 circ.waves)
    1        20.79563      free vibration frequency (cps): FREQ(1 ,1 )
    2        11.98785      free vibration frequency (cps): FREQ(1 ,2 )
    3        26.23620      free vibration frequency (cps): FREQ(1 ,3 )
    4        14.29377      free vibration frequency (cps): FREQ(1 ,4 )

  BEHAVIOR OVER J =  stress component number
    5       0.1000000E-09  maximum stress in material 1: STRES1(1 ,1 )
    6       0.1000000E-09  maximum stress in material 1: STRES1(1 ,2 )
    7       0.1000000E-09  maximum stress in material 1: STRES1(1 ,3 )
    8       0.1000000E-09  maximum stress in material 1: STRES1(1 ,4 )
    9       0.1000000E-09  maximum stress in material 1: STRES1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
   10       0.1000000E-09  maximum stress in material 2: STRES2(1 ,1 )
   11       0.1000000E-09  maximum stress in material 2: STRES2(1 ,2 )
   12       0.1000000E-09  maximum stress in material 2: STRES2(1 ,3 )
   13       0.1000000E-09  maximum stress in material 2: STRES2(1 ,4 )
   14       0.1000000E-09  maximum stress in material 2: STRES2(1 ,5 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)
   15       0.1000000E+11  buckling of skirt as a shell: SHLBUK(1 ,1 )
   16       0.1000000E+11  buckling of skirt as a shell: SHLBUK(1 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)
   17       0.1000000E-09  launch-hold force in a skirt: FORCE(1 ,1 )
   18       0.1000000E-09  launch-hold force in a skirt: FORCE(1 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)

 CHAPTER 12: Maximum effective stress in the propellant tank/
 skirt system - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case
 The tank/skirt system is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The purpose of this model is to compute the maximum
```

```
 effective stress in the isotropic propellant tank and the
 maximum stress in the supporting skirt(s), which consist of
 five segments each of combined isotropic and laminated
 composite material. This is an "INDIC=3" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case  1:
 maximum stress in propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  0.0000E+00 in which JCOL = 1
oneskirt.BEHX811

 ***** MAX. NORMAL DISP.: PROPELLANT TANK *******

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  7.9681E-01, LOCATW(1)=1000*ISEG+I=  6001
 ********************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  3.6054E+00 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
  2  5.1397E+01 fiber tension : matl=2 ,  A , seg=2 , node=1 , layer=11,z= 0.04  ;FS=  1.00
  3  4.2492E+00 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
  4  2.2908E+00 transv tension: matl=2 ,  A , seg=3 , node=91, layer=8 ,z= 0.02  ;FS=  1.00
  5  1.0799E+01 in-plane shear: matl=2 ,  A , seg=3 , node=92, layer=1 ,z=-0.05  ;FS=  1.00
  6  9.9369E-01 fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
  7  2.8139E+00 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
  8  1.3974E+00 transv tension: matl=3 ,  A , seg=18, node=6 , layer=1 ,z=-0.03  ;FS=  1.00
  9  1.8388E+00 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 10  1.5450E+00 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 11  1.5188E+00 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 12  1.3104E+00 effect. stress: matl=6 ,  A , seg=18, node=5 , layer=2 ,z= 0.03  ;FS=  1.00
 13  1.5674E+00 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 ****************************************************
 Stress=  2.7350E+03 fiber tension : matl=2 ,  A , seg=2 , node=1 , layer=11,z= 0.04  ;FS=  1.00
 Stress=  5.0317E+04 fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
 Stress=  2.4643E+04 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
 Stress=  1.7769E+04 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
 Stress=  4.6084E+03 transv tension: matl=2 ,  A , seg=3 , node=91, layer=8 ,z= 0.02  ;FS=  1.00
 Stress=  3.5781E+04 transv tension: matl=3 ,  A , seg=18, node=6 , layer=1 ,z=-0.03  ;FS=  1.00
 Stress=  2.7192E+04 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  5.8244E+02 in-plane shear: matl=2 ,  A , seg=3 , node=92, layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  1.3868E+04 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  3.2363E+04 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 Stress=  3.2921E+04 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 Stress=  3.8157E+04 effect. stress: matl=6 ,  A , seg=18, node=5 , layer=2 ,z= 0.03  ;FS=  1.00
 Stress=  3.1901E+04 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 Modified maximum stress components for Load Case  1 STRESS2(i),i=1,6=
     5.0317E+04     1.7769E+04     3.5781E+04     2.7192E+04     4.6299E+03     3.8157E+04
     fiber tension  fiber compres. transv tension transv compres in-plane shear effect. stress

 ***** MAX. STRESS IN THE PROPELLANT TANK *******

 ****** MAX. EFF. STRESS IN ISOTROPIC WALL,LOAD A ******
 STRMAX(1)=  1.1141E+04, LOCATS(1)=1000*ISEG+I=  5013
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0317E+04
fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
 ******************************************************
   19        50317.44      maximum stress in the propellant tank: TNKSTR(1 ,1 )
```

```
 BIGBOSOR4 input file for load case  1:
 maximum stress in propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  9.0000E+01 in which JCOL = 2
oneskirt.BEHX821

 ***** MAX. NORMAL DISP.: PROPELLANT TANK *******

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  7.9681E-01, LOCATW(1)=1000*ISEG+I=  6001
 ********************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  3.6054E+00 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
  2  5.1397E+01 fiber tension : matl=2 ,  A , seg=2 , node=1 , layer=11,z= 0.04  ;FS=  1.00
  3  4.2492E+00 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
  4  2.2908E+00 transv tension: matl=2 ,  A , seg=3 , node=91, layer=8 ,z= 0.02  ;FS=  1.00
  5  1.0799E+01 in-plane shear: matl=2 ,  A , seg=3 , node=92, layer=1 ,z=-0.05  ;FS=  1.00
  6  9.9369E-01 fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
  7  2.8139E+00 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
  8  1.3974E+00 transv tension: matl=3 ,  A , seg=18, node=6 , layer=1 ,z=-0.03  ;FS=  1.00
  9  1.8388E+00 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 10  1.5450E+00 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 11  1.5188E+00 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 12  1.3104E+00 effect. stress: matl=6 ,  A , seg=18, node=5 , layer=2 ,z= 0.03  ;FS=  1.00
 13  1.5674E+00 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 **************************************************
 Stress=  2.7350E+03 fiber tension : matl=2 ,  A , seg=2 , node=1 , layer=11,z= 0.04  ;FS=  1.00
 Stress=  5.0317E+04 fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
 Stress=  2.4643E+04 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
 Stress=  1.7769E+04 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
 Stress=  4.6084E+03 transv tension: matl=2 ,  A , seg=3 , node=91, layer=8 ,z= 0.02  ;FS=  1.00
 Stress=  3.5781E+04 transv tension: matl=3 ,  A , seg=18, node=6 , layer=1 ,z=-0.03  ;FS=  1.00
 Stress=  2.7192E+04 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  5.8244E+02 in-plane shear: matl=2 ,  A , seg=3 , node=92, layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  1.3868E+04 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  3.2363E+04 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 Stress=  3.2921E+04 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 Stress=  3.8157E+04 effect. stress: matl=6 ,  A , seg=18, node=5 , layer=2 ,z= 0.03  ;FS=  1.00
 Stress=  3.1901E+04 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 Modified maximum stress components for Load Case  1 STRESS2(i),i=1,6=
     5.0317E+04     1.7769E+04     3.5781E+04     2.7192E+04     4.6299E+03     3.8157E+04
     fiber tension  fiber compres. transv tension transv compres in-plane shear effect. stress

 ***** MAX. STRESS IN THE PROPELLANT TANK *******

 ****** MAX. EFF. STRESS IN ISOTROPIC WALL,LOAD A ******
 STRMAX(1)=  1.1141E+04, LOCATS(1)=1000*ISEG+I=  5013
 ****************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0317E+04
fiber tension : matl=3 ,  A , seg=17, node=8 , layer=1 ,z=-0.26  ;FS=  1.00
 ****************************************************
   20        50317.44      maximum stress in the propellant tank: TNKSTR(1 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)

 CHAPTER 13: Buckling of the propellant tank/skirt system
```

```
 - BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
 This tank/skirt model is analogous to that
 described in CHAPTER 12 (*.BEHX8xy) except that in this case
 we are interested in buckling rather than maximum stress.
 The propellant tank/skirt system is loaded by PRESS, GAXIAL,
 GLATRL and TNKCOOL. The purpose of this model is to compute
 the minimum buckling load in the propellant tank/skirt system.
 This is an "INDIC=4" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case  1:
 buckling in the propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  0.0000E+00 in which JCOL = 1
oneskirt.BEHX911

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  1.0087E+00(n=   3 circ.waves); IFAILD= 0
  1.0108E+00(n=   5 circ.waves); IFAILD= 0
  1.0140E+00(n=   7 circ.waves); IFAILD= 0
  1.0180E+00(n=   9 circ.waves); IFAILD= 0
  1.0229E+00(n=  11 circ.waves); IFAILD= 0
  1.0284E+00(n=  13 circ.waves); IFAILD= 0
  1.0323E+00(n=  15 circ.waves); IFAILD= 0
  1.0225E+00(n=  17 circ.waves); IFAILD= 0
  9.9804E-01(n=  19 circ.waves); IFAILD= 0
  9.9763E-01(n=  21 circ.waves); IFAILD= 0
  1.0112E+00(n=  23 circ.waves); IFAILD= 0
  1.0328E+00(n=  25 circ.waves); IFAILD= 0
  1.0528E+00(n=  27 circ.waves); IFAILD= 0
  1.0752E+00(n=  29 circ.waves); IFAILD= 0
  1.1049E+00(n=  31 circ.waves); IFAILD= 0
  1.1479E+00(n=  33 circ.waves); IFAILD= 0
  1.2043E+00(n=  35 circ.waves); IFAILD= 0
  1.2630E+00(n=  37 circ.waves); IFAILD= 0
  1.3285E+00(n=  39 circ.waves); IFAILD= 0
  1.4042E+00(n=  41 circ.waves); IFAILD= 0
  1.4928E+00(n=  43 circ.waves); IFAILD= 0
  1.5728E+00(n=  45 circ.waves); IFAILD= 0
  1.6538E+00(n=  47 circ.waves); IFAILD= 0
  1.7364E+00(n=  49 circ.waves); IFAILD= 0
  1.8209E+00(n=  51 circ.waves); IFAILD= 0
  1.9072E+00(n=  53 circ.waves); IFAILD= 0
  1.9954E+00(n=  55 circ.waves); IFAILD= 0
  2.0856E+00(n=  57 circ.waves); IFAILD= 0
  2.0680E+00(n=  59 circ.waves); IFAILD= 0
  2.0433E+00(n=  61 circ.waves); IFAILD= 0
  2.0263E+00(n=  63 circ.waves); IFAILD= 0
  2.0163E+00(n=  65 circ.waves); IFAILD= 0
  2.0127E+00(n=  67 circ.waves); IFAILD= 0
  2.0147E+00(n=  69 circ.waves); IFAILD= 0
  2.0219E+00(n=  71 circ.waves); IFAILD= 0
  2.0340E+00(n=  73 circ.waves); IFAILD= 0
  2.0504E+00(n=  75 circ.waves); IFAILD= 0
  2.0709E+00(n=  77 circ.waves); IFAILD= 0
  2.0953E+00(n=  79 circ.waves); IFAILD= 0
  2.1233E+00(n=  81 circ.waves); IFAILD= 0
  2.1547E+00(n=  83 circ.waves); IFAILD= 0
```

```
  2.1894E+00(n=  85 circ.waves); IFAILD= 0
  2.2271E+00(n=  87 circ.waves); IFAILD= 0
  2.2677E+00(n=  89 circ.waves); IFAILD= 0
  2.3112E+00(n=  91 circ.waves); IFAILD= 0
  2.3574E+00(n=  93 circ.waves); IFAILD= 0
  2.4061E+00(n=  95 circ.waves); IFAILD= 0
  2.4574E+00(n=  97 circ.waves); IFAILD= 0
  2.5110E+00(n=  99 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  9.9763E-01
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   21
   21       0.9976277      propellant tank buckling load factor: TNKBUK(1 ,1 )


 BIGBOSOR4 input file for load case  1:
 buckling in the propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  9.0000E+01 in which JCOL = 2
oneskirt.BEHX921

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  1.0087E+00(n=   3 circ.waves); IFAILD= 0
  1.0108E+00(n=   5 circ.waves); IFAILD= 0
  1.0140E+00(n=   7 circ.waves); IFAILD= 0
  1.0180E+00(n=   9 circ.waves); IFAILD= 0
  1.0229E+00(n=  11 circ.waves); IFAILD= 0
  1.0284E+00(n=  13 circ.waves); IFAILD= 0
  1.0404E+00(n=  15 circ.waves); IFAILD= 0
  1.0225E+00(n=  17 circ.waves); IFAILD= 0
  9.9804E-01(n=  19 circ.waves); IFAILD= 0
  9.9763E-01(n=  21 circ.waves); IFAILD= 0
  1.0112E+00(n=  23 circ.waves); IFAILD= 0
  1.0328E+00(n=  25 circ.waves); IFAILD= 0
  1.0527E+00(n=  27 circ.waves); IFAILD= 0
  1.0752E+00(n=  29 circ.waves); IFAILD= 0
  1.1049E+00(n=  31 circ.waves); IFAILD= 0
  1.1479E+00(n=  33 circ.waves); IFAILD= 0
  1.2043E+00(n=  35 circ.waves); IFAILD= 0
  1.2629E+00(n=  37 circ.waves); IFAILD= 0
  1.3285E+00(n=  39 circ.waves); IFAILD= 0
  1.4042E+00(n=  41 circ.waves); IFAILD= 0
  1.4903E+00(n=  43 circ.waves); IFAILD= 0
  1.5728E+00(n=  45 circ.waves); IFAILD= 0
  1.6538E+00(n=  47 circ.waves); IFAILD= 0
  1.7364E+00(n=  49 circ.waves); IFAILD= 0
  1.8209E+00(n=  51 circ.waves); IFAILD= 0
  1.9072E+00(n=  53 circ.waves); IFAILD= 0
  1.9954E+00(n=  55 circ.waves); IFAILD= 0
  2.0856E+00(n=  57 circ.waves); IFAILD= 0
  2.0680E+00(n=  59 circ.waves); IFAILD= 0
  2.0433E+00(n=  61 circ.waves); IFAILD= 0
  2.0263E+00(n=  63 circ.waves); IFAILD= 0
  2.0163E+00(n=  65 circ.waves); IFAILD= 0
  2.0127E+00(n=  67 circ.waves); IFAILD= 0
  2.0147E+00(n=  69 circ.waves); IFAILD= 0
  2.0219E+00(n=  71 circ.waves); IFAILD= 0
  2.0340E+00(n=  73 circ.waves); IFAILD= 0
  2.0504E+00(n=  75 circ.waves); IFAILD= 0
  2.0709E+00(n=  77 circ.waves); IFAILD= 0
```

```
 2.0953E+00(n=  79 circ.waves); IFAILD= 0
 2.1233E+00(n=  81 circ.waves); IFAILD= 0
 2.1547E+00(n=  83 circ.waves); IFAILD= 0
 2.1894E+00(n=  85 circ.waves); IFAILD= 0
 2.2271E+00(n=  87 circ.waves); IFAILD= 0
 2.2677E+00(n=  89 circ.waves); IFAILD= 0
 2.3112E+00(n=  91 circ.waves); IFAILD= 0
 2.3574E+00(n=  93 circ.waves); IFAILD= 0
 2.4061E+00(n=  95 circ.waves); IFAILD= 0
 2.4574E+00(n=  97 circ.waves); IFAILD= 0
 2.5110E+00(n=  99 circ.waves); IFAILD= 0
Critical buckling load factor from BIGBOSOR4, TNKBUK=  9.9763E-01
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   21
  22       0.9976277      propellant tank buckling load factor: TNKBUK(1 ,2 )

CHAPTER 14: Computation of the objective:
In general the objective has the form:

objective =
      WGT*(normalized weight of empty tank)
+(1.-WGT)*(normalized total skirt conductance)

in which (normalized weight of empty tank) =    TOTMAS/TNKNRM
and      (normalized total skirt conductance) = CONDCT/CONNRM
and WGT, TNKNRM, CONNRM are input variables provided by the
End user during his/her interactive "BEGIN" session (*.BEG).

If WGT = 0, then the objective is simply the total skirt
conductance, CONDCT. Note that the listed definition of the
objective is always "total conductance into the tank: CONDCT".

WGT,TOTMAS,TNKNRM,CONDCT,CONNRM,CONDT(1)=
 5.0000E-01  1.0799E+01  1.0000E+01  2.3539E-03  2.0000E-03  6.2168E-04

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

BEH.   CURRENT
NO.     VALUE            DEFINITION
 1    2.080E+01    free vibration frequency (cps): FREQ(1 ,1 )
 2    1.199E+01    free vibration frequency (cps): FREQ(1 ,2 )
 3    2.624E+01    free vibration frequency (cps): FREQ(1 ,3 )
 4    1.429E+01    free vibration frequency (cps): FREQ(1 ,4 )
 5    1.000E-10    maximum stress in material 1: STRES1(1 ,1 )
 6    1.000E-10    maximum stress in material 1: STRES1(1 ,2 )
 7    1.000E-10    maximum stress in material 1: STRES1(1 ,3 )
 8    1.000E-10    maximum stress in material 1: STRES1(1 ,4 )
 9    1.000E-10    maximum stress in material 1: STRES1(1 ,5 )
10    1.000E-10    maximum stress in material 2: STRES2(1 ,1 )
11    1.000E-10    maximum stress in material 2: STRES2(1 ,2 )
12    1.000E-10    maximum stress in material 2: STRES2(1 ,3 )
13    1.000E-10    maximum stress in material 2: STRES2(1 ,4 )
14    1.000E-10    maximum stress in material 2: STRES2(1 ,5 )
15    1.000E+10    buckling of skirt as a shell: SHLBUK(1 ,1 )
16    1.000E+10    buckling of skirt as a shell: SHLBUK(1 ,2 )
17    1.000E-10    launch-hold force in a skirt: FORCE(1 ,1 )
18    1.000E-10    launch-hold force in a skirt: FORCE(1 ,2 )
19    5.032E+04    maximum stress in the propellant tank: TNKSTR(1 ,1 )
```

```
 20    5.032E+04    maximum stress in the propellant tank: TNKSTR(1 ,2 )
 21    9.976E-01    propellant tank buckling load factor: TNKBUK(1 ,1 )
 22    9.976E-01    propellant tank buckling load factor: TNKBUK(1 ,2 )

 ******* 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    7.330E-01  (FREQ(1 ,1 )/FREQA(1 ,1 )) / FREQF(1 ,1 )-1; F.S.=  1.20
  2   -1.013E-03  (FREQ(1 ,2 )/FREQA(1 ,2 )) / FREQF(1 ,2 )-1; F.S.=  1.20
  3    1.186E+00  (FREQ(1 ,3 )/FREQA(1 ,3 )) / FREQF(1 ,3 )-1; F.S.=  1.20
  4    1.911E-01  (FREQ(1 ,4 )/FREQA(1 ,4 )) / FREQF(1 ,4 )-1; F.S.=  1.20
  5   -6.309E-03  (TNKSTRA(1 ,1 )/TNKSTR(1 ,1 )) / TNKSTRF(1 ,1 )-1; F.S.=  1.00
  6   -6.309E-03  (TNKSTRA(1 ,2 )/TNKSTR(1 ,2 )) / TNKSTRF(1 ,2 )-1; F.S.=  1.00
  7   -2.372E-03  (TNKBUK(1 ,1 )/TNKBUKA(1 ,1 )) / TNKBUKF(1 ,1 )-1; F.S.=  1.00
  8   -2.372E-03  (TNKBUK(1 ,2 )/TNKBUKA(1 ,2 )) / TNKBUKF(1 ,2 )-1; F.S.=  1.00
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER       DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E-02 1.2510E-01  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 6.4820E-02  2.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 7.4940E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 5.4320E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   N     N     Y      4    1.00E+00  0.00E+00 5.4320E+00  0.00E+00  spacing of the
tank orthogrid rings: RNGSPC
   6   Y     N     N      0    0.00E+00  1.00E-01 5.2020E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
   7   Y     N     N      0    0.00E+00  2.00E-01 2.0000E-01  1.00E+00  height of the
tank orthogrid stringers: STRHI
   8   N     N     Y      6    1.00E+00  0.00E+00 5.2020E-01  0.00E+00  thickness of the
tank orthogrid rings: RNGTHK
   9   N     N     Y      7    1.00E+00  0.00E+00 2.0000E-01  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 3.0000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   Y     N     N      0    0.00E+00  2.00E+01 9.0450E+01  2.90E+02  global axial
coordinate of "ground": ZGRND(1 )
  12   N     N     N      0    0.00E+00  0.00E+00 3.0000E+01  0.00E+00  axial length of
the propellant tank doubler: DUBAXL(1 )
  13   Y     N     N      0    0.00E+00  2.00E-02 7.6930E-02  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  14   Y     N     N      0    0.00E+00  5.00E-02 5.4450E-02  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  15   N     N     Y     14    5.00E+00  0.00E+00 2.7230E-01  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
```

```
  16   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  tank-end length
of one-layered skirt part: LNGTNK1(1 )
  17   Y     N     N      0    0.00E+00  5.00E-02 1.5320E-01  1.00E+00  tank-end
thickness of tapered skirt part: THKTNK1(1 )
  18   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  tank-end length
of tapered prongs: LNGTNK2(1 )
  19   Y     N     N      0    0.00E+00  3.00E-02 3.1270E-02  3.00E-01  tank-end
thickness of one tapered prong: THKTNK2(1 )
  20   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  "ground" end
length of one-layered skirt part: LNGVEH1(1
  21   Y     N     N      0    0.00E+00  5.00E-02 1.9510E-01  1.00E+00  "ground"-end
thickness of tapered skirt part: THKVEH1(1 )
  22   Y     N     N      0    0.00E+00  2.00E+00 2.0000E+00  1.00E+01  "ground"-end
length of tapered prongs: LNGVEH2(1 )
  23   Y     Y     N      0    0.00E+00  3.00E-02 4.2190E-02  3.00E-01  "ground"-end
thickness of one tapered prong: THKVEH2(1 )
  24   Y     Y     N      0    0.00E+00  5.00E-03 8.7980E-03  1.00E-01  thickness of a
lamina: THICK(1 )
  25   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  26   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  27   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(4 )
  28   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  29   N     N     Y     24    1.00E+00  0.00E+00 8.7980E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  30   Y     N     N      0    0.00E+00  1.00E+01 3.3740E+01  8.00E+01  layup angle:
ANGLE(1 )
  31   N     N     Y     30   -1.00E+00  0.00E+00-3.3740E+01  0.00E+00  layup angle:
ANGLE(2 )
  32   Y     N     N      0    0.00E+00  1.00E+01 7.6350E+01  8.00E+01  layup angle:
ANGLE(3 )
  33   N     N     Y     32   -1.00E+00  0.00E+00-7.6350E+01  0.00E+00  layup angle:
ANGLE(4 )
  34   Y     N     N      0    0.00E+00  1.00E+01 2.4830E+01  8.00E+01  layup angle:
ANGLE(5 )
  35   N     N     Y     34   -1.00E+00  0.00E+00-2.4830E+01  0.00E+00  layup angle:
ANGLE(6 )
  BEHAVIOR FOR  2 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 2

  BEHAVIOR OVER J =  vibration mode type

 CHAPTER 6: Free vibration analysis-BEHX1x, x=1,2; x=load case)
 This is a BIGBOSOR4 model of the propellant tank with skirts.
 There is no loading. The mass of the
 propellant is "lumped" into the middle wall of the three-
 layered wall (inner layer = smeared orthogrid; middle layer=
 propellant tank wall of constant thickness; outer layer=
 tapered doubler centered on the global axial coordinate where
 the skirts (AFT and FORWARD) attached to the tank.
```

```
 BIGBOSOR4 input file for: free vibration frequencies for Load Case 2
oneskirt.BEHX12

 FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
  2.0796E+01(n= 0 circ.waves)  2.6236E+01(n= 0 circ.waves)
  1.1988E+01(n= 1 circ.waves)  1.4294E+01(n= 1 circ.waves)
    1        20.79563      free vibration frequency (cps): FREQ(2 ,1 )
    2        11.98785      free vibration frequency (cps): FREQ(2 ,2 )
    3        26.23620      free vibration frequency (cps): FREQ(2 ,3 )
    4        14.29377      free vibration frequency (cps): FREQ(2 ,4 )

  BEHAVIOR OVER J =  stress component number
    5       0.1000000E-09  maximum stress in material 1: STRES1(2 ,1 )
    6       0.1000000E-09  maximum stress in material 1: STRES1(2 ,2 )
    7       0.1000000E-09  maximum stress in material 1: STRES1(2 ,3 )
    8       0.1000000E-09  maximum stress in material 1: STRES1(2 ,4 )
    9       0.1000000E-09  maximum stress in material 1: STRES1(2 ,5 )

  BEHAVIOR OVER J =  stress component number
   10       0.1000000E-09  maximum stress in material 2: STRES2(2 ,1 )
   11       0.1000000E-09  maximum stress in material 2: STRES2(2 ,2 )
   12       0.1000000E-09  maximum stress in material 2: STRES2(2 ,3 )
   13       0.1000000E-09  maximum stress in material 2: STRES2(2 ,4 )
   14       0.1000000E-09  maximum stress in material 2: STRES2(2 ,5 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)
   15       0.1000000E+11  buckling of skirt as a shell: SHLBUK(2 ,1 )
   16       0.1000000E+11  buckling of skirt as a shell: SHLBUK(2 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)
   17       0.1000000E-09  launch-hold force in a skirt: FORCE(2 ,1 )
   18       0.1000000E-09  launch-hold force in a skirt: FORCE(2 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)
```

CHAPTER 12: Maximum effective stress in the propellant tank/ skirt system - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case The tank/skirt system is loaded by PRESS, GAXIAL, GLATRL, and TNKCOOL. The purpose of this model is to compute the maximum effective stress in the isotropic propellant tank and the maximum stress in the supporting skirt(s), which consist of five segments each of combined isotropic and laminated composite material. This is an "INDIC=3" BIGBOSOR4 model.

```
 BIGBOSOR4 input file for load case  2:
 maximum stress in propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  0.0000E+00 in which JCOL = 1
oneskirt.BEHX812

 ***** MAX. NORMAL DISP.: PROPELLANT TANK *******

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)= -1.3141E+00, LOCATW(1)=1000*ISEG+I= 22011
 *******************************************************
```

```
 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  2.5774E+00 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
  2  7.7465E+00 fiber tension : matl=2 ,  A , seg=3 , node=2 , layer=5 ,z=-0.02  ;FS=  1.00
  3  5.6918E+00 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
  4  2.1014E+00 transv tension: matl=2 ,  A , seg=3 , node=99, layer=3 ,z=-0.04  ;FS=  1.00
  5  5.5767E+00 in-plane shear: matl=2 ,  A , seg=3 , node=3 , layer=1 ,z=-0.05  ;FS=  1.00
  6  1.0287E+00 fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
  7  2.8321E+00 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
  8  1.8875E+00 transv tension: matl=3 ,  A , seg=21, node=49, layer=1 ,z=-0.23  ;FS=  1.00
  9  1.5975E+00 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 10  1.9780E+00 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 11  1.7903E+00 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 12  1.7309E+00 effect. stress: matl=6 ,  A , seg=18, node=52, layer=2 ,z= 0.03  ;FS=  1.00
 13  1.3887E+00 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 ****************************************************
 Stress=  1.8146E+04 fiber tension : matl=2 ,  A , seg=3 , node=2 , layer=5 ,z=-0.02  ;FS=  1.00
 Stress=  4.8606E+04 fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  1.8397E+04 fiber compres.: matl=2 ,  A , seg=4 , node=13, layer=13,z= 0.05  ;FS=  1.00
 Stress=  1.7655E+04 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
 Stress=  5.0237E+03 transv tension: matl=2 ,  A , seg=3 , node=99, layer=3 ,z=-0.04  ;FS=  1.00
 Stress=  2.6490E+04 transv tension: matl=3 ,  A , seg=21, node=49, layer=1 ,z=-0.23  ;FS=  1.00
 Stress=  3.1298E+04 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  1.1279E+03 in-plane shear: matl=2 ,  A , seg=3 , node=3 , layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  1.9400E+04 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  2.5278E+04 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 Stress=  2.7929E+04 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 Stress=  2.8887E+04 effect. stress: matl=6 ,  A , seg=18, node=52, layer=2 ,z= 0.03  ;FS=  1.00
 Stress=  3.6004E+04 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 Modified maximum stress components for Load Case  2 STRESS2(i),i=1,6=
     4.8606E+04     1.7655E+04     2.6490E+04     3.1298E+04     8.9659E+03     3.6004E+04
     fiber tension  fiber compres. transv tension transv compres in-plane shear effect. stress

 ***** MAX. STRESS IN THE PROPELLANT TANK *******

 ****** MAX. EFF. STRESS IN ISOTROPIC WALL,LOAD A ******
 STRMAX(1)=  1.0116E+04, LOCATS(1)=1000*ISEG+I=  5013
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     4.8606E+04
fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
 ******************************************************
   19        48605.59      maximum stress in the propellant tank: TNKSTR(2 ,1 )


 BIGBOSOR4 input file for load case  2:
 maximum stress in propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  9.0000E+01 in which JCOL = 2
oneskirt.BEHX822

 ***** MAX. NORMAL DISP.: PROPELLANT TANK *******

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)= -5.6845E-01, LOCATW(1)=1000*ISEG+I= 23003
 *******************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  1.8182E+00 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
  2  5.3060E+00 fiber tension : matl=2 ,  A , seg=4 , node=1 , layer=2 ,z=-0.05  ;FS=  1.00
  3  2.9371E+00 fiber compres.: matl=2 ,  A , seg=4 , node=1 , layer=12,z= 0.04  ;FS=  1.00
  4  1.7030E+00 transv tension: matl=2 ,  A , seg=3 , node=92, layer=11,z= 0.04  ;FS=  1.00
```

```
  5  3.2414E+00 in-plane shear: matl=2 ,  A , seg=4 , node=1 , layer=4 ,z=-0.04  ;FS=  1.00
  6  1.0028E+00 fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
  7  2.6346E+00 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
  8  1.6918E+00 transv tension: matl=3 ,  A , seg=21, node=48, layer=1 ,z=-0.03  ;FS=  1.00
  9  1.6345E+00 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 10  1.9927E+00 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 11  1.5849E+00 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 12  1.5337E+00 effect. stress: matl=6 ,  A , seg=18, node=51, layer=2 ,z= 0.03  ;FS=  1.00
 13  1.4005E+00 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 ***************************************************
 Stress=  2.6493E+04 fiber tension : matl=2 ,  A , seg=4 , node=1 , layer=2 ,z=-0.05  ;FS=  1.00
 Stress=  4.9860E+04 fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  3.5652E+04 fiber compres.: matl=2 ,  A , seg=4 , node=1 , layer=12,z= 0.04  ;FS=  1.00
 Stress=  1.8978E+04 fiber compres.: matl=3 ,  A , seg=21, node=51, layer=1 ,z=-0.23  ;FS=  1.00
 Stress=  6.1992E+03 transv tension: matl=2 ,  A , seg=3 , node=92, layer=11,z= 0.04  ;FS=  1.00
 Stress=  2.9554E+04 transv tension: matl=3 ,  A , seg=21, node=48, layer=1 ,z=-0.03  ;FS=  1.00
 Stress=  3.0591E+04 transv compres: matl=3 ,  A , seg=23, node=1 , layer=1 ,z=-0.24  ;FS=  1.00
 Stress=  1.9405E+03 in-plane shear: matl=2 ,  A , seg=4 , node=1 , layer=4 ,z=-0.04  ;FS=  1.00
 Stress=  2.7500E+04 effect. stress: matl=1 ,  A , seg=4 , node=2 , layer=1 ,z=-0.05  ;FS=  1.00
 Stress=  2.5091E+04 effect. stress: matl=4 ,  A , seg=17, node=3 , layer=2 ,z=-0.06  ;FS=  1.00
 Stress=  3.1548E+04 effect. stress: matl=5 ,  A , seg=19, node=2 , layer=3 ,z= 0.03  ;FS=  1.00
 Stress=  3.2601E+04 effect. stress: matl=6 ,  A , seg=18, node=51, layer=2 ,z= 0.03  ;FS=  1.00
 Stress=  3.5702E+04 effect. stress: matl=7 ,  A , seg=23, node=1 , layer=2 ,z=-0.04  ;FS=  1.00
 Modified maximum stress components for Load Case  2 STRESS2(i),i=1,6=
     4.9860E+04     1.8978E+04     2.9554E+04     3.0591E+04     1.5426E+04     3.5702E+04
     fiber tension  fiber compres. transv tension transv compres in-plane shear effect. stress

 ***** MAX. STRESS IN THE PROPELLANT TANK *******

 ****** MAX. EFF. STRESS IN ISOTROPIC WALL,LOAD A ******
 STRMAX(1)=  1.8136E+04, LOCATS(1)=1000*ISEG+I=  5013
 ****************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     4.9860E+04
fiber tension : matl=3 ,  A , seg=22, node=6 , layer=1 ,z=-0.24  ;FS=  1.00
 ****************************************************
   20        49860.14      maximum stress in the propellant tank: TNKSTR(2 ,2 )

  BEHAVIOR OVER J =  skirt number (1 for aft skirt)

 CHAPTER 13: Buckling of the propellant tank/skirt system
 - BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
 This tank/skirt model is analogous to that
 described in CHAPTER 12 (*.BEHX8xy) except that in this case
 we are interested in buckling rather than maximum stress.
 The propellant tank/skirt system is loaded by PRESS, GAXIAL,
 GLATRL and TNKCOOL. The purpose of this model is to compute
 the minimum buckling load in the propellant tank/skirt system.
 This is an "INDIC=4" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case  2:
 buckling in the propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  0.0000E+00 in which JCOL = 1
oneskirt.BEHX912

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  6.3998E+02(n=   3 circ.waves); IFAILD= 0
  1.8816E+02(n=   5 circ.waves); IFAILD= 0
```

```
  7.5511E+01(n=   7 circ.waves); IFAILD= 0
  4.2061E+01(n=   9 circ.waves); IFAILD= 0
  2.7502E+01(n=  11 circ.waves); IFAILD= 0
  1.9623E+01(n=  13 circ.waves); IFAILD= 0
  1.3529E+01(n=  15 circ.waves); IFAILD= 0
  7.8013E+00(n=  17 circ.waves); IFAILD= 0
  6.4064E+00(n=  19 circ.waves); IFAILD= 0
  6.1490E+00(n=  21 circ.waves); IFAILD= 0
  6.1039E+00(n=  23 circ.waves); IFAILD= 0
  5.1677E+00(n=  25 circ.waves); IFAILD= 0
  4.4643E+00(n=  27 circ.waves); IFAILD= 0
  3.9239E+00(n=  29 circ.waves); IFAILD= 0
  3.5002E+00(n=  31 circ.waves); IFAILD= 0
  3.1626E+00(n=  33 circ.waves); IFAILD= 0
  2.8900E+00(n=  35 circ.waves); IFAILD= 0
  2.6680E+00(n=  37 circ.waves); IFAILD= 0
  2.4860E+00(n=  39 circ.waves); IFAILD= 0
  2.3362E+00(n=  41 circ.waves); IFAILD= 0
  2.2120E+00(n=  43 circ.waves); IFAILD= 0
  2.1071E+00(n=  45 circ.waves); IFAILD= 0
  2.0169E+00(n=  47 circ.waves); IFAILD= 0
  1.9415E+00(n=  49 circ.waves); IFAILD= 0
  1.8795E+00(n=  51 circ.waves); IFAILD= 0
  1.8292E+00(n=  53 circ.waves); IFAILD= 0
  1.7891E+00(n=  55 circ.waves); IFAILD= 0
  1.7577E+00(n=  57 circ.waves); IFAILD= 0
  1.7340E+00(n=  59 circ.waves); IFAILD= 0
  1.7171E+00(n=  61 circ.waves); IFAILD= 0
  1.7063E+00(n=  63 circ.waves); IFAILD= 0
  1.7009E+00(n=  65 circ.waves); IFAILD= 0
  1.7005E+00(n=  67 circ.waves); IFAILD= 0
  1.7045E+00(n=  69 circ.waves); IFAILD= 0
  1.7127E+00(n=  71 circ.waves); IFAILD= 0
  1.7247E+00(n=  73 circ.waves); IFAILD= 0
  1.7403E+00(n=  75 circ.waves); IFAILD= 0
  1.7592E+00(n=  77 circ.waves); IFAILD= 0
  1.7812E+00(n=  79 circ.waves); IFAILD= 0
  1.8061E+00(n=  81 circ.waves); IFAILD= 0
  1.8339E+00(n=  83 circ.waves); IFAILD= 0
  1.8643E+00(n=  85 circ.waves); IFAILD= 0
  1.8972E+00(n=  87 circ.waves); IFAILD= 0
  1.9326E+00(n=  89 circ.waves); IFAILD= 0
  1.9703E+00(n=  91 circ.waves); IFAILD= 0
  2.0103E+00(n=  93 circ.waves); IFAILD= 0
  2.0524E+00(n=  95 circ.waves); IFAILD= 0
  2.0966E+00(n=  97 circ.waves); IFAILD= 0
  2.1429E+00(n=  99 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.7005E+00
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   67
   21        1.700472      propellant tank buckling load factor: TNKBUK(2 ,1 )


 BIGBOSOR4 input file for load case  2:
 buckling in the propellant tank/skirt system from the
 prebuckling load distribution on the meridian at angle,
 CIRCANG(JCOL)=  9.0000E+01 in which JCOL = 2
oneskirt.BEHX922
```

```
BUCKLING OF THE PROPELLANT TANK (BEHX9)
 2.1429E+00(n=   3 circ.waves); IFAILD= 1
 2.3972E+02(n=   5 circ.waves); IFAILD= 0
 8.9090E+01(n=   7 circ.waves); IFAILD= 0
 4.7566E+01(n=   9 circ.waves); IFAILD= 0
 3.0457E+01(n=  11 circ.waves); IFAILD= 0
 2.1503E+01(n=  13 circ.waves); IFAILD= 0
 1.6114E+01(n=  15 circ.waves); IFAILD= 0
 1.2563E+01(n=  17 circ.waves); IFAILD= 0
 1.0069E+01(n=  19 circ.waves); IFAILD= 0
 8.2359E+00(n=  21 circ.waves); IFAILD= 0
 6.8521E+00(n=  23 circ.waves); IFAILD= 0
 5.7963E+00(n=  25 circ.waves); IFAILD= 0
 4.9868E+00(n=  27 circ.waves); IFAILD= 0
 4.3604E+00(n=  29 circ.waves); IFAILD= 0
 3.8696E+00(n=  31 circ.waves); IFAILD= 0
 3.4796E+00(n=  33 circ.waves); IFAILD= 0
 3.1660E+00(n=  35 circ.waves); IFAILD= 0
 2.9115E+00(n=  37 circ.waves); IFAILD= 0
 2.7031E+00(n=  39 circ.waves); IFAILD= 0
 2.5306E+00(n=  41 circ.waves); IFAILD= 0
 2.3838E+00(n=  43 circ.waves); IFAILD= 0
 2.2564E+00(n=  45 circ.waves); IFAILD= 0
 2.1494E+00(n=  47 circ.waves); IFAILD= 0
 2.0613E+00(n=  49 circ.waves); IFAILD= 0
 1.9891E+00(n=  51 circ.waves); IFAILD= 0
 1.9305E+00(n=  53 circ.waves); IFAILD= 0
 1.8836E+00(n=  55 circ.waves); IFAILD= 0
 1.8466E+00(n=  57 circ.waves); IFAILD= 0
 1.8183E+00(n=  59 circ.waves); IFAILD= 0
 1.7976E+00(n=  61 circ.waves); IFAILD= 0
 1.7837E+00(n=  63 circ.waves); IFAILD= 0
 1.7758E+00(n=  65 circ.waves); IFAILD= 0
 1.7734E+00(n=  67 circ.waves); IFAILD= 0
 1.7759E+00(n=  69 circ.waves); IFAILD= 0
 1.7829E+00(n=  71 circ.waves); IFAILD= 0
 1.7940E+00(n=  73 circ.waves); IFAILD= 0
 1.8090E+00(n=  75 circ.waves); IFAILD= 0
 1.8275E+00(n=  77 circ.waves); IFAILD= 0
 1.8494E+00(n=  79 circ.waves); IFAILD= 0
 1.8745E+00(n=  81 circ.waves); IFAILD= 0
 1.9025E+00(n=  83 circ.waves); IFAILD= 0
 1.9334E+00(n=  85 circ.waves); IFAILD= 0
 1.9669E+00(n=  87 circ.waves); IFAILD= 0
 2.0030E+00(n=  89 circ.waves); IFAILD= 0
 2.0416E+00(n=  91 circ.waves); IFAILD= 0
 2.0825E+00(n=  93 circ.waves); IFAILD= 0
 2.1257E+00(n=  95 circ.waves); IFAILD= 0
 2.1712E+00(n=  97 circ.waves); IFAILD= 0
 2.2187E+00(n=  99 circ.waves); IFAILD= 0
Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.7734E+00
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   67
  22        1.773388      propellant tank buckling load factor: TNKBUK(2 ,2 )

***** RESULTS FOR LOAD SET NO.  2  ******
PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)

BEH.   CURRENT
```

```
NO.     VALUE            DEFINITION
 1    2.080E+01    free vibration frequency (cps): FREQ(2 ,1 )
 2    1.199E+01    free vibration frequency (cps): FREQ(2 ,2 )
 3    2.624E+01    free vibration frequency (cps): FREQ(2 ,3 )
 4    1.429E+01    free vibration frequency (cps): FREQ(2 ,4 )
 5    1.000E-10    maximum stress in material 1: STRES1(2 ,1 )
 6    1.000E-10    maximum stress in material 1: STRES1(2 ,2 )
 7    1.000E-10    maximum stress in material 1: STRES1(2 ,3 )
 8    1.000E-10    maximum stress in material 1: STRES1(2 ,4 )
 9    1.000E-10    maximum stress in material 1: STRES1(2 ,5 )
10    1.000E-10    maximum stress in material 2: STRES2(2 ,1 )
11    1.000E-10    maximum stress in material 2: STRES2(2 ,2 )
12    1.000E-10    maximum stress in material 2: STRES2(2 ,3 )
13    1.000E-10    maximum stress in material 2: STRES2(2 ,4 )
14    1.000E-10    maximum stress in material 2: STRES2(2 ,5 )
15    1.000E+10    buckling of skirt as a shell: SHLBUK(2 ,1 )
16    1.000E+10    buckling of skirt as a shell: SHLBUK(2 ,2 )
17    1.000E-10    launch-hold force in a skirt: FORCE(2 ,1 )
18    1.000E-10    launch-hold force in a skirt: FORCE(2 ,2 )
19    4.861E+04    maximum stress in the propellant tank: TNKSTR(2 ,1 )
20    4.986E+04    maximum stress in the propellant tank: TNKSTR(2 ,2 )
21    1.700E+00    propellant tank buckling load factor: TNKBUK(2 ,1 )
22    1.773E+00    propellant tank buckling load factor: TNKBUK(2 ,2 )

******* 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.  2  ******
MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)

MARGIN CURRENT
NO.     VALUE            DEFINITION
 1    7.330E-01  (FREQ(2 ,1 )/FREQA(2 ,1 )) / FREQF(2 ,1 )-1; F.S.=  1.20
 2   -1.013E-03  (FREQ(2 ,2 )/FREQA(2 ,2 )) / FREQF(2 ,2 )-1; F.S.=  1.20
 3    1.186E+00  (FREQ(2 ,3 )/FREQA(2 ,3 )) / FREQF(2 ,3 )-1; F.S.=  1.20
 4    1.911E-01  (FREQ(2 ,4 )/FREQA(2 ,4 )) / FREQF(2 ,4 )-1; F.S.=  1.20
 5    2.869E-02  (TNKSTRA(2 ,1 )/TNKSTR(2 ,1 )) / TNKSTRF(2 ,1 )-1; F.S.=  1.00
 6    2.805E-03  (TNKSTRA(2 ,2 )/TNKSTR(2 ,2 )) / TNKSTRF(2 ,2 )-1; F.S.=  1.00
 7    7.005E-01  (TNKBUK(2 ,1 )/TNKBUKA(2 ,1 )) / TNKBUKF(2 ,1 )-1; F.S.=  1.00
 8    7.734E-01  (TNKBUK(2 ,2 )/TNKBUKA(2 ,2 )) / TNKBUKF(2 ,2 )-1; F.S.=  1.00

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

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    1.128E+00  WGTxTOTMAS/TNKNRM +(1-WGT)xCONDCT/CONNRM: CONDCT

*************                          ************
******************** DESIGN OBJECTIVE ******************
******************************************************
***********  ALL 2 LOAD CASES PROCESSED ***********
******************************************************
```

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

VAR. NO.	CURRENT VALUE	DEFINITION
1	3.864E+02	acceleration of gravity: GRAV
2	3.000E+02	diameter of launch vehicle: DIAVEH
3	2.000E+02	diameter of the aft dome of the tank: AFTDIA
4	5.000E+01	height of the aft dome of the tank: AFTHI
5	2.000E+02	diameter of the forward dome of the tank: FWDDIA
6	5.000E+01	height of the forward dome of the tank: FWDHI
7	4.000E+02	axial dist. from aft dome apex to fwd dome apex: FLTANK
8	1.000E+02	global axial coordinate of the aft dome apex: ZAPEX
9	2.560E-03	weight density of the propellant: DENPRP
10	3.000E+02	global axial coordinate of the tank cg: ZCG
11	1.000E+07	Young's modulus of the cold tank material: ETANK
12	3.000E-01	Poisson's ratio of the tank material: NUTANK
13	2.500E-04	mass density of the tank material: DENTNK
14	1.000E-05	coef.thermal expansion of tank material: ALTNK
15	1.000E+07	hoop modulus of the tank ring: TRNGE(1)
16	1.000E-05	coef.of thermal expansion of the tank ring: ALRNGT(1)
17	2.100E+07	modulus in the fiber direction: E1(1)
18	1.600E+06	modulus transverse to fibers: E2(1)
19	6.790E+05	in-plane shear modulus: G12(1)
20	2.300E-02	small Poisson's ratio: NU(1)
21	6.270E+05	x-z out-of-plane shear modulus: G13(1)
22	3.340E+05	y-z out-of-plane shear modulus: G23(1)
23	1.000E-06	coef.of thermal expansion along fibers: ALPHA1(1)
24	1.000E-05	coef.of thermal expan.transverse to fibers: ALPHA2(1)
25	1.700E+02	curing delta temperature (positive): TEMTUR(1)
26	7.270E-03	conductivity along the fibers: COND1(1)
27	4.370E-03	conductivity transverse to fibers: COND2(1)
28	5.700E-02	weight density of the material: DENSTY(1)
29	5.000E-01	objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
30	1.000E+01	normalizing empty tank mass: TNKNRM
31	2.000E-03	normalizing total skirt conductance: CONNRM

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

VAR. NO.	CURRENT VALUE	DEFINITION
1	2.500E+01	propellant tank ullage pressure: PRESS(1)
2	2.500E+01	propellant tank ullage pressure: PRESS(2)
3	1.000E+01	quasi-static axial g-loading: GAXIAL(1)
4	0.000E+00	quasi-static axial g-loading: GAXIAL(2)
5	0.000E+00	quasi-static lateral g-loading: GLATRL(1)
6	1.000E+01	quasi-static lateral g-loading: GLATRL(2)
7	-2.000E+02	propellant tank cool-down from cryogen: TNKCOOL(1)
8	-2.000E+02	propellant tank cool-down from cryogen: TNKCOOL(2)

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

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.000E+01	minimum allowable frequency (cps): FREQA(1 ,1)
2	1.000E+01	minimum allowable frequency (cps): FREQA(2 ,1)
3	1.000E+01	minimum allowable frequency (cps): FREQA(1 ,2)
4	1.000E+01	minimum allowable frequency (cps): FREQA(2 ,2)
5	1.000E+01	minimum allowable frequency (cps): FREQA(1 ,3)

6	1.000E+01	minimum allowable frequency (cps): FREQA(2 ,3)
7	1.000E+01	minimum allowable frequency (cps): FREQA(1 ,4)
8	1.000E+01	minimum allowable frequency (cps): FREQA(2 ,4)
9	1.406E+05	maximum allowable stress in material 1: STRES1A(1 ,1)
10	1.406E+05	maximum allowable stress in material 1: STRES1A(2 ,1)
11	1.047E+05	maximum allowable stress in material 1: STRES1A(1 ,2)
12	1.047E+05	maximum allowable stress in material 1: STRES1A(2 ,2)
13	1.056E+04	maximum allowable stress in material 1: STRES1A(1 ,3)
14	1.056E+04	maximum allowable stress in material 1: STRES1A(2 ,3)
15	1.453E+04	maximum allowable stress in material 1: STRES1A(1 ,4)
16	1.453E+04	maximum allowable stress in material 1: STRES1A(2 ,4)
17	6.290E+03	maximum allowable stress in material 1: STRES1A(1 ,5)
18	6.290E+03	maximum allowable stress in material 1: STRES1A(2 ,5)
19	1.406E+05	maximum allowable stress in material 2: STRES2A(1 ,1)
20	1.406E+05	maximum allowable stress in material 2: STRES2A(2 ,1)
21	1.047E+05	maximum allowable stress in material 2: STRES2A(1 ,2)
22	1.047E+05	maximum allowable stress in material 2: STRES2A(2 ,2)
23	1.056E+04	maximum allowable stress in material 2: STRES2A(1 ,3)
24	1.056E+04	maximum allowable stress in material 2: STRES2A(2 ,3)
25	1.453E+04	maximum allowable stress in material 2: STRES2A(1 ,4)
26	1.453E+04	maximum allowable stress in material 2: STRES2A(2 ,4)
27	6.290E+03	maximum allowable stress in material 2: STRES2A(1 ,5)
28	6.290E+03	maximum allowable stress in material 2: STRES2A(2 ,5)
29	1.000E+00	allowable for shell buckling of skirt: SHLBUKA(1 ,1)
30	1.000E+00	allowable for shell buckling of skirt: SHLBUKA(2 ,1)
31	1.000E+00	allowable for shell buckling of skirt: SHLBUKA(1 ,2)
32	1.000E+00	allowable for shell buckling of skirt: SHLBUKA(2 ,2)
33	1.500E+04	maximum allowable launch-hold force in skirt: FORCEA(1 ,1)
34	1.500E+04	maximum allowable launch-hold force in skirt: FORCEA(2 ,1)
35	1.500E+04	maximum allowable launch-hold force in skirt: FORCEA(1 ,2)
36	1.500E+04	maximum allowable launch-hold force in skirt: FORCEA(2 ,2)
37	5.000E+04	allowable for propellant tank stress: TNKSTRA(1 ,1)
38	5.000E+04	allowable for propellant tank stress: TNKSTRA(2 ,1)
39	5.000E+04	allowable for propellant tank stress: TNKSTRA(1 ,2)
40	5.000E+04	allowable for propellant tank stress: TNKSTRA(2 ,2)
41	1.000E+00	allowable for propellant tank buckling: TNKBUKA(1 ,1)
42	1.000E+00	allowable for propellant tank buckling: TNKBUKA(2 ,1)
43	1.000E+00	allowable for propellant tank buckling: TNKBUKA(1 ,2)
44	1.000E+00	allowable for propellant tank buckling: TNKBUKA(2 ,2)

PARAMETERS WHICH ARE FACTORS OF SAFETY

VAR. NO.	CURRENT VALUE	DEFINITION
1	1.200E+00	factor of safety for freqency: FREQF(1 ,1)
2	1.200E+00	factor of safety for freqency: FREQF(2 ,1)
3	1.200E+00	factor of safety for freqency: FREQF(1 ,2)
4	1.200E+00	factor of safety for freqency: FREQF(2 ,2)
5	1.200E+00	factor of safety for freqency: FREQF(1 ,3)
6	1.200E+00	factor of safety for freqency: FREQF(2 ,3)
7	1.200E+00	factor of safety for freqency: FREQF(1 ,4)
8	1.200E+00	factor of safety for freqency: FREQF(2 ,4)
9	1.500E+00	factor of safety for stress, matl 1: STRES1F(1 ,1)
10	1.500E+00	factor of safety for stress, matl 1: STRES1F(2 ,1)
11	1.500E+00	factor of safety for stress, matl 1: STRES1F(1 ,2)
12	1.500E+00	factor of safety for stress, matl 1: STRES1F(2 ,2)
13	1.500E+00	factor of safety for stress, matl 1: STRES1F(1 ,3)
14	1.500E+00	factor of safety for stress, matl 1: STRES1F(2 ,3)
15	1.500E+00	factor of safety for stress, matl 1: STRES1F(1 ,4)

```
16    1.500E+00  factor of safety for stress, matl 1: STRES1F(2 ,4 )
17    1.500E+00  factor of safety for stress, matl 1: STRES1F(1 ,5 )
18    1.500E+00  factor of safety for stress, matl 1: STRES1F(2 ,5 )
19    1.500E+00  factor of safety for stress, matl 2: STRES2F(1 ,1 )
20    1.500E+00  factor of safety for stress, matl 2: STRES2F(2 ,1 )
21    1.500E+00  factor of safety for stress, matl 2: STRES2F(1 ,2 )
22    1.500E+00  factor of safety for stress, matl 2: STRES2F(2 ,2 )
23    1.500E+00  factor of safety for stress, matl 2: STRES2F(1 ,3 )
24    1.500E+00  factor of safety for stress, matl 2: STRES2F(2 ,3 )
25    1.500E+00  factor of safety for stress, matl 2: STRES2F(1 ,4 )
26    1.500E+00  factor of safety for stress, matl 2: STRES2F(2 ,4 )
27    1.500E+00  factor of safety for stress, matl 2: STRES2F(1 ,5 )
28    1.500E+00  factor of safety for stress, matl 2: STRES2F(2 ,5 )
29    2.000E+00  factor of safety for shell buckling of skirt: SHLBUKF(1 ,1 )
30    2.000E+00  factor of safety for shell buckling of skirt: SHLBUKF(2 ,1 )
31    2.000E+00  factor of safety for shell buckling of skirt: SHLBUKF(1 ,2 )
32    2.000E+00  factor of safety for shell buckling of skirt: SHLBUKF(2 ,2 )
33    1.000E+00  factor of safety for launch-hold force: FORCEF(1 ,1 )
34    1.000E+00  factor of safety for launch-hold force: FORCEF(2 ,1 )
35    1.000E+00  factor of safety for launch-hold force: FORCEF(1 ,2 )
36    1.000E+00  factor of safety for launch-hold force: FORCEF(2 ,2 )
37    1.000E+00  factor of safety for tank stress: TNKSTRF(1 ,1 )
38    1.000E+00  factor of safety for tank stress: TNKSTRF(2 ,1 )
39    1.000E+00  factor of safety for tank stress: TNKSTRF(1 ,2 )
40    1.000E+00  factor of safety for tank stress: TNKSTRF(2 ,2 )
41    1.000E+00  factor of safety for tank buckling: TNKBUKF(1 ,1 )
42    1.000E+00  factor of safety for tank buckling: TNKBUKF(2 ,1 )
43    1.000E+00  factor of safety for tank buckling: TNKBUKF(1 ,2 )
44    1.000E+00  factor of safety for tank buckling: TNKBUKF(2 ,2 )

   0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED



DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

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

Table 7 Input data for the GENOPT processor, CHANGE, by means of which optimized designs can be archived (oneskirt.CHG file).
(These data are provided by the End user, long propellant tank, one skirt)

```
=====================================================================
     N        $ Do you want a tutorial session and tutorial output?
     Y        $ Do you want to change any values in Parameter Set No. 1?
        1     $ Number of parameter to change (1, 2, 3, . .)
  0.1251000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        2     $ Number of parameter to change (1, 2, 3, . .)
  0.6482000E-01 $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        3     $ Number of parameter to change (1, 2, 3, . .)
  0.0749400   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        4     $ Number of parameter to change (1, 2, 3, . .)
   5.432000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        5     $ Number of parameter to change (1, 2, 3, . .)
   5.432000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        6     $ Number of parameter to change (1, 2, 3, . .)
  0.5202000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        7     $ Number of parameter to change (1, 2, 3, . .)
  0.2000000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        8     $ Number of parameter to change (1, 2, 3, . .)
  0.5202000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
        9     $ Number of parameter to change (1, 2, 3, . .)
  0.2000000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
       10     $ Number of parameter to change (1, 2, 3, . .)
   300.0000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
       11     $ Number of parameter to change (1, 2, 3, . .)
   90.45000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
       12     $ Number of parameter to change (1, 2, 3, . .)
   30.00000   $ New value of the parameter
     y        $ Want to change any other parameters in this set?
```

```
      13       $ Number of parameter to change (1, 2, 3, . .)
 0.0769300     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      14       $ Number of parameter to change (1, 2, 3, . .)
 0.0544500     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      15       $ Number of parameter to change (1, 2, 3, . .)
 0.2723000     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      16       $ Number of parameter to change (1, 2, 3, . .)
  2.000000     $ New value of the parameter
    y
      17       $ Want to change any other parameters in this set?
   0.1532
    y
      18       $ Number of parameter to change (1, 2, 3, . .)
  2.000000     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      19       $ Number of parameter to change (1, 2, 3, . .)
 0.3127000E-01 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      20       $ Number of parameter to change (1, 2, 3, . .)
  2.000000     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      21       $ Number of parameter to change (1, 2, 3, . .)
 0.1951000     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      22       $ Number of parameter to change (1, 2, 3, . .)
  2.000000     $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      23       $ Number of parameter to change (1, 2, 3, . .)
 0.4219000E-01 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      24       $ Number of parameter to change (1, 2, 3, . .)
 0.8798000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      25       $ Number of parameter to change (1, 2, 3, . .)
 0.8798000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      26       $ Number of parameter to change (1, 2, 3, . .)
 0.8798000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      27       $ Number of parameter to change (1, 2, 3, . .)
 0.8798000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      28       $ Number of parameter to change (1, 2, 3, . .)
 0.8798000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
```

```
      29       $ Number of parameter to change (1, 2, 3, . .)
  0.8798000E-02 $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      30       $ Number of parameter to change (1, 2, 3, . .)
   33.74000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      31       $ Number of parameter to change (1, 2, 3, . .)
  -33.74000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      32       $ Number of parameter to change (1, 2, 3, . .)
   76.35000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      33       $ Number of parameter to change (1, 2, 3, . .)
  -76.35000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      34       $ Number of parameter to change (1, 2, 3, . .)
   24.83000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      35       $ Number of parameter to change (1, 2, 3, . .)
  -24.83000    $ New value of the parameter
     n         $ Want to change any other parameters in this set?
     N         $ Do you want to change values of any "fixed" parameters?
     N         $ Do you want to change any loads?
     N         $ Do you want to change values of allowables?
     N         $ Do you want to change any factors of safety?
=================================================================
```

Table 8 Input data for the GENOPT processor, CHOOSEPLOT (oneskirt.CPL file). This type of input leads to a plot analogous to those displayed in Figs. 14 – 21.

```
=================================================================================
      N         $ Do you want a tutorial session and tutorial output?
      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) ?
         4      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        19      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        20      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        21      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        22      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        41      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        42      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        43      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        44      $ 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.
================================================================================
```