Table 1 Typical run stream for GENOPT/BIGBOSOR4
(The user's input is in 16pt **boldface**)

```
=========================================================
GENOPT RUNSTREAM FOR THE GENERIC CASE "tank"
AND THE SPECIFIC CASE "test"
=========================================================

COMMAND                    MEANING OF COMMAND
```

`cd /home/progs/genoptcase` `go to "genoptcase" in order to run GENOPT`

`genoptlog` `activate GENOPT commands`

```
[The following will appear on your screen:]
-----------------------------------------------------
GENOPT commands have been activated.

  gentext      GENOPT user generates a prompt file.
  genprograms  GENOPT user generates (makes) executables:
               begin, decide, mainsetup, optimize,
               change, chooseplot, and diplot.
  begin        End user provides starting data.
  decide       End user chooses decision variables, bounds,
               linked variables, and inequality constraints.
  mainsetup    End user sets up strategy parameters.
  optimize     End user performs optimization.
  change       End user changes some parameters.
  autochange   New values for decision variables randomly
  superopt     End user find global optimum (autochange/optimize)...
  superduperopt     End user executes superopt/chooseplot x times...
  chooseplot   End user chooses which variable to plot vs.
               iterations.
  diplot       End user plots variables vs. iterations.
  insert       GENOPT user adds parameters to the problem.
  cleangen     GENOPT user cleans up GENeric case files.
  cleanspec    End user cleans up SPECific case files.
------------------------------------------------------

COMMAND                           MEANING OF COMMAND
```

`gentext` `GENOPT user provides input`

` GENERIC CASE NAME:` **`tank`**

[GENOPT user provide input interactively for the generic case, called "tank". At the end of this long interactive session the following files will exist:]

```
-------------------------------------------------------
-rw-rw-r-- 1 bush bush  11081 Nov 16 05:32 tank.CHA
-rw-rw-r-- 1 bush bush   2796 Nov 16 05:32 tank.COM <you use in bosdec
-rw-rw-r-- 1 bush bush  16185 Nov 16 05:32 tank.CON
-rw-rw-r-- 1 bush bush 155702 Nov 16 05:32 tank.DAT
-rw-rw-r-- 1 bush bush  39212 Nov 16 05:32 tank.DEF <you inspect this
-rw-r--r-- 1 bush bush 155703 Nov 16 05:32 tank.INP <you archive this
-rw-rw-r-- 1 bush bush  81105 Nov 16 05:32 tank.NEW
-rw-rw-r-- 1 bush bush  63078 Nov 16 05:32 tank.PRO <you inspect this
-rw-rw-r-- 1 bush bush   4064 Nov 16 05:32 tank.REA
-rw-rw-r-- 1 bush bush   1964 Nov 16 05:32 tank.SET
-rw-rw-r-- 1 bush bush  18147 Nov 16 05:32 tank.SUB
-rw-rw-r-- 1 bush bush   4064 Nov 16 05:32 tank.WRI

-rw-rw-r-- 1 bush bush 105530 Nov 16 05:32 begin.new <GENOPT fleshes out
-rw-rw-r-- 1 bush bush 117928 Nov 16 06:10 behavior.new <you flesh out
-rw-rw-r-- 1 bush bush  25016 Nov 16 05:32 change.new <GENOPT fleshes out
-rw-rw-r-- 1 bush bush  18575 Nov 16 05:32 stoget.new <GENOPT fleshes out
-rw-rw-r-- 1 bush bush  48932 Nov 16 05:58 struct.new <you flesh out
---------------------------------------------------------
```

[The GENOPT user must next "flesh out" the skeletal libraries,
struct.new and behavior.new. The GENOPT user must also create
from scratch the library, /home/progs/bosdec/sources/bosdec.src.
The library, bosdec.src (archived version is called "bosdec.tank"),
generates valid input files for BIGBOSOR4. The archived versions
of these "fleshed out" libraries are called (by the GENOPT user):
struct.tank, behavior.tank, bosdec.tank in this work
struct.tank and behavior.tank are located in /home/progs/genoptcase
bosdec.tank is located in /home/progs/bosdec/sources]

COMMAND   MEANING OF COMMAND

genprograms   FORTRAN software is compiled.

[The following might appear on your screen:]

```
-------------------------------------------------------------
The purpose of genprograms is to generate the executables from the
source files created/modified by the GENOPT user.

make: Nothing to be done for `genoptcase'. [in this example only]

Congratulations!  Your code compiled successfully.  You should
```

now check to make sure that you get correct results from a simple test case with a known answer before attempting a more complicated case.

```
Here is a list of all your newly created executables:
-rwxrwxr-x 1 bush bush 98115 Nov 16 07:12 autochange.x86_64
-rwxrwxr-x 1 bush bush 278397 Nov 16 05:44 begin.x86_64
-rwxrwxr-x 1 bush bush 152154 Nov 16 05:44 change.x86_64
-rwxrwxr-x 1 bush bush 164203 Nov 16 05:44 chooseplot.x86_64
-rwxrwxr-x 1 bush bush 179523 Nov 16 05:44 decide.x86_64
-rwxrwxr-x 1 bush bush 105256 Nov 16 05:44 mainsetup.x86_64
-rwxrwxr-x 1 bush bush 2115251 Nov 18 05:56 optimize.x86_64
-rwxrwxr-x 1 bush bush 134692 Nov 16 07:12 store.x86_64
-rwxrwxr-x 1 bush bush 72419 Nov 16 05:44 zeroit.x86_64
```

Next, type the command BEGIN to input data for a new case.

[An output list from the “make” called “genprograms” is stored in a file called “usermake.log”. You should inspect this file, looking for possible FORTRAN errors you might have made while “fleshing out” the struct.new and behavior.new libraries and while creating the bosdec.src library from scratch.]

[However, even though the compilation appears (from the congratulatory statement above) to have been successful, the GENOPT user must inspect the file called "usermake.log" to look for FORTRAN errors. Also, even if there are no FORTRAN errors, there will probably exist a number of logical errors that the GENOPT user will discover upon trying to run a specific case for the first time. If there are FORTRAN errors, the GENOPT user corrects them and then executes "genprograms" again.]

[If everything appears to be okay it is time to test the FORTRAN software created by the GENOPT user by running a SPECIFIC case. In this example the SPECIFIC case is called "test". Now the End user takes over. Initially the GENOPT user and the End user are the same person because initially there will doubtless exist many logical errors to be eliminated before the processing of SPECIFIC cases is assigned to a person different from the GENOPT user. In fact, in most projects the GENOPT user and the End user will be the same person. That is true in the present "tank"/"test" case described here and in all the GENOPT literature generated as of this writing.]

COMMAND MEANING OF COMMAND

begin interactively provide input data for the GENOPT processor, BEGIN

[The following two files are created by execution of BEGIN:]

```
----------------------------------------------------------
-rw-rw-r-- 1 bush bush 18649 Jan  6 06:45 test.BEG
-rw-rw-r-- 1 bush bush 17378 Jan  7 16:49 test.OPB
----------------------------------------------------------
```

[The file, test.BEG, is an "image" of the interactive "BEGIN" session. test.BEG can be used for future executions of BEGIN for the same SPECIFIC case. The file, test.OPB, contains a summary of "BEGIN" data for the SPECIFIC case, “test”.]

COMMAND MEANING OF COMMAND

decide interactively provide input data for the GENOPT processor, DECIDE

[The following two files are created by execution of DECIDE:]

```
----------------------------------------------------------
-rw-rw-r-- 1 bush bush 17758 Dec 27 12:07 test.DEC
-rw-rw-r-- 1 bush bush 14510 Jan  7 16:49 test.OPD
----------------------------------------------------------
```

[The file, test.DEC, is an "image" of the interactive "DECIDE" session. test.DEC can be used for future executions of DECIDE for the same SPECIFIC case. The file, test.OPD, contains a summary of "DECIDE" data for the SPECIFIC case, “test”.]

COMMAND MEANING OF COMMAND

mainsetup interactively provide input data for the GENOPT processor, MAINSETUP

[The following file is created by execution of MAINSETUP:]

```
----------------------------------------------------------
-rw-rw-r-- 1 bush bush 1059 Jan  9 06:08 test.OPT
----------------------------------------------------------
```

[The file, test.OPT, is an "image" of the interactive "MAINSETUP" session. test.OPT can be used for future executions of MAINSETUP for the same SPECIFIC case.]

[Next, execute the GENOPT mainprocessor, which is called "OPTIMIZE". During the initial phases in a GENOPT project execute "OPTIMIZE" for a "fixed" (given) design, not for optimization. For the analysis of a "fixed" design use the analysis type index, ITYPE = 2, as input for MAINSETUP:

```
 2 $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
```

In other words, initially take baby steps in order more easily to eliminate logical bugs in the "fleshed out" FORTRAN libraries, struct.new and behavior.new and bosdec.src.]

COMMAND	MEANING OF COMMAND
optimize	launch a "batch" execution of the GENOPT processor, OPTIMIZE (ITYPE=2)

[In the initial phases of a GENOPT project the "optimize" execution will probably "bomb". The GENOPT user must eliminate the cause of the "bomb", re-execute "genprograms", and re-execute "optimize". The GENOPT user performs this cycle as many times as necessary to obtain a successful execution of "optimize".]

[The following files are created by execution of OPTIMIZE for a "fixed" design (ITYPE = 2 as input to MAINSETUP:]

```
--------------------------------------------------------------
-rw-rw-r-- 1 bush bush 125238 Jan  9 06:13 test.OPM
```

and:

```
-rw-rw-r-- 1 bush bush 101334 Jan  9 06:12 test.BEHX011
-rw-rw-r-- 1 bush bush 101334 Jan  9 06:13 test.BEHX012
-rw-rw-r-- 1 bush bush   5130 Jan  9 06:12 test.BEHX021
-rw-rw-r-- 1 bush bush   5130 Jan  9 06:13 test.BEHX022
-rw-rw-r-- 1 bush bush  68831 Jan  9 06:12 test.BEHX031
-rw-rw-r-- 1 bush bush  68831 Jan  9 06:13 test.BEHX032
-rw-rw-r-- 1 bush bush 101334 Jan  9 06:12 test.BEHX041
-rw-rw-r-- 1 bush bush 101334 Jan  9 06:13 test.BEHX042
-rw-rw-r-- 1 bush bush  59786 Jan  9 06:12 test.BEHX11
-rw-rw-r-- 1 bush bush  59786 Jan  9 06:13 test.BEHX12
-rw-rw-r-- 1 bush bush   4942 Jan  9 06:13 test.BEHX21
-rw-rw-r-- 1 bush bush   4942 Jan  9 06:13 test.BEHX22
-rw-rw-r-- 1 bush bush   5176 Jan  9 06:13 test.BEHX31
-rw-rw-r-- 1 bush bush   5176 Jan  9 06:13 test.BEHX32
-rw-rw-r-- 1 bush bush   5119 Jan  9 06:13 test.BEHX511
-rw-rw-r-- 1 bush bush   5119 Jan  9 06:13 test.BEHX512
-rw-rw-r-- 1 bush bush   5353 Jan  9 06:13 test.BEHX521
-rw-rw-r-- 1 bush bush   5353 Jan  9 06:13 test.BEHX522
```

```
-rw-rw-r-- 1 bush bush   5406 Jan  9 06:13 test.BEHX611
-rw-rw-r-- 1 bush bush   5406 Jan  9 06:13 test.BEHX612
-rw-rw-r-- 1 bush bush   5640 Jan  9 06:13 test.BEHX621
-rw-rw-r-- 1 bush bush   5640 Jan  9 06:13 test.BEHX622
-rw-rw-r-- 1 bush bush 101312 Jan  9 06:13 test.BEHX71
-rw-rw-r-- 1 bush bush 101312 Jan  9 06:13 test.BEHX72
-rw-rw-r-- 1 bush bush 107713 Jan  9 06:13 test.BEHX811
-rw-rw-r-- 1 bush bush 107713 Jan  9 06:13 test.BEHX812
-rw-rw-r-- 1 bush bush 107713 Jan  9 06:13 test.BEHX821
-rw-rw-r-- 1 bush bush 107713 Jan  9 06:13 test.BEHX822
-rw-rw-r-- 1 bush bush 107888 Jan  9 06:13 test.BEHX911
-rw-rw-r-- 1 bush bush 107888 Jan  9 06:13 test.BEHX912
-rw-rw-r-- 1 bush bush 107888 Jan  9 06:13 test.BEHX921
-rw-rw-r-- 1 bush bush 107888 Jan  9 06:13 test.BEHX922
-----------------------------------------------------------
```

[The file, test.OPM, lists the output from OPTIMIZE. The GENOPT user must inspect this file carefully to be certain that the results are reasonable. At this early stage in the GENOPT project the GENOPT user will doubtless discover that more revisions of the "fleshed out" libraries, struct.new, behavior.new and bosdec.src, are required. At each step (cycle) in the process the GENOPT user MUST update the archive versions of struct.new and behavior.new and possibly bosdec.src.]

[In this work the archived versions are called struct.tank and behavior.tank. The latest archived versions of the struct and behavior libraries MUST be saved because each new execution of GENTEXT writes over earlier versions of struct.new, behavior.new. If, in one of your development cycles, you introduce a new variable or variables, you MUST correspondingly update bosdec.src by replacing the old “tank.COM” common blocks that were copied into the bosdec library with the latest version of the common blocks now stored in the file called “tank.COM”. You must also see to it that your archived versions of the “struct” and “behavior” libraries always contain the latest version of the labeled common blocks that always comprise the file called “tank.COM” (in this “tank” project).]

[The many files, test.BEHX*, are valid input files for BIGBOSOR4. Details of what these files contain are provided in the file, bigbosor4.input.test.BEHX.files. Also described in the file, bigbosor4.input.test.BEHX.files, is the sequence of BIGBOSOR4 executions required in the use of these test.BEHX* files to obtain results, including plots, from “stand-alone” BIGBOSOR4. Please inspect the file, bigbosor4.input.test.BEHX.files.]

[After the GENOPT user has thoroughly de-bugged the new FORTRAN software created by him/her in the "fleshed out" libraries, struct.new, behavior.new, bosdec.src, he/she is ready to do some optimization.]

COMMAND	MEANING OF COMMAND
mainsetup	interactively provide input data for the GENOPT processor, MAINSETUP, this time with the use of analysis type index, ITYPE = 1 (optimization)
optimize	launch a "batch" execution of the GENOPT processor, OPTIMIZE

[For the SPECIFIC case called "test" the OPTIMIZE processor requires about 20 minutes on the writer's superfast 64-bit desk-top computer. In the optimization mode of execution, the GENOPT processor, OPTIMIZE, produces the following two files:]

```
----------------------------------------------------------
-rw-rw-r-- 1 bush bush 1562490 Jan  9 06:40 test.OPM
-rw-rw-r-- 1 bush bush 24489 Jan  9 06:40 test.OPP
----------------------------------------------------------
```

Near the end of the test.OPP file data such as the following will be listed:

```
 ********** OBJECTIVE FOR   6 ITERATIONS *********
 total conductance into the tank: CONDCT =
  5.6663E+00  7.9732E+00  8.7266E+00  9.0540E+00  8.2210E+00  8.3451E+00
  Absolute values of maximum constraint gradients, GRDPLT =
  2.1194E+00  8.8661E+00  6.6150E+00  5.9323E+01  5.0250E+01  0.0000E+00

 =============================================================
 ITERATION                                        NUMBER OF
  NUMBER      OBJECTIVE     THE DESIGN IS...   CRITICAL MARGINS
 -------------------------------------------------------------
 -------------------------------------------------------OPTIMIZE
     1         5.6663E+00      NOT FEASIBLE         13
     2         7.9732E+00      NOT FEASIBLE         11
     3         8.7266E+00      NOT FEASIBLE         11
     4         9.0540E+00      NOT FEASIBLE          9
     5         8.2210E+00      NOT FEASIBLE         10
     6         8.3451E+00     MOSTLY UNFEASIB        7
 ======================================================================
```

[In the initial phases of a GENOPT project the GENOPT user should inspect both the *.OPM and *.OPP files. If everything looks reasonable, the GENOPT user may next execute the GENOPT processor called SUPEROPT. SUPEROPT executes OPTIMIZE in a loop for a total of about 470 design iterations. For the SPECIFIC case called "test" the SUPEROPT process requires about 24 hours on the writer's superfast desk-top computer. There also exists a GENOPT processor called “SUPERDUPEROPT”. SUPERDUPEROPT executes SUPEROPT in a loop. SUPERDUPEROPT was not used in the “tank” project because of the long computer run times required for each execution of SUPEROPT.]

COMMAND	MEANING OF COMMAND
superopt	launch a "batch" execution of the GENOPT processor, SUPEROPT

*************************** NOTE ********************************
In the process of launching each execution of SUPEROPT the End user is prompted as follows:

Enter specific case name: **test**
Enter number of executions of OPTIMIZE
for each execution of AUTOCHANGE (5 or 6 or 7 or 8 or 9 or 10 or ....15):**6**
B (background), F (foreground): **b**
H (high) or L (low) priority: **L**

In every execution of SUPEROPT during this study the End user (the writer) chose six executions of OPTIMIZE for every execution of AUTOCHANGE.
****

[The GENOPT user can terminate the SUPEROPT execution at any time if he/she wants to obtain details about the "best" optimum design determined so far. He/she does not need to wait until SUPEROPT finishes 24 hours later. The most important file to inspect is the test.OPP file, especially the part of the test.OPP file near its end where information is provided about the best FEASIBLE design and the best ALMOST FEASIBLE design. The test.OPM file is not as important for SUPEROPT runs as the test.OPP file because test.OPM is overwritten with each execution of OPTIMIZE in the SUPEROPT loop. The test.OPP file contains results from all the many executions of OPTIMIZE performed since the launching of the SUPEROPT execution.]

[The GENOPT user or the End user can obtain plots of design variables, and/or design margins, and and/or design objective as functions of design iterations as follows:]

COMMAND	MEANING OF COMMAND
chooseplot	Interactively choose what to plot with use of the GENOPT processor called CHOOSEPLOT.

[CHOOSEPLOT creates the following files:]

```
----------------------------------------------------------
-rw-rw-r-- 1 bush bush     222 Nov 19 04:03 test.CPL
-rw-rw-r-- 1 bush bush     222 Nov 19 04:03 test.OPL
----------------------------------------------------------
```

[In this particular example the test.CPL file contains only three lines:]

```
-----------------------------------------------------------
 N  $ Do you want a tutorial session and tutorial output?
 N  $ Any design variables to be plotted v. iterations (Y or N)?
 N  $ Any design margins to be plotted v. iterations (Y or N)?
-----------------------------------------------------------
```

[Hence, only one plot will exist: the objective function versus design iterations completed before termination of the SUPEROPT run by the GENOPT user or End user before the completion of the very long SUPEROPT execution.]

COMMAND	MEANING OF COMMAND
diplot	obtain a postscript file, test.5.ps
gv test.5.ps	obtain the plot on your computer screen.

[The file, superoptobjective.png (Fig.19), contains the image of this plot corresponding to a complete execution of SUPEROPT.]

[The GENOPT user or End user will probably next want to save the "best" FEASIBLE or ALMOST FEASIBLE design after his/her termination of the SUPEROPT execution or after SUPEROPT has completed on its own 24 hours later. In order to do this the GENOPT user or End user first obtains a list of the best optimum design on his/her screen by looking near the end of the test.OPP file. For example, here is such a list in the SPECIFIC case called "test":]

```
----------------------------------------------------------------
  VALUES OF DESIGN VARIABLES CORRESPONDING TO BEST FEASIBLE DESIGN
 VAR.   CURRENT
 NO.     VALUE            DEFINITION
  1    5.997E-02  thickness of the tank aft dome skin: THKAFT
  2    4.742E-02  thickness of the tank cylinder skin: THKMID
  3    3.622E-02  thickness of the forward tank dome skin: THKFWD
  4    8.839E+00  spacing of the tank orthogrid stringers: STRSPC
  5    8.839E+00  spacing of the tank orthogrid rings: RNGSPC
  6    1.409E-01  thickness of the tank orthogrid stringers: STRTHK
  7    1.000E+00  height of the tank orthogrid stringers: STRHI
  8    1.409E-01  thickness of the tank orthogrid rings: RNGTHK
  9    1.000E+00  height of the tank orthogrid rings: RNGHI
 10    1.500E+02  global axial coordinate of tank support ring: ZTANK(1 )
 11    4.500E+02  global axial coordinate of tank support ring: ZTANK(2 )
 12    8.283E+01  global axial coordinate of "ground": ZGRND(1 )
 13    5.097E+02  global axial coordinate of "ground": ZGRND(2 )
 14    6.000E+00  circ.angle (deg.) to pinned tank end of strut: ATANK(1 )
 15    6.000E+00  circ.angle (deg.) to pinned tank end of strut: ATANK(2 )
 16    4.500E+01  circ.angle to pinned "ground" end of strut: AGRND(1 )
 17    4.500E+01  circ.angle to pinned "ground" end of strut: AGRND(2 )
 18    7.261E+00  inner diam. of support tube active at launch: IDTUBE(1 )
 19    7.245E+00  inner diam. of support tube active at launch: IDTUBE(2 )
 20    3.000E+01  axial length of the propellant tank doubler: DUBAXL(1 )
 21    1.101E-01  max.thickness of the propellant tank doubler: DUBTHK(1 )
 22    3.151E-01  thickness of the tank reinforcement ring: TRNGTH(1 )
 23    1.576E+00  height of the tank reinforcement ring: TRNGHI(1 )
 24    6.514E-03  thickness of a lamina: THICK(1 )
 25    6.514E-03  thickness of a lamina: THICK(2 )
 26    6.514E-03  thickness of a lamina: THICK(3 )
 27    6.514E-03  thickness of a lamina: THICK(4 )
 28    6.514E-03  thickness of a lamina: THICK(5 )
 29    6.514E-03  thickness of a lamina: THICK(6 )
 30    6.495E-03  thickness of a lamina: THICK(7 )
 31    6.495E-03  thickness of a lamina: THICK(8 )
 32    6.495E-03  thickness of a lamina: THICK(9 )
 33    6.495E-03  thickness of a lamina: THICK(10)
 34    6.495E-03  thickness of a lamina: THICK(11)
 35    6.495E-03  thickness of a lamina: THICK(12)
 36    1.401E+01  layup angle: ANGLE(1 )
 37   -1.401E+01  layup angle: ANGLE(2 )
 38    6.353E+01  layup angle: ANGLE(3 )
 39   -6.353E+01  layup angle: ANGLE(4 )
 40    1.000E+01  layup angle: ANGLE(5 )
 41   -1.000E+01  layup angle: ANGLE(6 )
 42    6.012E+01  layup angle: ANGLE(7 )
 43   -6.012E+01  layup angle: ANGLE(8 )
 44    1.000E+01  layup angle: ANGLE(9 )
```

```
 45   -1.000E+01  layup angle: ANGLE(10)
 46    1.000E+01  layup angle: ANGLE(11)
 47   -1.000E+01  layup angle: ANGLE(12)
-------------------------------------------------------------------------
```

[The GENOPT user or End user enters the appropriate values during the iteractive session associated with the CHANGE processor of GENOPT, as follows:

COMMAND	MEANING OF COMMAND
change	Interactively provide the optimum design listed above with the use of the GENOPT processor called CHANGE.

[CHANGE creates the following files:]

```
-------------------------------------------------------------
-rw-rw-r-- 1 bush bush    8445 Nov 19 04:23 test.CHG
-rw-rw-r-- 1 bush bush   20332 Nov 19 05:51 test.OPC
-------------------------------------------------------------
```

[The file, test.CHG, is an "image" of the interactive "CHANGE" session. test.CHG can be used for future executions of CHANGE for the same SPECIFIC case.

***************** IMPORTANT NOTE ********************
It cannot be overemphasized how important it is to archive optimum designs via the use of CHANGE. Then, in the future, it will be possible to use the previously determined optimum design as a new "starting design" for possibly further optimization under different conditions than those that produced the optimum design saved in test.CHG.
****

A run stream in which this is done is as follows:]

COMMAND	MEANING OF COMMAND
cleanspec	Clean up SPECIFIC files.
begin	Execute the GENOPT processor BEGIN with use of test.BEG as the input file rather than provide data interactively one datum at a time.
change	Execute the GENOPT processor CHANGE with us of test.CHG as the input

file rather than provide data
interactively one datum at a time

decide — Execute the GENOPT processor DECIDE with us of test.DEC as the input file rather than provide data interactively one datum at a time

mainsetup — Execute the GENOPT processor MAINSETUP with us of test.OPT as the input file rather than provide data interactively one datum at a time

optimize (or **superopt**) — Launch a "batch" run of the GENOPT mainprocessor, OPTIMIZE (or SUPEROPT)

[Next, the GENOPT user or the End user will want to perform the analysis of the optimum design with use of the analysis type, ITYPE = 2, as input in MAINSETUP, that is, the analysis of a "fixed" design rather than optimization. In this sample runstream that would be the analysis of the "fixed" design with the dimensions given in the file, test.CHG.]

COMMAND	MEANING OF COMMAND
change	Execute the GENOPT processor CHANGE with us of test.CHG as the input file rather than provide data interactively one datum at a time
mainsetup	Execute the GENOPT processor MAINSETUP with us of test.OPT as the input file rather than provide data interactively one datum at a time. Set analysis type, ITYPE = 2
optimize	Launch a "batch" run of the GENOPT mainprocessor, OPTIMIZE

[Next, the GENOPT user or the End user may want to obtain various plots from BIGBOSOR4 corresponding to the various

behaviors represented by the BIGBOSOR4 input files, test.BEHX*, listed above. These test.BEHX* files now pertain to the optimum design obtained from SUPEROPT. Please see the file, bigbosor4.input.test.BEHX.files, for details on how to do this.]

[There follows a digression from the run stream listed so far. There are two items in this rather lengthy digression: ITEM 1 “HISTORICAL FOOTNOTE”, and ITEM 2 “TWO BIGBOSOR4/BOSDEC MODELS…”]

**** BEGIN THE DIGRESSION *****
ITEM 1:
HISTORICAL FOOTNOTE CONCERNING CERTAIN DECEMBER 6 UPDATES (You do not have to read this "historical" section; it's a detail included here mostly so that I will be reminded of one of the important things I did during the development of the "tank" capability:

SUBROUTINE BOSDEC was modified after the run stream listed above was executed. The modification was significant. The load components, PRESS (uniform ullage pressure) and TNKCOOL (propellant tank cool-down), were introduced into the BIGBOSOR4 models of the propellant tank with attached springs (the models associated with *.BEHX01x and *.BEHX041x, x = 1,2; x=load case). The "bosdec" modification is as follows:

```
      DO 230 I = 1,NSEGS
         EXSKIN(I) = ETANK
         EYSKIN(I) = ETANK
         UXYSKN(I) = NUTANK
         GSKIN(I) = ETANK/(2.*(1.+NUTANK))
         A1SKIN(I) = ALTNK
         A2SKIN(I) = ALTNK
         SMSKIN(I) = DENTNK
         IDISAB(I) = 1
C BEG DEC 3, 2011
C        IF (INDX.EQ.4.OR.INDX.EQ.5.OR.INDX.EQ.6) IDISAB(I) = 0
         IF (INDX.EQ.5.OR.INDX.EQ.6) IDISAB(I) = 0
C END DEC 3, 2011
  230 CONTINUE
C
```

The main effects of the modification are:

1. The maximum and minimum loads in the struts are increased somewhat. This affects primarily stress and buckling of the struts.

2. The effective spring constants of the struts accounting for the flexibility of the propellant tank change somewhat. This affects primarily the free vibration frequencies of the strut-supported propellant tank.

ITEM 2:
TWO BIGBOSOR4/BOSDEC MODELS OF "LUMPING" THE PROPELLANT MASS INTO THE MIDDLE LAYER OF THE PROPELLANT TANK WALL

The shell-of-revolution analyzer, BIGBOSOR4, does not handle problems in which the density of the wall material varies along the meridian of a given shell segment. However, in the free vibration BIGBOSOR4 "tank" model the mass of the propellant is "lumped" into one of the three layers (the middle layer) of the propellant tank wall. For the two ellipsoidal end domes the amount of propellant mass "lumped" into this middle layer (which has constant thickness) should vary along the meridian of each ellipsoidal dome because the radius from the axis of revolution to the shell wall reference surface varies along the meridian and the slope of the shell wall varies along the meridian.

The formula for the effective added mass of the propellant, rho(add), for a shell of one layer is:

rho(add) = 0.5*(r/t) x sqrt[1.-(dr/ds)^2] x rho(fluid)

in which r = radius at a meridional point from the axis of revolution to the shell wall reference surface, t = wall thickness at that meridional point, dr/ds = derivative of r with respect to the meridional arc length "s", and rho(fluid) is the mass density of the fluid in the tank. The formula for the added mass, rho(add), is valid for a point on the meridian, and rho(add) varies along any meridian of a shell segment in which the radius, r, varies along the meridian.

For this "tank" project only, so-called "temporary" versions of BIGBOSOR4 and SUBROUTINE BOSDEC were created. Optimized designs of most of the specific cases were found from two BIGBOSOR4/BOSDEC models:

(1) The "regular" model in which the "permanent" versions of BIGBOSOR4 and SUBROUTINE BOSDEC are used, that is, the model in which the effective density of shell wall and "lumped" propellant must be constant within each shell segment.

(2) The "temporary" model in which the "temporary" versions of BIGBOSOR4 and SUBROUTINE BOSDEC are used, that is, the model in which the effective density of shell wall and "lumped" propellant can vary along the meridian within each shell segment.

APPENDIX 2 lists the FORTRAN differences between the "regular" (permanent) model and the "temporary" model.

The "regular" BIGBOSOR4 model is stored in the files called addbosor4.regular and bosdec.tank. The "temporary" model is stored in the files called addbosor4.density.var and bosdec.density.var.

In order to execute GENOPT/BIGBOSOR4 with the "regular" (permanent) model, type the following:

cp /home/progs/genopt/case/tank/addbosor4.regular /home/progs/bosdec/sources/addbosor4.src

cp /home/progs/genopt/case/tank/bosdec.tank /home/progs/bosdec/sources/bosdec.src

then execute the GENOPT processor called "genprograms" as follows:

/home/progs/genoptcase/genprograms

then run the specific case with use of the "regular" model that has been compiled by the GENOPT processor called "genprograms".

In order to execute GENOPT/BIGBOSOR4 with the "temporary" model, type the following:

cp /home/progs/genopt/case/tank/addbosor4.density.var /home/progs/bosdec/sources/addbosor4.src

cp /home/progs/genopt/case/tank/bosdec.density.var /home/progs/bosdec/sources/bosdec.src

then execute "genprograms" as follows:

```
/home/progs/genoptcase/genprograms

then run the specific case with use of the
"temporary" model that has been compiled
by the GENOPT processor called "genprograms".

*************** IMPORTANT NOTE ********************
The temporary versions of BIGBOSOR4 and BOSDEC, when
executed with ITYPE = 2 (fixed design) in the *.OPT
file, produce the files, *.BEHXxxx, just as do the
permanent versions of BIGBOSOR4 and BOSDEC. However,
it is emphasized that the two files pertaining to
free vibration of the tank/strut system, *.BEHX11 and
*.BEHX12, when used as input files for BIGBOSOR4 in
the analyses described in the file,
bigbosor4.input.test.BEHX.files,
produce inappropriate results because the effective
mass of the tank wall does not include the "lumped"
mass of the propellant whenever the *.BEHX11 and *.BEHX12
files have been generated via the temporary versions
of BIGBOSOR4 and BOSDEC. Therefore, what you must NEVER
do is generate the *.BEHX11 and *.BEHX12 files with use
of the temporary BIGBOSOR4 and BOSDEC, then run the
"stand-alone" BIGBOSOR4 (which is always the permanent
version of BIGBOSOR4) using those *.BEHX11 and *.BEHX12
files as input to the stand-alone version of BIGBOSOR4.
All of the other *.BEHXxxx files generated via the
temporary versions of BIGBOSOR4 and BOSDEC are okay
because those models do not involve "lumping" the
propellant mass into the middle layer of the tank wall.
In order to get plots of the free vibration modes, you
must generate appropriate *.BEHX11 and *.BEHX12 files by
first copying the "permanent" versions of addbosor4
(addbosor4.regular) and bosdec (bosdec.tank) into
../bosdec/sources/addbosor4.src and ..bosdec/sources/bosdec.src,
respectively, then run "genprograms", and then execute the
case called "*" with use of ITYPE=2 in the *.OPT file.
Then, when you follow the directions listed in the file,
bigbosor4.input.test.BEHX.files,
you will obtain the plots you want.
**** END THE DIGRESSION *****

[Please see the file, bigbosor4.input.test.BEHX.files, for details
on how to obtain results from the “stand-alone” BIGBOSOR4 that
correspond to optimum designs obtained with GENOPT/BIGBOSOR4.
NOTE: The version of BIGBOSOR4 used in connection with GENOPT, that
is, when used in the string, “GENOPT/BIGBOSOR4”, is different from
the stand-alone version of BIGBOSOR4 that is used in connection with
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the files, test.BEHX11, test.BEHX12, etc. For example, the files addbosor4.density.var and addbosor4.regular referred to above in ITEM 2 of the digression are the versions of BIGBOSOR4 used in connection with GENOPT. These are not the same as the “stand-alone” version of BIGBOSOR4, which is the version that has been distributed world wide.]

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 arrangement of struts and the optimum
    design of struts within that arrangement 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 or spherical. It is made of isotropic material.
    It may have locally thickened regions and stiffening rings
    to handle the concentrated loads applied by the struts.

    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 struts 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 layered orthotropic 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
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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 may be struts attached to the tank at a number of axial locations. At each of these axial locations there are n sets of two struts each. In each pair of two struts, one strut has a positive azimuthal angle and the other strut has an equal negative azimuthal angle. These positive and negative azimuthal angles are the same for each of the n sets of struts at that particular axial coordinate of the tank wall.

All the struts at a given axial coordinate are attached to the same external ring, which is part of the propellant tank. All the struts at a given axial coordinate are attached to "ground" (the launch vehicle, assumed to be rigid in this model) at the same (different) axial coordinate. Therefore, all the struts at the given "ground" axial coordinate have the same inclination or declination angle.

There may be different numbers of strut pairs at different axial locations. The plus and minus azimuthal angles and inclination or declination angles in each group of struts, that is, at each axial location may differ.

For each strut at a given axial location one end of the strut is attached to the propellant tank and the other end of the strut is connected to "ground", in which "ground" means the (rigid) launch vehicle that carries the propellant tank. There is no launch vehicle model in this study.

To summarize:
1. There may be up to 3 axial locations at which structs are attached to the propellant tank and to ground.
2. At each axial location all the attachment points of the struts to the tank have the same axial coordinate; the struts are attached to the propellant tank along a ring.
3. The other ends of these struts are attached to "ground"

at the same axial location (in general different from the axial location of the tank-end of these struts).
4. There are n(i) strut pairs at each axial location in which i corresponds to a particular axial location. n(1), n(2), n(3)... may differ from eachother.

The arrangement of struts that support a tank is analogous to that described in the paper:
David Bushnell, "Improved optimum design of dewar supports", Computers & Structures, Vol. 29, No. 1, pp. 1-56, 1988

In that paper the quantity n = 3, that is, there are three strut pairs at each of one or two axial locations.

Much of the terminology in the present work is "borrowed" from the "dewar" paper just cited.

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:
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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
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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 strut support ring number
ZTANK = global axial coordinate of a tank support ring
ZGRND = global axial coordinate of "ground" (launch vehicle) for all the struts attached at ZTANK

5. Dimensions of strut types:
STRTYP = index for type of strut arrangement and struts
INPAIRS= strut type number
NPAIRS = number of strut pairs for strut type INPAIRS
FITTNK = length of strut end fitting attached to tank
FEATNK = axial "EA" stiffness of strut end fitting at tank
ALFITT = coefficient of thermal expansion of strut end fitting attached to the tank
FITVEH = length of strut end fitting attached to "ground"
FEAVEH = axial "EA" stiffeness of "ground" strut end fitting
ALFITV = coefficient of thermal expansion of strut end fitting attached to "ground"
ATANK = circumferential angle (degrees) to pinned end of the first strut attached to the tank
AGRND = circumferential angle (degrees) to pinned end of the first strut attached to "ground" (launch vehicle)
IDTUBE = inner diameter of the strut support tube that is active during the launch phase of the mission
ODINNR = outer diameter of the orbital tube assembly that is located inside the strut support tube (PODS)
FLINNR = length of the "folded" orbital tube assembly
NTUBES = number of tubes in the PODS folded tube concept
ISTRUT = index for simple strut (1) or PODS strut (2)

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 strut tubes:
JWALTYP= 1 means launch tube; 2 means orbital tube
IWALTYP= strut wall type number
WALTYP = type of laminated composite strut 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
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 tubes 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 strut conductance)
TNKNRM = normalizing empty tank mass
CONNRM = normalizing total strut 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 struts are located on 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 strut 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. This information is needed later to ascertain whether or not the struts clear the domes and the diameters of the support rings that are attached to the tank.
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 struts to the tank are located within the aft or forward domes. NOTE: So far in this study it is assumed that no struts are attached to either end dome of the propellant tank. All sets of struts 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 struts 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 struts 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 struts 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 struts 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 struts. 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 3 sets
of struts arrayed in a manner similar to that shown in Fig. 1
of the paper, "Improved Optimum Design of Dewar Supports",
Computers & Structures, Vol. 29, No. 1, pp. 1-56, 1988. Each
set of struts contains 2 x n(i) identical pin-ended members,
arranged in n(i) pairs spaced at 360/n(i) angles in the azimuthal
plane. One subset of n(i) is "clockwise slanting" and the other
subset of n(i) is "anticlockwise slanting" by the same
amount. The pin-ended member may be a simple tube or a tube
with a disconnect system (PODS). Each strut has end fittings
at each end of lengths, FITTNK and FITVEH. Each strut is
assumed to be pinned at each of its two ends.

For each set of tank supports 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 struts
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. The locations (azimuthal angles) of both ends of one of the n "anticlockwise slanting" struts. These angles are called ADEWP and AVACP in Fig. 1 of the 1988 dewar paper cited above.
6. The lengths of end fittings by means of which the pin-ended struts are attached to the support rings (FITTNK, FITVEH)
7. The axial stiffness, "EA", of the end fittings (FEATNK, FEAVEH)
8. Diameters of the tubes in a strut (IDTUBE, ODINNR)
9. For each tube in a support strut:
9.1 number of layers through the tube thickness
9.2 layer type indicator for each layer
9.3 For each new layer type;
9.3.1 thickness
9.3.2 winding (layup) angle
9.3.3 material type indicator
10. Material properties for each material type. The strut tubes 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 struts 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 might be 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 SET OF 2 x n STRUTS, 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 strut that is connected to "ground", that is, the end of a strut 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 strut types for
each set of struts. A set of struts is associated with
as axial location. You may, for example, have 10 sets of
struts located at 10 different axial locations, but some
of these sets of struts have strut types that are the same.
A "strut type" is associated with a bundle of variables.
Associated with a given "strut type" is the following
"bundle" of variables:
NPAIRS = number of strut pairs attached to the propellant
tank support ring
ATANK and AGRND = angles of the propellant tank end and the
launch vehicle end of the first strut in the set of struts
FITTNK, FEATNK, ALFITT, FITVEH, FEAVEH, ALFITV = lengths,
"EA" axial stiffnesses, and coefficients of thermal expansion
of the strut end fittings at the propellant tank end of the
strut (FITTNK, FEATNK and ALFITT) and at the "ground"
(launch vehicle) end of the strut (FITVEH, FEAVEH
and ALFITV)
IDTUBE, FACLEN, DTSUP, ODINNR, FLINNR, NTUBES, ISTRUT =
inner diameter of strut launch tube, factor by which to
reduce the length of strut tube used in the model for
buckling of the strut tube as a shell, average strut
temperature minus ambient (room) temperature,
Outer diameter of the inner orbital tube, length of the
orbital tube assembly, number of "folded" tubes in the
orbital tube assembly, and type of strut (simple or
compound (PODS).

180.1 type of strut arrangement: STRTYP
180.2

You must provide STRTYP for each strut set axial location

185.0

Next, you will be asked to give the number of strut pairs
at each axial level. NPAIRS can differ at each axial level.
In the research that
led to the 1988 "dewar" paper cited above NPAIRS was fixed at 3.
Here we are allowed any number of strut pairs greater than or
equal to 3 (NPAIRS must be greater than or equal to 3).

A "strut pair" consists of one strut with a clockwise slant
and the other strut with an equal anticlockwise slant. See
Fig. 1 of the 1988 "dewar" paper for an example in which
NPAIRS = 3, which means that there are six struts at each
of possibly two axial locations. Here we can have up to
10 axial locations and the number of strut pairs can differ

at each axial level.

Next, you will see the prompt:
"Number INPAIRS of rows in the array NPAIRS: INPAIRS"
What is wanted is the number of different strut types.
For large propellant tanks with a cylindrical part of significant length, you will probably want INPAIRS = 2
INPAIRS = 2 means two strut types. These two different strut types correspond respectively to the set of struts attached nearer the aft end of the propellant tank (strut type 1) and the set of struts attached nearer the forward end of the propellant tank (strut type 2). In this work all struts attached at a given propellant tank support ring are always of the same type. With "aft" and "forward" sets of struts the strut types are different at the two axial locations mainly because each of the two sets of struts is slanted differently. Even if the laminates in all struts are the same, the strut types are different because of the different slanting in each of the two sets.

190.1 Number INPAIRS of rows in the array NPAIRS: INPAIRS
195.1 number of strut pairs: NPAIRS
195.2

Next, you will be asked to give the number of strut pairs at each axial level. NPAIRS can differ at each axial level. In the research that led to the 1988 "dewar" paper cited above NPAIRS was fixed at 3. Here we are allowed any number of strut pairs greater than or equal to 3 (NPAIRS must be greater than or equal to 3).

A "strut pair" consists of one strut with a clockwise slant and the other strut with an equal anticlockwise slant. See Fig. 1 of the 1988 "dewar" paper for an example in which NPAIRS = 3, which means that there are six struts at each of possibly two axial locations. Here we can have up to 10 axial locations and the number of strut pairs can differ at each axial level.

200.0

Next, you will be asked to provide data relative to the strut fittings at the propellant tank end of a strut (length of end fitting = FITTNK, axial "EA" stiffness of end fitting = FEATNK, coefficient of thermal expansion of end fitting = ALFITT) and at the launch vehicle end of a strut (length of end fitting = FITVEH, axial "EA" stiffness of end fitting = FEAVEH, coefficient of thermal expansion of end fitting = ALFITV).

For a sketch of a strut, see the upper right part
of Fig. 1 of the 1988 "dewar" paper cited above.

205.1 length of end fitting attached to tank ring: FITTNK
205.2
This end fitting has axial stiffness "EA" and has infinite conductivity. You should use as this length the distance between the point at which the strut is pinned to the propellant tank support ring and point along the strut where the elastic composite strut tube begins.

210.1 axial "EA" stiffness of tank-end strut fitting: FEATNK
210.2
This is the axial stiffness of the end fitting at the end of the strut attached to the propellant tank support ring. The fitting "spring" constant is K = EA/L, in which EA is the axial stiffness of the end fitting and L is the axial length of the end fitting, FITTNK.

215.1 Coef.of thermal expansion of tank end fitting: ALFITT
215.2
What is wanted here is the coefficient of thermal expansion, alpha = ALFITT, of the end fitting that is pinned to the propellant tank support ring.

220.1 length of strut end fitting attached to "ground": FITVEH
220.2
This end fitting has axial stiffness "EA" and has infinite conductivity. You shuold use as this length the distance between the point at which the strut is pinned to the launch vehicle ("ground") and the point along the strut where the composite strut tube begins.

225.1 axial "EA" stiffness of "ground" end strut fitting: FEAVEH
225.2
This is the axial stiffness of the end fitting at the end of the strut attached to the launch vehicle ("ground"). The end fitting "spring" constant is K = EA/L, in which EA is the axial stiffness of the end fitting and L is the axial length of the end fitting, FITVEH.

230.1 coef.of thermal expan. of "ground" end fitting: ALFITV
230.2
What is wanted here is the coefficient of thermal expansion, alpha = ALFITV, for the strut end fitting that is pinned to "ground" (pinned to the launch vehicle).

235.0

This set of 2 x NPAIRS support struts is arranged in two subsets of NPAIRS each. The NPAIRS members of the first subset are spaced at 360/NPAIRS-degree intervals and slant anticlockwise between the propellant tank (called "dewar" in Fig. 1 of the 1988 "dewar" paper) and the launch vehicle (called "vacuum shell" in the "dewar" paper) as viewed from the forward (fwd) end of the propellant tank. The first strut in this subset of NPAIRS struts is pinned to the propellant tank support ring at a circumferential angle called ATANK (called ADEWP in the 1988 "dewar" paper). This first strut is pinned to the launch vehicle (called "vacuum shell support ring" at a circumferential angle called AGRND (called AVACP in the "dewar" paper). See Fig. 1 of the 1988 "dewar" paper).

The NPAIRS struts in the second subset are spaced at 360/NPAIRS degrees and slant clockwise by the same amount (THETA in Fig. 1) that the first set slants anticlockwise. The frst strut in this second subset of NPAIRS struts is pinned to the propellant tank support ring at a circumferential angle equal to -ATANK.

In Fig. 1 of the "dewar" paper The first subset of NPAIRS = 3 "anticlockwise" slanting struts are labelled 1, 2, and 3 in the top view in Fig. 1. The second subset of NPAIRS = 3 "clockwise" slanting struts are labelled 4, 5, and 6.

NOTE: THE RECOMMENDED VALUE OF ATANK: 15.0 degrees.

240.1 circ.angle (deg.) to pinned tank end of strut: ATANK
240.2

Must be positive and less than 60 degrees. This angle is measured from the x-axis shown in Fig. 1 of the "dewar" paper. You might try 15 deg.

245.1 circ.angle to pinned "ground" end of strut: AGRND
245.2

Must be positive. If NPAIRS = 3 you might try a starting value, AGRND = ATANK + 45 degrees

250.0

Next, you will be asked to provide input relating to the strut tubes: IDTUBE, FACLEN, DTSUP, ODINNR, FLINNR, NTUBES and ISTRUT:
IDTUBE = inner diameter of support tube active during launch
FACLEN = factor less than unity used to reduce the length

of the composite strut tube analyzed for shell buckling.
DTSUP = average strut temperatue - ambient (room) temp.
ODINNR = outer diameter of tube assembly active during launch hold and in orbit
FLINNR = length of the orbital tube assembly
NTUBES = number of "folded" tubes in orbital tube assembly
ISTRUT = index for type of strut: 1=simple; 2=PODS

255.1 inner diam. of support tube active at launch: IDTUBE
255.2

This is the inner diameter of the outermost support tube, the tube through which all loads pass during the launch phase of the mission.

260.0

Next, you will be asked to provide a factor by which the strut launch tube length is to be multiplied for the analysis of buckling of the launch tube as a shell. This factor, called FACLEN, should be less than unity, probably something like 0.02 - 0.2. The purpose is to obtain shell buckling load factors that have converged with respect to nodal point density. Most strut launch tubes have a rather high length/diameter, something like 5 - 50. Shell buckling usually occurs with an axial wavelength that is smaller than a shell diameter, sometimes much smaller than a shell diameter. Therefore, in order to obtain a converged value for the critical shell buckling load factor one needs to analyze a rather short sub-length of the strut tube. The factor, FACLEN, accomplishes this.

265.1 length factor for strut buckling as a shell: FACLEN
265.2

Set 0.02 < FACLEN < 0.2

270.1 Average strut temperature minus ambient: DTSUP
270.2

What is wanted is the difference, DTSUP, between the average temperature of the support strut after the propellant tank has been filled with cryogenic material, and the ambient temperature. This will be a negative number. Use temperature units consistent with the value of ALSUP just provided by you.

275.1 outer diam.of the orbital tube assembly: ODINNR
275.2

This is the outer diameter of the orbital tube assembly, the "folded" tube assembly through which all loads pass during the orbital and launch-hold phases of the mission.

280.1 Length of the orbital tube assembly: FLINNR
280.2

This is the length of the orbital tube assembly, the "folded" tube assembly through which all loads pass during the orbital and launch-hold phases of the mission. If there are two tubes in the orbital tube assembly ("folded" orbital tube concept), FLINNR is the length of one of the tubes. The length of the other orbital tube is assumed to be the same. In the "folded" orbital tube concept this computer program accounts for the fact that there are two tubes through use of the input datum, NTUBES, which you will next provide.

285.1 Choose 1 or 2 tubes in the orbital tube assembly: NTUBES
285.2

You must choose NTUBES = 1 or 2 . With NTUBES = 2 the orbital tube assembly is a "folded" tube concept, which may reduce the conductivity of the support system in orbit by providing a longer path from propellant tank to "ground" (launch vehicle) than with NTUBES = 1. With NTUBES = 2 the strut is softer because the effective spring length of the folded tube is twice that of the single orbital tube. (NOTE: the two "folded" tubes are assumed to be of the same length, FLINNR, and to have the same wall construction. One of these two orbital tubes fits inside the other.

290.0

Next, you will be asked what type of struts support the propellant tank. You have two choices:

1. ISTRUT = 1 means the strut is a simple composite tube with end fittings.
2. ISTRUT = 2 means the strut has an orbital disconnect feature. The compound strut has the main composite tube active during the launch phase plus a disconnect "folded" tube active during launch-hold or in orbit. This smaller "inner" tube or tube bundle is near the cold (propellant tank) end of the strut. It has a much smaller conductance than the main tube active during launch (the outer tube) which has a larger cross section area and which is, on the average, warmer than the "orbital" tube or tube bundle.

295.1 index for simple strut (1), "PODS" strut (2): ISTRUT
295.2

ISTRUT = 1 means that the support strut is a simple laminated composite tube with end fittings.

ISTRUT = 2 means that the support strut is a compound strut
with a laminated composite tube active during launch and
a much smaller composite laminated tube or tube bundle
("folded tube") active during launch hold and in orbit.

300.0
Next, you will be asked to provide an index for
the type of wall construction (type of composite laminate)
associated with the struct type, STRTYP. All struts attached
to a given propellant tank ring have the same wall type.
Sets of struts at different propellant tank rings may have
different composite layups, that is, different wall types.

305.1 type of wall constructions in strut type STRTYP: WALTYP
305.2
Probably the struts at different axial levels will have the
same wall type, but struts at different levels MAY have
different wall types, that is, different composite layups.

310.0
You will next be asked to provide the cross-section
dimensions of an external ring with tee-shaped cross section
to be attached to the cylindrical portion of the propellant
tank at its midlength. You will be asked to provide the
height and thickness of the web and the height and thickness
of the outstanding flange. These are decision variable
candidates.

315.1 height of mid-tank T-ring web: WEBHI
315.2
This is the distance measured from the outer surface of
the wall of the propellant tank to the middle surface of
the outstanding flange of the T-shaped external ring.

320.1 thickness of mid-tank T-ring web: WEBTHK
325.1 width (height) of mid-tank T-ring flange: FLGHI
330.1 thickness of mid-tank T-ring flange: FLGTHK

335.0
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).

340.1 propellant tank reinforcement type: RNGTYP
340.2
The propellant tank reinforcement type is associated with the bundle of tapered doubler and discrete ring properties.

345.0
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 strut 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

350.1 Number IDUBAXL of rows in the array DUBAXL: IDUBAXL
355.1 axial length of the propellant tank doubler: DUBAXL
355.2
This is the axial length of the axisymmetric doubler

360.1 max.thickness of the propellant tank doubler: DUBTHK
360.2
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.

365.0
Next, you will be asked to provide properties of the external rings to which the propellant tank end of the support struts 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

370.1 thickness of the tank reinforcement ring: TRNGTH
370.2
This ring is part of the propellant tank reinforcement
The propellant tank end of the strut is attached to the
centroid of this ring, which has a rectangular cross section.
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.)

375.1 height of the tank reinforcement ring: TRNGHI
375.2
TRNGHI is the dimension of the ring measured normal to the
tank skin.

380.1 hoop modulus of the tank ring: TRNGE
380.2
The hoop modulus is the stiffness/area of the tank support
ring in units, for example, of lb/in**2.

385.1 coef.of thermal expansion of the tank ring: ALRNGT
385.2
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
struts. Units of ALRNGT are "per degree xxx". Use consistent
units for this quantity and the temperature difference you
will be asked for below.

390.0
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 strut launch tubes and the strut orbital tubes.
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)

395.1 Number ITHICK of rows in the array THICK: ITHICK
400.1 thickness of a lamina: THICK
400.2
It is possible to have multiple adjacent plies of the same
thickness type (same thickness index).

405.1 layup angle: ANGLE
405.2
Please provide the layup angle in degrees

410.1 Material type: MATTYP
410.2
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".

415.0
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.

420.1 Number JLAYTYP of columns in the array, LAYTYP: JLAYTYP
425.1 Number ILAYTYP of rows in this column of LAYTYP: ILAYTYP
430.1 layer type index: LAYTYP
430.2
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.

435.0
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

440.1 Number IE1 of rows in the array E1: IE1
445.1 modulus in the fiber direction: E1
450.1 modulus transverse to fibers: E2
455.1 in-plane shear modulus: G12
460.1 small Poisson's ratio: NU
460.2

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

465.1 x-z out-of-plane shear modulus: G13
465.2

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.

470.1 y-z out-of-plane shear modulus: G23
470.2

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.

475.1 coef.of thermal expansion along fibers: ALPHA1
480.1 coef.of thermal expan.transverse to fibers: ALPHA2
485.1 curing delta temperature (positive): TEMTUR
485.2

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.

490.1 conductivity along the fibers: COND1
490.2

This is the conductivity along the fibers in a unidirectional
ply of a composite laminate.

495.1 conductivity transverse to fibers: COND2
495.2

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

500.1 weight density of the material: DENSTY
500.2
e.g. aluminum = 0.1 lb/in^3
many composite materials have DENSTY = 0.057 lb/in^3

505.0
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 struts.

510.1 objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
510.2
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 strut conductance)
If WGT = 0.0 the objective is given by:
OBJECTIVE = (total strut 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 strut conductance
With WGT > 0.0 the objective will be as follows:
OBJECTIVE = WGT*(empty tank mass)/TNKNRM
+(1.-WGT)*(total strut conductance)/CONNRM

515.1 normalizing empty tank mass: TNKNRM
515.2
In general, the objective is defined as:
OBJECTIVE = WGT*(normalized empty tank mass)
+(1.-WGT)*(normalized total strut conductance)
If WGT = 0.0 the objective is given by:
OBJECTIVE = (total strut 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 strut conductance
With WGT > 0.0 the objective will be as follows:
OBJECTIVE = WGT*(empty tank mass)/TNKNRM

+(1.-WGT)*(total strut conductance)/CONNRM

520.1 normalizing total strut conductance: CONNRM
520.2
In general, the objective is defined as:
OBJECTIVE = WGT*(normalized empty tank mass)
+(1.-WGT)*(normalized total strut conductance)
If WGT = 0.0 the objective is given by:
OBJECTIVE = (total strut conductance)
You will next be asked to provide the variable:
CONNRM = the normalizing quantity for total strut conductance
With WGT > 0.0 the objective will be as follows:
OBJECTIVE = WGT*(empty tank mass)/TNKNRM
+(1.-WGT)*(total strut conductance)/CONNRM

525.0
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 tube and the inner orbital tube assembly in series.

530.1 IPHASE=1=launch phase; IPHASE=2=orbital phase: IPHASE
530.2
help for IPHASE

535.0
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 strut 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 strut 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

540.1 Number NCASES of load cases (environments): NCASES
545.1 propellant tank ullage pressure: PRESS
545.2
The propellant tank is internally pressurized in addition
to the pressure head provided by the propellant.

550.1 quasi-static axial g-loading: GAXIAL
550.2
Provide the ultimate axial g-loading to be seen by the
propellant tank.

555.1 quasi-static lateral g-loading: GLATRL
555.2
Provide the ultimate resultant lateral g-loading to be seen
by the propellant tank.

560.1 propellant tank cool-down from cryogen: TNKCOOL
560.2
This is the temperature decrease after the tank has been
filled with cryogen.

565.0
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. column buckling of a strut
4. shell buckling of a strut launch tube
5. force in a strut in the launch-hold condition
6. maximum effective stress in the propellant tank

7. 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/strut 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 strut-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.

570.1 Number JFREQ of columns in the array, FREQ: JFREQ
575.0 free vibration frequency (cps): FREQ
575.2
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)

580.1 minimum allowable frequency (cps): FREQA
580.2
Typically the minimum allowable frequency during the launch phase of the mission is significantly higher than the minimum allowable frequency in orbit.

585.1 factor of safety for freqency: FREQF
585.2
One suggestion would be a factor of safety of something like 1.2.

590.0
Next, you will be asked to provide behavioral variables relating to stress in the laminated composite strut tubes. 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.

595.1 Number JSTRES1 of columns in the array, STRES1: JSTRES1
600.0 maximum stress in material 1: STRES1
600.2
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)

605.1 maximum allowable stress in material 1: STRES1A
610.1 factor of safety for stress, matl 1: STRES1F
610.2
Generally use a factor of safety between 1.0 and 1.5.

615.0 maximum stress in material 2: STRES2
615.2
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.

620.1 maximum allowable stress in material 2: STRES2A
625.1 factor of safety for stress, matl 2: STRES2F
625.2
Generally use a factor of safety between 1.0 and 1.5.

630.0 maximum stress in material 3: STRES3
630.2
In an analogous manner to the behaviors, STRES1 and STRES2,
there are six components of stress in the array, STRES3. The
only difference here is that we are concerned with material
type 3 instead of material type 1 or material type 2.
NOTE: Three different materials may be used as a device
in order to permit the computation of maximum stresses in
different parts of the structure. For example, we will want
to compute the maximum stress components in strut types
1 and 2 and also in the orbital tubes in a "pods" strut
application. The materials out of which these various
parts of the structure are made might all be the same
composite material. However, we pretend that different

parts of the structure are made of different materials
in order to compute stress margins for different parts
of the structure.

635.1 maximum allowable stress in material 3: STRES3A
640.1 factor of safety for stress, matl 3: STRES3F
640.2
Generally use a factor of safety between 1.0 and 1.5.

645.1 Number JCOLBUK of columns in the array, COLBUK: JCOLBUK
650.0 buckling of a strut as a column: COLBUK
650.2
This is the Euler buckling phenomenon.

655.1 allowable for column buckling of strut: COLBUKA
655.2
Always set COLBUKA = 1.0

660.1 factor of safety for Euler strut buckling: COLBUKF
660.2
Generally use a factor of safety between 1.0 and 1.5.

665.0 buckling of strut as a shell: SHLBUK
665.2
The shell buckling mode is a short-axial-wavelength mode
compared to the axial wavelength of the column buckling mode.
The critical shell buckling mode usually has multiple wave
around the circumference of the launch tube part of the strut.

670.1 allowable for shell buckling of strut: SHLBUKA
670.2
Always set SHLBUKA = 1.0

675.1 factor of safety for shell buckling of strut: SHLBUKF
675.2
Generally use a factor of safety of about 2.0 in order to
account for the inevitable presence of initial imperfection
in the cylindrical tube portion of the strut active during
the launch phase of the mission.

680.0 launch-hold force in a strut: FORCE
680.2
During lauch-hold a compound strut, that is, a strut that
has both a launch tube and a "folded" orbital tube, 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.

685.1 maximum allowable launch-hold force in strut: FORCEA
685.2
Consult the maker of "disconnect" struts for what the maximum allowable launch-hold/orbital FORCE should be.

690.1 factor of safety for launch-hold force: FORCEF
690.2
Generally use a factor of safety between 1.0 and 1.5.

695.0 maximum stress in the propellant tank: TNKSTR
695.2
It is assumed here that the propellant tank is made of isotropic material with a single layer in the shell wall.

700.1 allowable for propellant tank stress: TNKSTRA
700.2
Conult the experts for what this maximum allowable stress should be.

705.1 factor of safety for tank stress: TNKSTRF
705.2
Use a factor of safety between 1.0 and 2.0

710.0 propellant tank buckling load factor: TNKBUK
710.2
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 struts "poke at" the propellant tank.

715.1 allowable for propellant tank buckling: TNKBUKA
715.2
Always set TNKBUKA = 1.0

720.1 factor of safety for tank buckling: TNKBUKF
720.2
Generally use a factor of safety between 1.0 and 1.2

725.0
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.

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

Table 3 Glossary of variables used in the generic case, “tank” (This is part of the tank.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                          (tank.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   = strut support ring number in ZTANK(IZTANK)
C    y   (   10,    0)    1     165   ZTANK    = global axial coordinate of tank support ring
C    y   (   10,    0)    1     170   ZGRND    = global axial coordinate of "ground"
C    y   (   10,    0)    2     180   STRTYP   = type of strut arrangement
C    n   (    0,    0)    2     190   INPAIRS  = strut type number in NPAIRS(INPAIRS)
C    y   (    3,    0)    2     195   NPAIRS   = number of strut pairs
C    y   (    3,    0)    2     205   FITTNK   = length of end fitting attached to tank ring
C    y   (    3,    0)    2     210   FEATNK   = axial "EA" stiffness of tank-end strut fitting
C    y   (    3,    0)    2     215   ALFITT   = Coef.of thermal expansion of tank end fitting
C    y   (    3,    0)    2     220   FITVEH   = length of strut end fitting attached to "ground"
C    y   (    3,    0)    2     225   FEAVEH   = axial "EA" stiffness of "ground" end strut fitting
C    y   (    3,    0)    2     230   ALFITV   = coef.of thermal expan. of "ground" end fitting
C    y   (    3,    0)    1     240   ATANK    = circ.angle (deg.) to pinned tank end of strut
C    y   (    3,    0)    1     245   AGRND    = circ.angle to pinned "ground" end of strut
C    y   (    3,    0)    1     255   IDTUBE   = inner diam. of support tube active at launch
C    y   (    3,    0)    2     265   FACLEN   = length factor for strut buckling as a shell
C    y   (    3,    0)    2     270   DTSUP    = Average strut temperature minus ambient
C    y   (    3,    0)    2     275   ODINNR   = outer diam.of the orbital tube assembly
C    y   (    3,    0)    2     280   FLINNR   = Length of the orbital tube assembly
C    n   (    0,    0)    2     285   NTUBES   = Choose 1 or 2 tubes in the orbital tube assembly
C    n   (    0,    0)    2     295   ISTRUT   = index for simple strut (1), "PODS" strut (2)
C    y   (    3,    0)    2     305   WALTYP   = type of wall constructions in strut type STRTYP
C    n   (    0,    0)    1     315   WEBHI    = height of mid-tank T-ring web
C    n   (    0,    0)    1     320   WEBTHK   = thickness of mid-tank T-ring web
C    n   (    0,    0)    1     325   FLGHI    = width (height) of mid-tank T-ring flange
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C    n   (    0,    0)    1      330   FLGTHK   = thickness of mid-tank T-ring flange
C    y   (    3,    0)    2      340   RNGTYP   = propellant tank reinforcement type
C    n   (    0,    0)    2      350   IDUBAXL  = propellant tank reinforcement type number in
DUBAXL(IDUBAXL)
C    y   (    3,    0)    1      355   DUBAXL   = axial length of the propellant tank doubler
C    y   (    3,    0)    1      360   DUBTHK   = max.thickness of the propellant tank doubler
C    y   (    3,    0)    1      370   TRNGTH   = thickness of the tank reinforcement ring
C    y   (    3,    0)    1      375   TRNGHI   = height of the tank reinforcement ring
C    y   (    3,    0)    2      380   TRNGE    = hoop modulus of the tank ring
C    y   (    3,    0)    2      385   ALRNGT   = coef.of thermal expansion of the tank ring
C    n   (    0,    0)    2      395   ITHICK   = thickness index in THICK(ITHICK)
C    y   (   15,    0)    1      400   THICK    = thickness of a lamina
C    y   (   15,    0)    1      405   ANGLE    = layup angle
C    y   (   15,    0)    2      410   MATTYP   = Material type
C    n   (    0,    0)    2      420   JLAYTYP  = wall type number in LAYTYP(ILAYTYP,JLAYTYP)
C    n   (    0,    0)    2      425   ILAYTYP  = layer number in LAYTYP(ILAYTYP,JLAYTYP)
C    y   (   90,    3)    2      430   LAYTYP   = layer type index
C    n   (    0,    0)    2      440   IE1      = material type in E1(IE1)
C    y   (    3,    0)    2      445   E1       = modulus in the fiber direction
C    y   (    3,    0)    2      450   E2       = modulus transverse to fibers
C    y   (    3,    0)    2      455   G12      = in-plane shear modulus
C    y   (    3,    0)    2      460   NU       = small Poisson's ratio
C    y   (    3,    0)    2      465   G13      = x-z out-of-plane shear modulus
C    y   (    3,    0)    2      470   G23      = y-z out-of-plane shear modulus
C    y   (    3,    0)    2      475   ALPHA1   = coef.of thermal expansion along fibers
C    y   (    3,    0)    2      480   ALPHA2   = coef.of thermal expan.transverse to fibers
C    y   (    3,    0)    2      485   TEMTUR   = curing delta temperature (positive)
C    y   (    3,    0)    2      490   COND1    = conductivity along the fibers
C    y   (    3,    0)    2      495   COND2    = conductivity transverse to fibers
C    y   (    3,    0)    2      500   DENSTY   = weight density of the material
C    n   (    0,    0)    2      510   WGT      = objective=WGT*(empty tank mass) +(1-
WGT)*(conductance)
C    n   (    0,    0)    2      515   TNKNRM   = normalizing empty tank mass
C    n   (    0,    0)    2      520   CONNRM   = normalizing total strut conductance
C    n   (    0,    0)    2      530   IPHASE   = IPHASE=1=launch phase; IPHASE=2=orbital phase
C    n   (    0,    0)    2      540   NCASES   = Number of load cases (number of environments)  in
PRESS(NCASES)
C    y   (   20,    0)    3      545   PRESS    = propellant tank ullage pressure
C    y   (   20,    0)    3      550   GAXIAL   = quasi-static axial g-loading
C    y   (   20,    0)    3      555   GLATRL   = quasi-static lateral g-loading
C    y   (   20,    0)    3      560   TNKCOOL  = propellant tank cool-down from cryogen
C    n   (    0,    0)    2      570   JFREQ    = vibration mode type in FREQ(NCASES,JFREQ)
C    y   (   20,    4)    4      575   FREQ     = free vibration frequency (cps)
C    y   (   20,    4)    5      580   FREQA    = minimum allowable frequency (cps)
C    y   (   20,    4)    6      585   FREQF    = factor of safety for freqency
C    n   (    0,    0)    2      595   JSTRES1  = stress component number in STRES1(NCASES,JSTRES1)
C    y   (   20,    6)    4      600   STRES1   = maximum stress in material 1
C    y   (   20,    6)    5      605   STRES1A  = maximum allowable stress in material 1
C    y   (   20,    6)    6      610   STRES1F  = factor of safety for stress, matl 1
C    y   (   20,    6)    4      615   STRES2   = maximum stress in material 2
C    y   (   20,    6)    5      620   STRES2A  = maximum allowable stress in material 2
C    y   (   20,    6)    6      625   STRES2F  = factor of safety for stress, matl 2
C    y   (   20,    6)    4      630   STRES3   = maximum stress in material 3
C    y   (   20,    6)    5      635   STRES3A  = maximum allowable stress in material 3
C    y   (   20,    6)    6      640   STRES3F  = factor of safety for stress, matl 3
C    n   (    0,    0)    2      645   JCOLBUK  = strut set number (1 for aft-most set) in
COLBUK(NCASES,JCOLBUK)
C    y   (   20,    3)    4      650   COLBUK   = buckling of a strut as a column
C    y   (   20,    3)    5      655   COLBUKA  = allowable for column buckling of strut
C    y   (   20,    3)    6      660   COLBUKF  = factor of safety for Euler strut buckling
C    y   (   20,    3)    4      665   SHLBUK   = buckling of strut as a shell
C    y   (   20,    3)    5      670   SHLBUKA  = allowable for shell buckling of strut
C    y   (   20,    3)    6      675   SHLBUKF  = factor of safety for shell buckling of strut
C    y   (   20,    3)    4      680   FORCE    = launch-hold force in a strut
C    y   (   20,    3)    5      685   FORCEA   = maximum allowable launch-hold force in strut
```

```
C    y   (  20,   3)    6     690   FORCEF   = factor of safety for launch-hold force
C    y   (  20,   3)    4     695   TNKSTR   = maximum stress in the propellant tank
C    y   (  20,   3)    5     700   TNKSTRA  = allowable for propellant tank stress
C    y   (  20,   3)    6     705   TNKSTRF  = factor of safety for tank stress
C    y   (  20,   3)    4     710   TNKBUK   = propellant tank buckling load factor
C    y   (  20,   3)    5     715   TNKBUKA  = allowable for propellant tank buckling
C    y   (  20,   3)    6     720   TNKBUKF  = factor of safety for tank buckling
C    n   (   0,   0)    7     730   CONDCT   = WGTxTOTMAS/TNKNRM +(1-WGT)xCONDCT/CONNRM
C===============================================================
```

Table 4 Input data for the GENOPT processor, BEGIN (test.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
       2        $ Number IZTANK  of rows in the array  ZTANK: IZTANK
     150        $ global axial coordinate of tank support ring: ZTANK(  1)
     450        $ global axial coordinate of tank support ring: ZTANK(  2)
      50        $ global axial coordinate of "ground": ZGRND(  1)
     550        $ global axial coordinate of "ground": ZGRND(  2)
       1        $ type of strut arrangement: STRTYP(  1)
       2        $ type of strut arrangement: STRTYP(  2)
       2        $ Number INPAIRS of rows in the array  NPAIRS: INPAIRS
       4        $ number of strut pairs: NPAIRS(  1)
       4        $ number of strut pairs: NPAIRS(  2)
       5        $ length of end fitting attached to tank ring: FITTNK(  1)
       5        $ length of end fitting attached to tank ring: FITTNK(  2)
  0.1000000E+08 $ axial "EA" stiffness of tank-end strut fitting: FEATNK(  1)
  0.1000000E+08 $ axial "EA" stiffness of tank-end strut fitting: FEATNK(  2)
  0.1000000E-04 $ Coef.of thermal expansion of tank end fitting: ALFITT(  1)
  0.1000000E-04 $ Coef.of thermal expansion of tank end fitting: ALFITT(  2)
       5        $ length of strut end fitting attached to "ground": FITVEH(  1)
       5        $ length of strut end fitting attached to "ground": FITVEH(  2)
  0.1000000E+08 $ axial "EA" stiffness of "ground" end strut fitting: FEAVEH(  1)
  0.1000000E+08 $ axial "EA" stiffness of "ground" end strut fitting: FEAVEH(  2)
```

```
0.1000000E-04 $ coef.of thermal expan. of "ground" end fitting: ALFITV(  1)
0.1000000E-04 $ coef.of thermal expan. of "ground" end fitting: ALFITV(  2)
      10      $ circ.angle (deg.) to pinned tank end of strut: ATANK(  1)
      10      $ circ.angle (deg.) to pinned tank end of strut: ATANK(  2)
      25      $ circ.angle to pinned "ground" end of strut: AGRND(  1)
      25      $ circ.angle to pinned "ground" end of strut: AGRND(  2)
       5      $ inner diam. of support tube active at launch: IDTUBE(  1)
       5      $ inner diam. of support tube active at launch: IDTUBE(  2)
0.1000000     $ length factor for strut buckling as a shell: FACLEN(  1)
0.1000000     $ length factor for strut buckling as a shell: FACLEN(  2)
    -100      $ Average strut temperature minus ambient: DTSUP(  1)
    -100      $ Average strut temperature minus ambient: DTSUP(  2)
       2      $ outer diam.of the orbital tube assembly: ODINNR(  1)
       2      $ outer diam.of the orbital tube assembly: ODINNR(  2)
       4      $ Length of the orbital tube assembly: FLINNR(  1)
       4      $ Length of the orbital tube assembly: FLINNR(  2)
       1      $ Choose 1 or 2 tubes in the orbital tube assembly: NTUBES
       1      $ index for simple strut (1), "PODS" strut (2): ISTRUT
       1      $ type of wall constructions in strut type STRTYP: WALTYP(  1)
       2      $ type of wall constructions in strut type STRTYP: WALTYP(  2)
 0.000001     $ height of mid-tank T-ring web: WEBHI
 0.000001     $ thickness of mid-tank T-ring web: WEBTHK
 0.000001     $ width (height) of mid-tank T-ring flange: FLGHI
 0.000001     $ thickness of mid-tank T-ring flange: FLGTHK
       1      $ propellant tank reinforcement type: RNGTYP(  1)
       1      $ propellant tank reinforcement type: RNGTYP(  2)
       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)
      12      $ Number ITHICK  of rows in the array  THICK: ITHICK
0.1000000     $ thickness of a lamina: THICK(  1)
0.1000000     $ thickness of a lamina: THICK(  2)
0.1000000     $ thickness of a lamina: THICK(  3)
0.1000000     $ thickness of a lamina: THICK(  4)
0.1000000     $ thickness of a lamina: THICK(  5)
0.1000000     $ thickness of a lamina: THICK(  6)
0.1000000     $ thickness of a lamina: THICK(  7)
0.1000000     $ thickness of a lamina: THICK(  8)
0.1000000     $ thickness of a lamina: THICK(  9)
0.1000000     $ thickness of a lamina: THICK( 10)
0.1000000     $ thickness of a lamina: THICK( 11)
0.1000000     $ thickness of a lamina: THICK( 12)
      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)
      45      $ layup angle: ANGLE(  7)
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      -45      $ layup angle: ANGLE(  8)
       45      $ layup angle: ANGLE(  9)
      -45      $ layup angle: ANGLE( 10)
       45      $ layup angle: ANGLE( 11)
      -45      $ layup angle: ANGLE( 12)
        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      $ Material type: MATTYP(  7)
        1      $ Material type: MATTYP(  8)
        1      $ Material type: MATTYP(  9)
        1      $ Material type: MATTYP( 10)
        1      $ Material type: MATTYP( 11)
        1      $ Material type: MATTYP( 12)
        2      $ 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)
       12      $ Number ILAYTYP of rows in this column of LAYTYP: ILAYTYP
        7      $ layer type index: LAYTYP(  1,  2)
        8      $ layer type index: LAYTYP(  2,  2)
        9      $ layer type index: LAYTYP(  3,  2)
       10      $ layer type index: LAYTYP(  4,  2)
       11      $ layer type index: LAYTYP(  5,  2)
       12      $ layer type index: LAYTYP(  6,  2)
       12      $ layer type index: LAYTYP(  7,  2)
       11      $ layer type index: LAYTYP(  8,  2)
       10      $ layer type index: LAYTYP(  9,  2)
        9      $ layer type index: LAYTYP( 10,  2)
        8      $ layer type index: LAYTYP( 11,  2)
        7      $ layer type index: LAYTYP( 12,  2)
        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)
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    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 strut conductance: CONNRM
      1       $ IPHASE=1=launch phase; IPHASE=2=orbital phase: IPHASE
      2       $ Number NCASES  of load cases (environments): NCASES
 25.00000     $ propellant tank ullage pressure: PRESS(  1)
 25.00000     $ 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)
-200.0000     $ propellant tank cool-down from cryogen: TNKCOOL(  1)
-200.0000     $ 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)
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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)
 140571       $ maximum allowable stress in material 3: STRES3A(  1,  1)
 140571       $ maximum allowable stress in material 3: STRES3A(  2,  1)
 104714       $ maximum allowable stress in material 3: STRES3A(  1,  2)
 104714       $ maximum allowable stress in material 3: STRES3A(  2,  2)
  10557       $ maximum allowable stress in material 3: STRES3A(  1,  3)
  10557       $ maximum allowable stress in material 3: STRES3A(  2,  3)
  14529       $ maximum allowable stress in material 3: STRES3A(  1,  4)
  14529       $ maximum allowable stress in material 3: STRES3A(  2,  4)
   6290       $ maximum allowable stress in material 3: STRES3A(  1,  5)
   6290       $ maximum allowable stress in material 3: STRES3A(  2,  5)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  1)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  1)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  2)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  2)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  3)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  3)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  4)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  4)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  5)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  5)
      2       $ Number JCOLBUK of columns in the array, COLBUK: JCOLBUK
      1       $ allowable for column buckling of strut: COLBUKA(  1,  1)
      1       $ allowable for column buckling of strut: COLBUKA(  2,  1)
      1       $ allowable for column buckling of strut: COLBUKA(  1,  2)
      1       $ allowable for column buckling of strut: COLBUKA(  2,  2)
      1       $ factor of safety for Euler strut buckling: COLBUKF(  1,  1)
      1       $ factor of safety for Euler strut buckling: COLBUKF(  2,  1)
      1       $ factor of safety for Euler strut buckling: COLBUKF(  1,  2)
      1       $ factor of safety for Euler strut buckling: COLBUKF(  2,  2)
      1       $ allowable for shell buckling of strut: SHLBUKA(  1,  1)
      1       $ allowable for shell buckling of strut: SHLBUKA(  2,  1)
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        1       $ allowable for shell buckling of strut: SHLBUKA(  1,  2)
        1       $ allowable for shell buckling of strut: SHLBUKA(  2,  2)
        2       $ factor of safety for shell buckling of strut: SHLBUKF(  1,  1)
        2       $ factor of safety for shell buckling of strut: SHLBUKF(  2,  1)
        2       $ factor of safety for shell buckling of strut: SHLBUKF(  1,  2)
        2       $ factor of safety for shell buckling of strut: SHLBUKF(  2,  2)
    15000       $ maximum allowable launch-hold force in strut: FORCEA(  1,  1)
    15000       $ maximum allowable launch-hold force in strut: FORCEA(  2,  1)
    15000       $ maximum allowable launch-hold force in strut: FORCEA(  1,  2)
    15000       $ maximum allowable launch-hold force in strut: 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)
   50000.00     $ allowable for propellant tank stress: TNKSTRA(  1,  1)
   50000.00     $ allowable for propellant tank stress: TNKSTRA(  2,  1)
   50000.00     $ allowable for propellant tank stress: TNKSTRA(  1,  2)
   50000.00     $ 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)
===========================================================================
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Table 5 Input data for the GENOPT processor, DECIDE (test.DEC file) (These data are provided by the End user for the specific case, "test")

```
=====================================================================
     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)
  0.4000000     $ 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) ?
        5      $ 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) ?
        8      $ 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) ?
       12      $ Choose a decision variable (1,2,3,...)
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      20        $ Lower bound of variable no.( 12)
     140        $ Upper bound of variable no.( 12)
    N           $ Do you want especially to restrict variable no.( 12)
    Y           $ Any more decision variables (Y or N) ?
      13        $ Choose a decision variable (1,2,3,...)
     475        $ Lower bound of variable no.( 13)
     650        $ 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,...)
  6.000000      $ Lower bound of variable no.( 14)
      20        $ Upper bound of variable no.( 14)
    N           $ Do you want especially to restrict variable no.( 14)
    Y           $ Any more decision variables (Y or N) ?
      15        $ Choose a decision variable (1,2,3,...)
       6        $ Lower bound of variable no.( 15)
      20        $ Upper bound of variable no.( 15)
    N           $ Do you want especially to restrict variable no.( 15)
    Y           $ Any more decision variables (Y or N) ?
      16        $ Choose a decision variable (1,2,3,...)
      25        $ Lower bound of variable no.( 16)
      45        $ 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,...)
      25        $ Lower bound of variable no.( 17)
      45        $ 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        $ Lower bound of variable no.( 18)
      20        $ 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,...)
       2        $ Lower bound of variable no.( 19)
      20        $ Upper bound of variable no.( 19)
    N           $ Do you want especially to restrict variable no.( 19)
    Y           $ Any more decision variables (Y or N) ?
      25        $ Choose a decision variable (1,2,3,...)
 0.2000000E-01 $ Lower bound of variable no.( 21)
  2.000000      $ Upper bound of variable no.( 21)
    N           $ Do you want especially to restrict variable no.( 21)
    Y           $ Any more decision variables (Y or N) ?
      26        $ Choose a decision variable (1,2,3,...)
 0.0500000      $ Lower bound of variable no.( 22)
  2.000000      $ Upper bound of variable no.( 22)
    N           $ Do you want especially to restrict variable no.( 22)
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    Y          $ Any more decision variables (Y or N) ?
      28       $ Choose a decision variable (1,2,3,...)
0.5000000E-02 $ Lower bound of variable no.( 24)
0.2000000      $ Upper bound of variable no.( 24)
    N          $ Do you want especially to restrict variable no.( 24)
    Y          $ Any more decision variables (Y or N) ?
      34       $ Choose a decision variable (1,2,3,...)
0.5000000E-02 $ Lower bound of variable no.( 30)
0.2000000      $ Upper bound of variable no.( 30)
    N          $ Do you want especially to restrict variable no.( 30)
    Y          $ Any more decision variables (Y or N) ?
      40       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 36)
      80       $ Upper bound of variable no.( 36)
    Y          $ Do you want especially to restrict variable no.( 36)
       2       $ Maximum permitted change in variable no.( 36)
    Y          $ Any more decision variables (Y or N) ?
      42       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 38)
      80       $ Upper bound of variable no.( 38)
    Y          $ Do you want especially to restrict variable no.( 38)
       2       $ Maximum permitted change in variable no.( 38)
    Y          $ Any more decision variables (Y or N) ?
      44       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 40)
      80       $ Upper bound of variable no.( 40)
    Y          $ Do you want especially to restrict variable no.( 40)
       2       $ Maximum permitted change in variable no.( 40)
    Y          $ Any more decision variables (Y or N) ?
      46       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 42)
      80       $ Upper bound of variable no.( 42)
    Y          $ Do you want especially to restrict variable no.( 42)
       2       $ Maximum permitted change in variable no.( 42)
    Y          $ Any more decision variables (Y or N) ?
      48       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 44)
      80       $ Upper bound of variable no.( 44)
    Y          $ Do you want especially to restrict variable no.( 44)
       2       $ Maximum permitted change in variable no.( 44)
    Y          $ Any more decision variables (Y or N) ?
      50       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 46)
      80       $ Upper bound of variable no.( 46)
    Y          $ Do you want especially to restrict variable no.( 46)
       2       $ Maximum permitted change in variable no.( 46)
    N          $ Any more decision variables (Y or N) ?
    Y          $ Any linked variables (Y or N) ?
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    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) ?
   27        $ Choose a linked variable (1,2,3,...)
    1        $ Choose type of linking (1=polynomial; 2=user-defined)
   26        $ 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) ?
   29        $ Choose a linked variable (1,2,3,...)
    1        $ Choose type of linking (1=polynomial; 2=user-defined)
   28        $ 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) ?
   30        $ Choose a linked variable (1,2,3,...)
    1        $ Choose type of linking (1=polynomial; 2=user-defined)
   28        $ 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)
   28        $ 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) ?
   32        $ Choose a linked variable (1,2,3,...)
    1        $ Choose type of linking (1=polynomial; 2=user-defined)
   28        $ 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) ?
```

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   33      $ Choose a linked variable (1,2,3,...)
    1      $ Choose type of linking (1=polynomial; 2=user-defined)
   28      $ 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?
Y          $ Any more linked variables (Y or N) ?
   36      $ 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?
Y          $ Any more linked variables (Y or N) ?
   37      $ 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?
Y          $ Any more linked variables (Y or N) ?
   38      $ 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?
Y          $ Any more linked variables (Y or N) ?
   39      $ 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?
Y          $ Any more linked variables (Y or N) ?
```

```
  41      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  40      $ 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) ?
  43      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  42      $ 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) ?
  45      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  44      $ 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) ?
  47      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  46      $ 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) ?
  49      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  48      $ 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) ?
  51      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  50      $ 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 6 Input data for the GENOPT processor, MAINSETUP (test.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
   0       $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
   1       $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
   5       $ How many design iterations in this run (3 to 25)?
N          $ Take "shortcuts" for perturbed designs (Y or N)?
   2       $ Choose 1 or 2 or 3 or 4 or 5 for IDESIGN
   1       $ Choose 1 or 2 or 3 or 4 or 5 for move limits, IMOVE
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 7 Input data for the GENOPT processor, MAINSETUP (test.OPT file), for a case in which design sensitivity (ITYPE=3) is being studied (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
   0       $ NPRINT= output index (0=GOOD, 1=ok, 2=debug, 3=too much)
   3       $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
  50       $ Choose a design variable (1, 2, 3, ...), IBVAR
 0.00      $ Starting value of the design parameter, VARBEG
 90.0      $ Ending value of the design parameter, VAREND
Y          $ Do you want to use the default for the number of steps?
===================================================================
```

The input data listed in this example, that is, the choice of "50" for the design variable, would lead to the plot given in Fig. 53old if the GENOPT/BIGBOSOR4, behavior.tank, bosdec.tank, and bosdec.density.var software had not been updated.

Table 8 Output from the GENOPT processor, OPTIMIZE, for a fixed, optimized design: the optimum design found with use of the "temporary" versions of bosdec (bosdec.density.var) and addbosor4 (addbosor4.density.var). The specific case is called "test" (long propellant tank with aft and forward sets of struts, 4 strut pairs per set. (test.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  test.OPT  FILE ***********
 ************ AUGUST, 2010 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  test.OPM  FILE *********


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




 STRUCTURAL ANALYSIS FOR DESIGN ITERATION NO.   0:
0
  STRUCTURAL ANALYSIS WITH UNPERTURBED DECISION VARIABLES
 VAR. DEC. ESCAPE LINK. LINKED  LINKING   LOWER     CURRENT    UPPER       DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT   BOUND      VALUE     BOUND
   1   Y     N     N      0    0.00E+00  2.00E-02 5.1880E-02  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 4.5270E-02  4.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 5.3200E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 3.6390E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   Y     N     N      0    0.00E+00  3.00E+00 4.4460E+00  1.00E+01  spacing of the
tank orthogrid rings: RNGSPC
```

```
   6   Y     N     N      0    0.00E+00  1.00E-01 1.0280E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
   7   Y     N     N      0    0.00E+00  2.00E-01 9.8060E-01  1.00E+00  height of the
tank orthogrid stringers: STRHI
   8   Y     N     N      0    0.00E+00  1.00E-01 1.7620E-01  1.00E+00  thickness of the
tank orthogrid rings: RNGTHK
   9   N     N     Y      7    1.00E+00  0.00E+00 9.8060E-01  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 1.5000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   N     N     N      0    0.00E+00  0.00E+00 4.5000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(2 )
  12   Y     N     N      0    0.00E+00  2.00E+01 8.9390E+01  1.40E+02  global axial
coordinate of "ground": ZGRND(1 )
  13   Y     N     N      0    0.00E+00  4.75E+02 5.0850E+02  6.50E+02  global axial
coordinate of "ground": ZGRND(2 )
  14   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(1 )
  15   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(2 )
  16   Y     N     N      0    0.00E+00  2.50E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(1 )
  17   Y     N     N      0    0.00E+00  2.50E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(2 )
  18   Y     N     N      0    0.00E+00  2.00E+00 6.7530E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(1 )
  19   Y     N     N      0    0.00E+00  2.00E+00 6.8560E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(2 )
  20   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  height of mid-
tank T-ring web: WEBHI
  21   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring web: WEBTHK
  22   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  width (height) of
mid-tank T-ring flange: FLGHI
  23   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring flange: FLGTHK
  24   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 )
  25   Y     N     N      0    0.00E+00  2.00E-02 8.5550E-01  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  26   Y     N     N      0    0.00E+00  5.00E-02 3.4980E-01  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  27   N     N     Y     26    5.00E+00  0.00E+00 1.7490E+00  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
  28   Y     Y     N      0    0.00E+00  5.00E-03 7.2710E-03  2.00E-01  thickness of a
lamina: THICK(1 )
  29   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  30   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  31   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(4 )
  32   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  33   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  34   Y     Y     N      0    0.00E+00  5.00E-03 7.2500E-03  2.00E-01  thickness of a
lamina: THICK(7 )
```

```
  35   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(8 )
  36   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(9 )
  37   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(10)
  38   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(11)
  39   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(12)
  40   Y     N     N      0    0.00E+00  1.00E+01 1.9920E+01  8.00E+01  layup angle:
ANGLE(1 )
  41   N     N     Y     40   -1.00E+00  0.00E+00-1.9920E+01  0.00E+00  layup angle:
ANGLE(2 )
  42   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(3 )
  43   N     N     Y     42   -1.00E+00  0.00E+00-1.0000E+01  0.00E+00  layup angle:
ANGLE(4 )
  44   Y     N     N      0    0.00E+00  1.00E+01 6.0420E+01  8.00E+01  layup angle:
ANGLE(5 )
  45   N     N     Y     44   -1.00E+00  0.00E+00-6.0420E+01  0.00E+00  layup angle:
ANGLE(6 )
  46   Y     N     N      0    0.00E+00  1.00E+01 1.5370E+01  8.00E+01  layup angle:
ANGLE(7 )
  47   N     N     Y     46   -1.00E+00  0.00E+00-1.5370E+01  0.00E+00  layup angle:
ANGLE(8 )
  48   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(9 )
  49   N     N     Y     48   -1.00E+00  0.00E+00-1.0000E+01  0.00E+00  layup angle:
ANGLE(10)
  50   Y     N     N      0    0.00E+00  1.00E+01 6.4480E+01  8.00E+01  layup angle:
ANGLE(11)
  51   N     N     Y     50   -1.00E+00  0.00E+00-6.4480E+01  0.00E+00  layup angle:
ANGLE(12)
  BEHAVIOR FOR  1 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 1
 Name of case= test                             ; ITYPEX=  2

 CHAPTER 1 (BEHX01x, x = 1,2,...; x=load case):
 Find the lengths of struts and the axial loads in the
 struts from a BIGBOSOR4 model of the propellant tank
 supported by springs with an arbitrarily assigned spring
 constant. The flexibility of the propellant tank is
 neglected, the strut end fittings are neglected, and the
 propellant tank is loaded by ullage pressure, PRESS, tank
 cool-down, TNKCOOL, axial acceleration, GAXIAL, and lateral
 acceleration, GLATRL. This is a first approximation.
 The BIGBOSOR4 model is stored in *.BEHX01x, x = 1, 2...,
 in which "x" represents the load case.


 BIGBOSOR4 input file for propellant tank supported by struts; Load Case 1
test.BEHX011
```

```
Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 9.5041E+03  9.5042E+03  9.5041E+03  9.5041E+03  9.5041E+03
 9.5041E+03  9.5042E+03  9.5042E+03
Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 9.5041E-03  9.5042E-03  9.5041E-03  9.5041E-03  9.5041E-03
 9.5041E-03  9.5042E-03  9.5042E-03

Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
 9.0626E+04  9.0626E+04  9.0626E+04  9.0626E+04  9.0626E+04
 9.0626E+04  9.0626E+04  9.0626E+04
Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
 9.0626E-02  9.0626E-02  9.0626E-02  9.0626E-02  9.0626E-02
 9.0626E-02  9.0626E-02  9.0626E-02

Length of strut, max. load, min. load for strut type 1; strut ring no.  1
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1327E+02  9.5042E+03  0.0000E+00

Length of strut, max. load, min. load for strut type 2; strut ring no.  2
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1216E+02  9.0626E+04  0.0000E+00
```

CHAPTER 2:
Optain PostScript plot files, *.PL6.ps, *.PL7.ps, *.PL8.ps, which contain a plan view of the AFT set of struts (*.PL6.ps), a plan view of the FORWARD set of struts (*.PL7.ps, if any), and an elevation view of both AFT and FORWARD sets of struts (*.PL8.ps). The FORTRAN software is "borrowed" from the "DEWAR" system (SUBROUTINE STPLOT and the subroutines called by STPLOT). These FORTRAN subroutines are part of the bosdec.tank library.

CHAPTER 3 (BEHX02x, x=1,2,...; x=load case):
1. Fill the "DEWAR" labelled common blocks with the proper quantities so that buckling load factors of the strut launch tubes (buckling as thin shells) and so that the 5 stress components in composite laminate plies can be determined from "PANDA-type" of analyses similar to those analyses that are used in the "DEWAR" system for buckling and stress of the strut launch tubes.

2. Compute from SUBROUTINE GETCIJ the 6 x 6 constitutive stiffness matrix for each type of strut tube. SUBROUTINE GETCIJ is very like a subroutine of the same name in PANDA2.

3. Find the axial stiffnesses of aft and forward strut tubes. These strut tube stiffnesses are to be used in the computation of spring constants associated with each strut in the AFT set of struts and associated with each strut in the FORWARD set of struts (if any). In the "DO 20" loop of SUBROUTINE STRUCT, I = 1 corresponds to the AFT set of struts and I = 2 corresponds to the FORWARD set of struts.

Composite laminate layup of the wall of strut tube type 1

```
 WALL PROPERTIES. . .
 AFT/ TYPE TUBE    LAYER  LAYER  THICKNESS   WINDING     MATERAL    CRACKING
 FWD        NO.     NO.   TYPE                ANGLE       TYPE       RATIO

 AFT  TUBE   1       1      1   7.2710E-03  1.9920E+01     1         1.0000E+00
 AFT  TUBE   1       2      2   7.2710E-03 -1.9920E+01     1         1.0000E+00
 AFT  TUBE   1       3      3   7.2710E-03  1.0000E+01     1         1.0000E+00
 AFT  TUBE   1       4      4   7.2710E-03 -1.0000E+01     1         1.0000E+00
 AFT  TUBE   1       5      5   7.2710E-03  6.0420E+01     1         1.0000E+00
 AFT  TUBE   1       6      6   7.2710E-03 -6.0420E+01     1         1.0000E+00
 AFT  TUBE   1       7      6   7.2710E-03 -6.0420E+01     1         1.0000E+00
 AFT  TUBE   1       8      5   7.2710E-03  6.0420E+01     1         1.0000E+00
 AFT  TUBE   1       9      4   7.2710E-03 -1.0000E+01     1         1.0000E+00
 AFT  TUBE   1      10      3   7.2710E-03  1.0000E+01     1         1.0000E+00
 AFT  TUBE   1      11      2   7.2710E-03 -1.9920E+01     1         1.0000E+00
 AFT  TUBE   1      12      1   7.2710E-03  1.9920E+01     1         1.0000E+00


 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 1

           COMPOUND SUPPORT TUBE NO. 1:   AFT LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  1.1570E+06  2.1778E+05  0.0000E+00  4.8828E-04  2.4414E-04  1.2207E-04     -5.4605E+02
-3.1910E-04
  2.1778E+05  4.7805E+05  0.0000E+00  3.6621E-04  4.8828E-04  0.0000E+00     -4.5773E+02
-8.1213E-04
  0.0000E+00  0.0000E+00  2.3458E+05  0.0000E+00  3.0518E-05  2.4414E-04      0.0000E+00
-2.4620E-19
  4.8828E-04  3.6621E-04  0.0000E+00  9.5205E+02  1.1835E+02  6.0078E+01     -9.5367E-07
1.6157E-10
  2.4414E-04  4.8828E-04  3.0518E-05  1.1835E+02  1.2484E+02  1.6337E+01     -1.1921E-06
-6.0313E-09
  1.2207E-04  0.0000E+00  2.4414E-04  6.0078E+01  1.6337E+01  1.2901E+02      0.0000E+00
9.9047E-10


 BIGBOSOR4 input file for Load Case 1:
 axial stiffness of a single launch tube, type 1
test.BEHX021

 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  1.1570E+06  2.1778E+05  4.7805E+05
 C111MD=axial stiffness/circ.length of launch tube type  1
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  1.0577E+06
 Launch tube "EA" and length and "spring constant" for tube type  1
   = TUBEEA,TUBLNG,TUBEK =  2.2730E+07  1.0327E+02  2.2010E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  1 =  1.8040E+05
 The flexibility of the propellant tank is neglected in the
 model that yields SPRCON. See below for model that includes
 the flexibility of the propellant tank and that yields FKTOTL

 Conductance of one strut of type  1 =  1.1615E-04

 Composite laminate layup of the wall of strut tube type 2
```

```
 WALL PROPERTIES. . .
 AFT/ TYPE TUBE   LAYER  LAYER  THICKNESS   WINDING     MATERAL    CRACKING
 FWD        NO.    NO.   TYPE                ANGLE       TYPE       RATIO

 FWD  TUBE   1      1      7   7.2500E-03  1.5370E+01     1         1.0000E+00
 FWD  TUBE   1      2      8   7.2500E-03 -1.5370E+01     1         1.0000E+00
 FWD  TUBE   1      3      9   7.2500E-03  1.0000E+01     1         1.0000E+00
 FWD  TUBE   1      4     10   7.2500E-03 -1.0000E+01     1         1.0000E+00
 FWD  TUBE   1      5     11   7.2500E-03  6.4480E+01     1         1.0000E+00
 FWD  TUBE   1      6     12   7.2500E-03 -6.4480E+01     1         1.0000E+00
 FWD  TUBE   1      7     12   7.2500E-03 -6.4480E+01     1         1.0000E+00
 FWD  TUBE   1      8     11   7.2500E-03  6.4480E+01     1         1.0000E+00
 FWD  TUBE   1      9     10   7.2500E-03 -1.0000E+01     1         1.0000E+00
 FWD  TUBE   1     10      9   7.2500E-03  1.0000E+01     1         1.0000E+00
 FWD  TUBE   1     11      8   7.2500E-03 -1.5370E+01     1         1.0000E+00
 FWD  TUBE   1     12      7   7.2500E-03  1.5370E+01     1         1.0000E+00


 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 2

           COMPOUND SUPPORT TUBE NO. 1:   FWD LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  1.1856E+06  1.7820E+05  0.0000E+00  4.8828E-03  7.9346E-04  1.2207E-04     -5.4357E+02
-3.4459E-04
  1.7820E+05  5.2255E+05  0.0000E+00  7.9346E-04  2.4109E-03 -4.5776E-05     -4.5731E+02
-7.5764E-04
  0.0000E+00  0.0000E+00  1.9496E+05  1.2207E-04 -4.5776E-05  9.1553E-04      0.0000E+00
-1.1045E-18
  4.8828E-03  7.9346E-04  1.2207E-04  1.0048E+03  8.8580E+01  5.1870E+01     -2.6226E-06
-3.3702E-10
  7.9346E-04  2.4109E-03 -4.5776E-05  8.8580E+01  1.2024E+02  1.3038E+01     -2.1458E-06
-1.6177E-10
  1.2207E-04 -4.5776E-05  9.1553E-04  5.1870E+01  1.3038E+01  9.9150E+01      0.0000E+00
2.7204E-10

 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  1.1856E+06  1.7820E+05  5.2255E+05
 C111MD=axial stiffness/circ.length of launch tube type  2
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  1.1249E+06
 Launch tube "EA" and length and "spring constant" for tube type  2
   = TUBEEA,TUBLNG,TUBEK =  2.4535E+07  1.0216E+02  2.4018E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  2 =  1.9366E+05
 The flexibility of the propellant tank is neglected in the
 model that yields SPRCON. See below for model that includes
 the flexibility of the propellant tank and that yields FKTOTL

 Conductance of one strut of type  2 =  1.1862E-04

 CHAPTER 4 (BEHX03x, x = 1,2,...; x=load case):
 Compute the linear static response of the propellant tank
 to concentrated loads applied by the struts (springs) to
 the tank along the tank support ring no. 1 (aft strut set)
 and along the tank support ring no. 2 (forward strut set).
 In this BIGBSOSOR4 model of the propellant tank the springs
 (struts) are replaced by concentrated loads obtained from
 the CHAPTER 1 computations. The concentrated loads are modeled
```

in BIGBOSOR4 as line loads with little triangular "pulses" centered about the circumferential angles where the struts are pinned to the propellant tank and at the global axial coordinates that corresponds to the global axial coordinates of the centroids of the aft and forward propellant tank support rings. The circumferential distributions of the line loads are expanded in Fourier series, and the static response to each Fourier component is superposed by BIGBOSOR4 in what is called in BIGBOSOR4 jargon an "INDIC=3" type of analysis. Sixty Fourier terms are used in the Fourier series expansion.

The purpose of this calculation is to find the maximum displacement of the propellant tank wall in the same direction as the axis of one of the struts: 1. the strut associated with the greatest tank wall displacement produced by the AFT strut set and 2. the strut associated with the greatest tank wall displacement produced by the FORWARD strut set. These two maximum local tank wall displacements are used in the determination of the spring constants to be associated with each of the AFT struts and with each of the FORWARD struts in the models in which the flexibility of the propellant tank is accounted for in the computation of the behavior(e.g.vibration)

In this BIGBOSOR4 model there exist "fake" springs, that is, springs with zero axial stiffness. These "fake" springs have no influence on the behavior.

```
 BIGBOSOR4 input file, Load Case 1, for the propellant tank with springs replaced by
concentrated loads (INDX=5)
test.BEHX031

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 -0.0000E+00 -0.0000E+00 -0.0000E+00 -0.0000E+00 -0.0000E+00
 -0.0000E+00 -0.0000E+00 -0.0000E+00
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 -5.6982E-02 -5.6984E-02 -5.6982E-02 -5.6983E-02 -5.6983E-02
 -5.6982E-02 -5.6984E-02 -5.6982E-02
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  6.0000E+00

 Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
 -0.0000E+00 -0.0000E+00 -0.0000E+00 -0.0000E+00 -0.0000E+00
 -0.0000E+00 -0.0000E+00 -0.0000E+00
 Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
 -1.9142E-01 -1.9142E-01 -1.9141E-01 -1.9142E-01 -1.9142E-01
 -1.9141E-01 -1.9142E-01 -1.9142E-01
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  2. Circumferential angle =  6.0000E+00
```

```
Absolute value of maximum "change in length" of any strut at strut ring no.  1
DISMAX(JRING)=  5.6984E-02
DISMAX is used in the derivation of the strut spring
constant, FKTOTL, that accounts for the flexibility of the
propellant tank.

Absolute value of maximum "change in length" of any strut at strut ring no.  2
DISMAX(JRING)=  1.9142E-01
DISMAX is used in the derivation of the strut spring
constant, FKTOTL, that accounts for the flexibility of the
propellant tank.

Spring constant at ring no.  1: FKTOTL(JRING)=  8.6663E+04
The reduced spring constant, FKTOTL, includes the flexibility
of the propellant tank. Compare with the spring constant
SPRCON=  1.8040E+05 which is the value of the spring
constant obtained neglecting the propellant tank flexibility.

Spring constant at ring no.  2: FKTOTL(JRING)=  1.3744E+05
The reduced spring constant, FKTOTL, includes the flexibility
of the propellant tank. Compare with the spring constant
SPRCON=  1.9366E+05 which is the value of the spring
constant obtained neglecting the propellant tank flexibility.

CHAPTER 5 (BEHX04x, x = 1, 2,...; x = load case):
Repeat the CHAPTER 1 type of computations with the new
(significantly smaller) spring constants that now account
for the flexibility of the propellant tank. The purpose of
this computation is to determine more accurate values of the
loads in each strut (spring) caused by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL. The updated strut loads are
used in the following computations:
1. Buckling of the most highly compressed strut of each type
(type 1 = "AFT"; type 2 = "FORWARD") as a column (BEHX5) and
as a shell (BEHX6).
2. Maximum of each of five stress components in each type
of strut (BEHX2 for AFT struts and BEHX3 for FORWARD struts).
3. Maximum stress in the propellant tank due to loading by
the AFT and FORWARD sets of struts and by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL (BEHX8).
4. Minimum buckling of the propellant tank under the AFT and
FORWARD sets of struts and by the loads, PRESS, GAXIAL,
GLATRL, and TNKCOOL (BEHX9).


BIGBOSOR4 input file for propellant tank under
Load Case 1 supported by struts (second approximation)
test.BEHX041

Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
-2.3729E+04 -2.3729E+04 -2.3729E+04 -2.3729E+04 -2.3729E+04
-2.3729E+04 -2.3729E+04 -2.3729E+04
Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
-2.7381E-01 -2.7381E-01 -2.7381E-01 -2.7381E-01 -2.7381E-01
-2.7381E-01 -2.7381E-01 -2.7381E-01
```

```
NOTE: The changes in axial length, SPRDLG, just listed
are significantly greater than those listed previously
because the springs are softer in this "BEHX04*" model
than those in the "BEHX01*" model, NOT because there is
more local deformation of the tank under these spring
loads. The change in length of the "effective" spring
caused by local deformation of the propellant tank is
listed above as the quantity called "DISMAX", which is
computed from the "BEHX03*" model in which the springs
are replaced by concentrated loads acting on the tank.

Circ. angle where the maximum concentrated AXIAL load is
applied to the propellant tank by the struts at the tank
support ring no.  1. Circumferential angle =  6.0000E+00
Minimum load in a strut (NSPTOT,KSTMIN,ANGMIN):
Ring Number  1: Strut no.  1; Circ. angle to strut=  6.0000E+00
Strut type =  1; CIRCANG(ITYPE)=  6.0000E+00

Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
 5.6533E+04  5.6533E+04  5.6533E+04  5.6533E+04  5.6533E+04
 5.6533E+04  5.6533E+04  5.6533E+04
Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
 4.1132E-01  4.1132E-01  4.1132E-01  4.1132E-01  4.1132E-01
 4.1132E-01  4.1132E-01  4.1132E-01
NOTE: The changes in axial length, SPRDLG, just listed
are significantly greater than those listed previously
because the springs are softer in this "BEHX04*" model
than those in the "BEHX01*" model, NOT because there is
more local deformation of the tank under these spring
loads. The change in length of the "effective" spring
caused by local deformation of the propellant tank is
listed above as the quantity called "DISMAX", which is
computed from the "BEHX03*" model in which the springs
are replaced by concentrated loads acting on the tank.

Circ. angle where the maximum concentrated AXIAL load is
applied to the propellant tank by the struts at the tank
support ring no.  2. Circumferential angle =  6.0000E+00

Maximum load in a strut (NSPTOT,KSTMAX,ANGMAX):
Ring Number  2: Strut no.  1; Circ. angle to strut=  6.0000E+00
Strut type =  2; CIRCANG(ITYPE)=  6.0000E+00

Length of strut, max. load, min. load for strut type 1; strut ring no.  1
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1327E+02  0.0000E+00 -2.3729E+04

Length of strut, max. load, min. load for strut type 2; strut ring no.  2
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1216E+02  5.6533E+04  0.0000E+00

 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 springs
(pinned struts) attached. 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
 each set of struts (AFT and FORWARD) are pinned to the tank.
 The strut (spring) stiffness takes into account the
 flexibility of the propellant tank wall.



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

 FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
 Total tank mass including "lumped" propellant, TOTMAS=  8.7338E+01
  1.1899E+01(n= 0 circ.waves)
  1.2029E+01(n= 1 circ.waves)
  1.2754E+01(n= 2 circ.waves)
  1.3330E+01(n= 3 circ.waves)
  1.6997E+01(n= 4 circ.waves)
    1        11.89938      free vibration frequency (cps): FREQ(1 ,1 )
    2        12.02899      free vibration frequency (cps): FREQ(1 ,2 )
    3        12.75356      free vibration frequency (cps): FREQ(1 ,3 )
    4        13.32958      free vibration frequency (cps): FREQ(1 ,4 )

  BEHAVIOR OVER J =  stress component number

 CHAPTER 7: strut stress analysis-BEHX2x, x=1,2; x=load case)
 This is the stress analysis from both BIGBOSOR4 and from
 a PANDA2-type of laminate analysis of the most highly loaded
 strut of the AFT set of struts (struts of type 1). The struts
 are tubes made of composite laminate. The most highly loaded
 strut under both axial tension and equal axial compression is
 analyzed. The tensile/compressive load to which the most
 highly loaded strut is subjected is derived in the computation
 under CHAPTER 5. The five stress "behavioral" constraints
 computed here correspond to:
 1. tension along the fibers of a ply,
 2. compression along the fibers of a ply,
 3. tension transverse to the fibers of a ply,
 4. compression transverse to the fibers of a ply,
 5. in-plane shear stress in a ply.
 Recorded as 5 behavioral constraints are the maximum values
 of each of the five components just listed from tension or
 compression and from a BIGBOSOR4 or a PANDA2-type of model.
 In other words, only the worst (highest) stress component from
 four computations (tension BIGBOSOR4,compression BIGBOSOR4,
 tension PANDA2, compression PANDA2) is recorded as each
 component behavioral constraint.


 BIGBOSOR4 input file for: maximum stress in a  strut of type 1 for load case 1
test.BEHX21

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  4.4172E+03  fiber tension
  8.6833E+03  fiber compres.
  4.2360E+03  transv tension
```

```
 0.0000E+00  transv compres
 3.3453E+02  in-plane shear

BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
 0.0000E+00  fiber tension
 2.3094E+04  fiber compres.
 3.7394E+03  transv tension
 0.0000E+00  transv compres
 8.3157E+02  in-plane shear

STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
Corresponding maximum stress components from PANDA-type model:
 0.0000E+00  tensile fiber
 7.8242E+03  compressive fiber
 3.4373E+03  tensile transverse
 0.0000E+00  compressive transverse
 2.8743E+02  in-plane shear


STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
Corresponding maximum stress components from PANDA-type model:
 0.0000E+00  tensile fiber
 2.1325E+04  compressive fiber
 3.2415E+03  tensile transverse
 0.0000E+00  compressive transverse
 5.9843E+02  in-plane shear

   5        4417.157      maximum stress in material 1: STRES1(1 ,1 )
   6        23093.95      maximum stress in material 1: STRES1(1 ,2 )
   7        4235.962      maximum stress in material 1: STRES1(1 ,3 )
   8       0.1000000E-09  maximum stress in material 1: STRES1(1 ,4 )
   9        831.5734      maximum stress in material 1: STRES1(1 ,5 )

 BEHAVIOR OVER J =  stress component number

CHAPTER 8: strut stress analysis-BEHX3x, x=1,2; x=load case)
This is the stress analysis from both BIGBOSOR4 and from
a PANDA2-type of laminate analysis of the most highly loaded
strut of the FWD set of struts (struts of type 2). The struts
are tubes made of composite laminate. The most highly loaded
strut under both axial tension and equal axial compression is
analyzed. The tensile/compressive load to which the most
highly loaded strut is subjected is derived in the computation
under CHAPTER 5. The five stress "behavioral" constraints
computed here correspond to:
1. tension along the fibers of a ply,
2. compression along the fibers of a ply,
3. tension transverse to the fibers of a ply,
4. compression transverse to the fibers of a ply,
5. in-plane shear stress in a ply.
Recorded as 5 behavioral constraints are the maximum values
of each of the five components just listed from tension or
compression and from a BIGBOSOR4 or a PANDA2-type of model.
In other words, only the worst (highest) stress component from
four computations (tension BIGBOSOR4,compression BIGBOSOR4,
tension PANDA2, compression PANDA2) is recorded as each
component behavioral constraint.
```

```
 BIGBOSOR4 input file for: maximum stress in a strut of type 2 for load case 1
test.BEHX31

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 2 (BEHX3)
  5.2046E+04  fiber tension
  1.2962E+04  fiber compres.
  6.9043E+03  transv tension
  0.0000E+00  transv compres
  1.9294E+03  in-plane shear

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 2 (BEHX3)
  5.0417E+03  fiber tension
  8.4333E+03  fiber compres.
  4.2430E+03  transv tension
  0.0000E+00  transv compres
  2.5734E+02  in-plane shear

 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
 Corresponding maximum stress components from PANDA-type model:
  4.5528E+04  tensile fiber
  1.1229E+04  compressive fiber
  6.1567E+03  tensile transverse
  0.0000E+00  compressive transverse
  1.8495E+03  in-plane shear


 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
 Corresponding maximum stress components from PANDA-type model:
  0.0000E+00  tensile fiber
  7.5825E+03  compressive fiber
  3.4716E+03  tensile transverse
  0.0000E+00  compressive transverse
  2.1808E+02  in-plane shear

   10        52045.89      maximum stress in material 2: STRES2(1 ,1 )
   11        12962.06      maximum stress in material 2: STRES2(1 ,2 )
   12        6904.269      maximum stress in material 2: STRES2(1 ,3 )
   13       0.1000000E-09  maximum stress in material 2: STRES2(1 ,4 )
   14        1929.446      maximum stress in material 2: STRES2(1 ,5 )

  BEHAVIOR OVER J =  stress component number
   15       0.1000000E-09  maximum stress in material 3: STRES3(1 ,1 )
   16       0.1000000E-09  maximum stress in material 3: STRES3(1 ,2 )
   17       0.1000000E-09  maximum stress in material 3: STRES3(1 ,3 )
   18       0.1000000E-09  maximum stress in material 3: STRES3(1 ,4 )
   19       0.1000000E-09  maximum stress in material 3: STRES3(1 ,5 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 9: Buckling of strut as a column
 -BEHX5xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of the strut. n = 1 circumferential wave
```

```
   corresponds to buckling of the strut as a column. The
   effect of propellant tank flexibility is NOT included in
   this BIGBOSOR4 model.
2. an Euler buckling model of the strut. This model is
   analogous to the column buckling model used in "DEWAR".
   The effect of propellant tank flexibility IS included.
The Euler buckling model usually gives the lower buckling
load factor, mainly because of propellant tank flexibility.
The buckling constraint is based on the minimum column
buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: column buckling of strut of type 1 for load case 1
test.BEHX511

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -2.3729E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  1 -2.3729E+04  0.0000E+00

 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  4.1386E+00(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  1; Strut length=  1.1327E+02 Load on strut= -2.3729E+04
 Column buckling of strut from Euler formula, COLBUC=  1.8615E+00
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
 the minimum value obtained from BIGBOSOR4 and the Euler model.
    20        1.861495      buckling of a strut as a column: COLBUK(1 ,1 )


 BIGBOSOR4 input file for: column buckling of strut of type 2 for load case 1
test.BEHX521

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  2 -2.3729E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  2 -2.3729E+04  0.0000E+00

 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  1.8852E+04(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  2; Strut length=  1.1216E+02 Load on strut= -1.0000E-08
 Column buckling of strut from Euler formula, COLBUC=  7.2890E+12
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
```

```
 the minimum value obtained from BIGBOSOR4 and the Euler model.
   21        18852.19      buckling of a strut as a column: COLBUK(1 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 10: Buckling of strut as a shell
 -BEHX6xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of a sub-length of the strut. A search
    is conducted over the number n of circumferential waves in
    the buckling mode to determine the critical buckling load
    factor. The effect of propellant tank flexibility is not
    relevant in this analysis.
 2. a PANDA2-type buckling model of the strut. This model is
    analogous to the shell buckling model used in "DEWAR".
    The effect of propellant tank flexibility is not relevant.

 The PANDA2-type buckling model usually gives the lower
 buckling load factor, mainly because of the effect of
 transverse shear deformation (t.s.d.) and the effect of the
 anisotropic terms, D16 and D26, that BIGBOSOR4 cannot handle.
 The buckling constraint is based on the minimum shell
 buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: shell buckling of strut type 1 for load case 1
test.BEHX611

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -2.3729E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  1 -2.3729E+04  0.0000E+00

 SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
  1.1757E+01(n= 0 circ.waves (from BIGBOSOR4))
  1.1673E+01(n= 1 circ.waves (from BIGBOSOR4))
  1.1421E+01(n= 2 circ.waves (from BIGBOSOR4))
  1.1002E+01(n= 3 circ.waves (from BIGBOSOR4))
  9.1256E+00(n= 4 circ.waves (from BIGBOSOR4))
  7.6420E+00(n= 5 circ.waves (from BIGBOSOR4))
  7.5187E+00(n= 6 circ.waves (from BIGBOSOR4))
  8.1512E+00(n= 7 circ.waves (from BIGBOSOR4))
  9.2733E+00(n= 8 circ.waves (from BIGBOSOR4))
  1.0841E+01(n= 9 circ.waves (from BIGBOSOR4))
  1.2760E+01(n=10 circ.waves (from BIGBOSOR4))
 Critical buckling load factor from BIGBOSOR4, SHLBUK=  7.5187E+00
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    6
 Strut type  1; Strut length=  1.1327E+02 Load on strut= -2.3729E+04
 Column buckling of strut from Euler formula, COLBUC=  1.8615E+00

 INFORMATION PERTAINING TO STRUT TYPE 1:
```

```
 IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (AFT) ARE:
 AFT support member. COLUMN buckling results (Euler formula):
  Effective bending stiffness of LAUNCH tube,      EI =  1.3296E+08
  Length of strut from pinned end to pinned end,    L =  1.1327E+02
  Force in strut tending to buckle it,          FORCE = -2.3729E+04
  Euler (column) buckling strain,    pi**2*I/(A*L**2) =  4.4998E-03
  Average strain in the column (g-loads minus temp.),e= -2.4173E-03
  Effective stiffness of strut for lateral (n=1) motions
    including knockdowns for shell and ring flexibility,
                                                   K1 =  8.6663E+04
  Effective stiffness of strut for axial (n=0) motions
   including only knockdown for axisymmetric shell flexibility,
                                                   K0 =  1.8040E+05
  Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                               COLBUC =  1.8615E+00

 AFT support member.SHELL buckling results(PANDA):
 Calculations for (1=launch tube,2=orbital tube)= 1
  Main diagonal of shell wall constitutive matrix, C(i,i):
    axial stiffness of shell wall,             C(1,1) =  1.1570E+06
    hoop  stiffness of shell wall,             C(2,2) =  4.7805E+05
    shear stiffness of shell wall,             C(3,3) =  2.3458E+05
    axial bending rigidity of shell wall       C(4,4) =  9.5205E+02
    hoop  bending rigidity of shell wall       C(5,5) =  1.2484E+02
    twisting      rigidity of shell wall       C(6,6) =  1.2901E+02
  Force in tube tending to buckle it,           FORCE = -2.3729E+04
  Length of tube used for SHELL buckling model, FLEFF =  2.0521E+01
  Load factor, shell buckling (PANDA analysis),SHLBC2 =  5.0170E+00
  Number of axial half-waves in buckle pattern,     m =     1
  Number of circumferential full waves in mode,     n =     3
  Slope of nodal lines of buckling pattern,    CSLOPE =  0.0000E+00
   22        5.017042      buckling of strut as a shell: SHLBUK(1 ,1 )


 BIGBOSOR4 input file for: shell buckling of strut type 2 for load case 1
test.BEHX621

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  2 -2.3729E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  2 -2.3729E+04  0.0000E+00

 SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
  3.7202E+04(n= 0 circ.waves (from BIGBOSOR4))
  1.8497E+04(n= 1 circ.waves (from BIGBOSOR4))
  5.1197E+03(n= 2 circ.waves (from BIGBOSOR4))
  1.3285E+03(n= 3 circ.waves (from BIGBOSOR4))
  5.1407E+02(n= 4 circ.waves (from BIGBOSOR4))
  2.8926E+02(n= 5 circ.waves (from BIGBOSOR4))
  2.0807E+02(n= 6 circ.waves (from BIGBOSOR4))
  1.7519E+02(n= 7 circ.waves (from BIGBOSOR4))
  1.6334E+02(n= 8 circ.waves (from BIGBOSOR4))
  1.6191E+02(n= 9 circ.waves (from BIGBOSOR4))
```

```
 1.6631E+02(n=10 circ.waves (from BIGBOSOR4))
Critical buckling load factor from BIGBOSOR4, SHLBUK=  1.6191E+02
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    9
Strut type  2; Strut length=  1.1216E+02 Load on strut= -1.0000E-08
Column buckling of strut from Euler formula, COLBUC=  7.2890E+12

INFORMATION PERTAINING TO STRUT TYPE 2:

IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (FWD) ARE:
FWD support member. COLUMN buckling results (Euler formula):
 Effective bending stiffness of LAUNCH tube,      EI =  1.4787E+08
 Length of strut from pinned end to pinned end,    L =  1.1216E+02
 Force in strut tending to buckle it,          FORCE = -1.0000E-08
 Euler (column) buckling strain,    pi**2*I/(A*L**2) =  4.7286E-03
 Average strain in the column (g-loads minus temp.),e= -6.4872E-16
 Effective stiffness of strut for lateral (n=1) motions
   including knockdowns for shell and ring flexibility,
                                                  K1 =  1.3744E+05
 Effective stiffness of strut for axial (n=0) motions
  including only knockdown for axisymmetric shell flexibility,
                                                  K0 =  1.9366E+05
 Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                              COLBUC =  7.2890E+12

FWD support member.SHELL buckling results(PANDA):
Calculations for (1=launch tube,2=orbital tube)= 1
 Main diagonal of shell wall constitutive matrix, C(i,i):
   axial stiffness of shell wall,            C(1,1) =  1.1856E+06
   hoop  stiffness of shell wall,            C(2,2) =  5.2255E+05
   shear stiffness of shell wall,            C(3,3) =  1.9496E+05
   axial bending rigidity of shell wall      C(4,4) =  1.0048E+03
   hoop  bending rigidity of shell wall      C(5,5) =  1.2024E+02
   twisting      rigidity of shell wall      C(6,6) =  9.9150E+01
 Force in tube tending to buckle it,          FORCE = -1.0000E-08
 Length of tube used for SHELL buckling model, FLEFF =  2.0829E+01
 Load factor, shell buckling (PANDA analysis),SHLBC2 =  1.1813E+13
 Number of axial half-waves in buckle pattern,     m =     1
 Number of circumferential full waves in mode,     n =     3
 Slope of nodal lines of buckling pattern,    CSLOPE =  0.0000E+00
  23        161.9068      buckling of strut as a shell: SHLBUK(1 ,2 )

 BEHAVIOR OVER J =  strut set number (1 for aft-most set)

CHAPTER 11: Launch-hold force in a strut
-BEHX7x, x=1,2; x=load case
If the propellant tank is oriented vertically in the launch
vehicle all the struts in each strut set experience the same
launch-hold force. The launch-hold force in the AFT struts
may differ from that in the FORWARD struts. Behavioral
constraints are computed for each set of struts. The
behavioral constraint is called "FORCE(i,j)", in which i =
the load case number and j =the strut set number (strut type).

FORCE(i,j) is computed from a BIGBOSOR4 model of the
propellant tank with struts (springs) attached to it. The
spring constants include the effect of the flexibility of the
propellant tank. The tank is loaded by PRESS, GAXIAL=1g, and
TNKCOOL. The maximum allowable strut launch-hold force is
```

```
 provided for each load case by the End user. The behavioral
 constraint, FORCE(i,j), must be less than the maximum
 allowable, FORCEA(i,j). The End user must supply FORCEA(i,j)
 at a small enough value so that if the struts contain a
 disconnect feature they will not "short out" during the
 launch-hold phase of a mission.

 BIGBOSOR4 input file for propellant tank supported
 by struts (launch-hold condition for load case 1)
test.BEHX71

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1327E+02  6.5812E+03  0.0000E+00

 Length of strut, max. load, min. load for strut type 2; strut ring no.  2
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1216E+02  1.4839E+04  0.0000E+00
   24        6581.190      launch-hold force in a strut: FORCE(1 ,1 )
   25        14838.99      launch-hold force in a strut: FORCE(1 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 12: Maximum effective stress in the isotropic
 propellant tank - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The model is analogous to that
 described in CHAPTER 4 (*.BEHX03x, x=1,2; x=load case).
 The propellant tank is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The modeling of the concentrated loads that replace
 the springs (struts) is described in CHAPTER 4. The purpose
 of this model is to compute the maximum effective stress in
 the propellant tank, which is assumed to be fabricated of
 isotropic material. This is an "INDIC=3" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case 1:
 maximum stress in the propellant tank from the prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 1
test.BEHX811

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  1.1969E+00, LOCATW(1)=1000*ISEG+I=  1001
 *******************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  1.0232E+00 fiber tension : matl=1 ,  A , seg=11, node=3 , layer=1 ,z= -1.01 ;FS=  1.00
  2  1.4154E+00 fiber compres.: matl=1 ,  A , seg=16, node=13, layer=1 ,z= -1.00 ;FS=  1.00
  3  1.2552E+00 transv tension: matl=1 ,  A , seg=14, node=7 , layer=1 ,z= -1.00 ;FS=  1.00
  4  1.6293E+00 transv compres: matl=1 ,  A , seg=1 , node=1 , layer=1 ,z= -1.01 ;FS=  1.00
  5  1.0064E+00 effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
  6  1.5057E+00 effect. stress: matl=3 ,  A , seg=16, node=2 , layer=3 ,z= 0.05  ;FS=  1.00
  7  1.0795E+00 effect. stress: matl=4 ,  A , seg=15, node=52, layer=2 ,z= 0.02  ;FS=  1.00
  8  1.4558E+00 effect. stress: matl=5 ,  A , seg=28, node=8 , layer=2 ,z= 0.03  ;FS=  1.00
 *******************************************************
 Maximum stress components for Load Case  1 STRESS2(i),i=1,6=
     4.8867E+04     3.5326E+04     3.9833E+04     3.0689E+04     0.0000E+00     4.9681E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     4.9681E+04
effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
 ******************************************************
   26        49681.38      maximum stress in the propellant tank: TNKSTR(1 ,1 )


 BIGBOSOR4 input file for load case 1:
 maximum stress in the propellant tank from the prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 2
test.BEHX821

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  1.1969E+00, LOCATW(1)=1000*ISEG+I=  1001
 ********************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  1.0232E+00 fiber tension : matl=1 ,  A , seg=11, node=3 , layer=1 ,z= -1.01 ;FS=  1.00
  2  1.4154E+00 fiber compres.: matl=1 ,  A , seg=16, node=13, layer=1 ,z= -1.00 ;FS=  1.00
  3  1.2552E+00 transv tension: matl=1 ,  A , seg=14, node=7 , layer=1 ,z= -1.00 ;FS=  1.00
  4  1.6293E+00 transv compres: matl=1 ,  A , seg=1 , node=1 , layer=1 ,z= -1.01 ;FS=  1.00
  5  1.0064E+00 effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
  6  1.5057E+00 effect. stress: matl=3 ,  A , seg=16, node=2 , layer=3 ,z= 0.05  ;FS=  1.00
  7  1.0795E+00 effect. stress: matl=4 ,  A , seg=15, node=52, layer=2 ,z= 0.02  ;FS=  1.00
  8  1.4558E+00 effect. stress: matl=5 ,  A , seg=28, node=8 , layer=2 ,z= 0.03  ;FS=  1.00
 ****************************************************
 Maximum stress components for Load Case  1 STRESS2(i),i=1,6=
     4.8867E+04     3.5326E+04     3.9833E+04     3.0689E+04     0.0000E+00     4.9681E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     4.9681E+04
effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
 ******************************************************
   27        49681.38      maximum stress in the propellant tank: TNKSTR(1 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 13: Buckling of the isotropic propellant tank
 - BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The 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 is loaded by PRESS, GAXIAL, GLATRL, and
```

TNKCOOL. The modeling of the concentrated loads that replace
the springs (struts) is described in CHAPTER 4. The purpose
of this model is to compute the minimum buckling load of
the propellant tank, which is assumed to be fabricated of
isotropic material. This is an "INDIC=4" BIGBOSOR4 model.

```
 BIGBOSOR4 input file for load case 1: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 1
test.BEHX911

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  4.1112E+01(n=  10 circ.waves); IFAILD= 0
  1.9403E+01(n=  15 circ.waves); IFAILD= 0
  1.2241E+01(n=  20 circ.waves); IFAILD= 0
  1.0786E+01(n=  25 circ.waves); IFAILD= 0
  1.1084E+01(n=  30 circ.waves); IFAILD= 0
  1.2252E+01(n=  35 circ.waves); IFAILD= 0
  1.3998E+01(n=  40 circ.waves); IFAILD= 0
  1.6191E+01(n=  45 circ.waves); IFAILD= 0
  1.8762E+01(n=  50 circ.waves); IFAILD= 0
  2.1667E+01(n=  55 circ.waves); IFAILD= 0
  2.4878E+01(n=  60 circ.waves); IFAILD= 0
  2.8373E+01(n=  65 circ.waves); IFAILD= 0
  3.2136E+01(n=  70 circ.waves); IFAILD= 0
  3.6152E+01(n=  75 circ.waves); IFAILD= 0
  4.0407E+01(n=  80 circ.waves); IFAILD= 0
  4.4890E+01(n=  85 circ.waves); IFAILD= 0
  4.9588E+01(n=  90 circ.waves); IFAILD= 0
  5.4487E+01(n=  95 circ.waves); IFAILD= 0
  5.9575E+01(n= 100 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.0786E+01
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
   28        10.78619      propellant tank buckling load factor: TNKBUK(1 ,1 )


 BIGBOSOR4 input file for load case 1: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 2
test.BEHX921

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  4.1112E+01(n=  10 circ.waves); IFAILD= 0
  1.9403E+01(n=  15 circ.waves); IFAILD= 0
  1.2241E+01(n=  20 circ.waves); IFAILD= 0
  1.0786E+01(n=  25 circ.waves); IFAILD= 0
  1.1084E+01(n=  30 circ.waves); IFAILD= 0
  1.2252E+01(n=  35 circ.waves); IFAILD= 0
  1.3998E+01(n=  40 circ.waves); IFAILD= 0
  1.6191E+01(n=  45 circ.waves); IFAILD= 0
  1.8762E+01(n=  50 circ.waves); IFAILD= 0
  2.1667E+01(n=  55 circ.waves); IFAILD= 0
  2.4878E+01(n=  60 circ.waves); IFAILD= 0
  2.8373E+01(n=  65 circ.waves); IFAILD= 0
  3.2136E+01(n=  70 circ.waves); IFAILD= 0
  3.6152E+01(n=  75 circ.waves); IFAILD= 0
  4.0407E+01(n=  80 circ.waves); IFAILD= 0
```

```
 4.4890E+01(n=  85 circ.waves); IFAILD= 0
 4.9588E+01(n=  90 circ.waves); IFAILD= 0
 5.4487E+01(n=  95 circ.waves); IFAILD= 0
 5.9575E+01(n= 100 circ.waves); IFAILD= 0
Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.0786E+01
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
  29        10.78619      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 strut conductance)

in which (normalized weight of empty tank) =    TOTMAS/TNKNRM
and      (normalized total strut 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 strut
conductance, CONDCT. Note that the listed definition of the
objective is always "total conductance into the tank: CONDCT".

WGT,TOTMAS,TNKNRM,CONDCT,CONNRM=
 5.0000E-01  1.1021E+01  1.0000E+01  1.8782E-03  2.0000E-03

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

BEH.   CURRENT
NO.     VALUE            DEFINITION
 1    1.190E+01    free vibration frequency (cps): FREQ(1 ,1 )
 2    1.203E+01    free vibration frequency (cps): FREQ(1 ,2 )
 3    1.275E+01    free vibration frequency (cps): FREQ(1 ,3 )
 4    1.333E+01    free vibration frequency (cps): FREQ(1 ,4 )
 5    4.417E+03    maximum stress in material 1: STRES1(1 ,1 )
 6    2.309E+04    maximum stress in material 1: STRES1(1 ,2 )
 7    4.236E+03    maximum stress in material 1: STRES1(1 ,3 )
 8    1.000E-10    maximum stress in material 1: STRES1(1 ,4 )
 9    8.316E+02    maximum stress in material 1: STRES1(1 ,5 )
10    5.205E+04    maximum stress in material 2: STRES2(1 ,1 )
11    1.296E+04    maximum stress in material 2: STRES2(1 ,2 )
12    6.904E+03    maximum stress in material 2: STRES2(1 ,3 )
13    1.000E-10    maximum stress in material 2: STRES2(1 ,4 )
14    1.929E+03    maximum stress in material 2: STRES2(1 ,5 )
15    1.000E-10    maximum stress in material 3: STRES3(1 ,1 )
16    1.000E-10    maximum stress in material 3: STRES3(1 ,2 )
17    1.000E-10    maximum stress in material 3: STRES3(1 ,3 )
18    1.000E-10    maximum stress in material 3: STRES3(1 ,4 )
19    1.000E-10    maximum stress in material 3: STRES3(1 ,5 )
20    1.861E+00    buckling of a strut as a column: COLBUK(1 ,1 )
21    1.885E+04    buckling of a strut as a column: COLBUK(1 ,2 )
22    5.017E+00    buckling of strut as a shell: SHLBUK(1 ,1 )
23    1.619E+02    buckling of strut as a shell: SHLBUK(1 ,2 )
24    6.581E+03    launch-hold force in a strut: FORCE(1 ,1 )
25    1.484E+04    launch-hold force in a strut: FORCE(1 ,2 )
26    4.968E+04    maximum stress in the propellant tank: TNKSTR(1 ,1 )
```

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 27    4.968E+04    maximum stress in the propellant tank: TNKSTR(1 ,2 )
 28    1.079E+01    propellant tank buckling load factor: TNKBUK(1 ,1 )
 29    1.079E+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   -8.385E-03  (FREQ(1 ,1 )/FREQA(1 ,1 )) / FREQF(1 ,1 )-1; F.S.=  1.20
  2    2.416E-03  (FREQ(1 ,2 )/FREQA(1 ,2 )) / FREQF(1 ,2 )-1; F.S.=  1.20
  3    6.280E-02  (FREQ(1 ,3 )/FREQA(1 ,3 )) / FREQF(1 ,3 )-1; F.S.=  1.20
  4    1.108E-01  (FREQ(1 ,4 )/FREQA(1 ,4 )) / FREQF(1 ,4 )-1; F.S.=  1.20
  5    2.022E+01  (STRES1A(1 ,1 )/STRES1(1 ,1 )) / STRES1F(1 ,1 )-1; F.S.=  1.50
  6    2.023E+00  (STRES1A(1 ,2 )/STRES1(1 ,2 )) / STRES1F(1 ,2 )-1; F.S.=  1.50
  7    6.615E-01  (STRES1A(1 ,3 )/STRES1(1 ,3 )) / STRES1F(1 ,3 )-1; F.S.=  1.50
  8    4.043E+00  (STRES1A(1 ,5 )/STRES1(1 ,5 )) / STRES1F(1 ,5 )-1; F.S.=  1.50
  9    8.006E-01  (STRES2A(1 ,1 )/STRES2(1 ,1 )) / STRES2F(1 ,1 )-1; F.S.=  1.50
 10    4.386E+00  (STRES2A(1 ,2 )/STRES2(1 ,2 )) / STRES2F(1 ,2 )-1; F.S.=  1.50
 11    1.937E-02  (STRES2A(1 ,3 )/STRES2(1 ,3 )) / STRES2F(1 ,3 )-1; F.S.=  1.50
 12    1.173E+00  (STRES2A(1 ,5 )/STRES2(1 ,5 )) / STRES2F(1 ,5 )-1; F.S.=  1.50
 13    8.615E-01  (COLBUK(1 ,1 )/COLBUKA(1 ,1 )) / COLBUKF(1 ,1 )-1; F.S.=  1.00
 14    1.885E+04  (COLBUK(1 ,2 )/COLBUKA(1 ,2 )) / COLBUKF(1 ,2 )-1; F.S.=  1.00
 15    1.509E+00  (SHLBUK(1 ,1 )/SHLBUKA(1 ,1 )) / SHLBUKF(1 ,1 )-1; F.S.=  2.00
 16    7.995E+01  (SHLBUK(1 ,2 )/SHLBUKA(1 ,2 )) / SHLBUKF(1 ,2 )-1; F.S.=  2.00
 17    1.279E+00  (FORCEA(1 ,1 )/FORCE(1 ,1 )) / FORCEF(1 ,1 )-1; F.S.=  1.00
 18    1.085E-02  (FORCEA(1 ,2 )/FORCE(1 ,2 )) / FORCEF(1 ,2 )-1; F.S.=  1.00
 19    6.413E-03  (TNKSTRA(1 ,1 )/TNKSTR(1 ,1 )) / TNKSTRF(1 ,1 )-1; F.S.=  1.00
 20    6.413E-03  (TNKSTRA(1 ,2 )/TNKSTR(1 ,2 )) / TNKSTRF(1 ,2 )-1; F.S.=  1.00
 21    9.786E+00  (TNKBUK(1 ,1 )/TNKBUKA(1 ,1 )) / TNKBUKF(1 ,1 )-1; F.S.=  1.00
 22    9.786E+00  (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 5.1880E-02  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 4.5270E-02  4.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 5.3200E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 3.6390E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   Y     N     N      0    0.00E+00  3.00E+00 4.4460E+00  1.00E+01  spacing of the
tank orthogrid rings: RNGSPC
   6   Y     N     N      0    0.00E+00  1.00E-01 1.0280E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
   7   Y     N     N      0    0.00E+00  2.00E-01 9.8060E-01  1.00E+00  height of the
tank orthogrid stringers: STRHI
   8   Y     N     N      0    0.00E+00  1.00E-01 1.7620E-01  1.00E+00  thickness of the
tank orthogrid rings: RNGTHK
```

```
   9   N     N     Y      7    1.00E+00  0.00E+00 9.8060E-01  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 1.5000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   N     N     N      0    0.00E+00  0.00E+00 4.5000E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(2 )
  12   Y     N     N      0    0.00E+00  2.00E+01 8.9390E+01  1.40E+02  global axial
coordinate of "ground": ZGRND(1 )
  13   Y     N     N      0    0.00E+00  4.75E+02 5.0850E+02  6.50E+02  global axial
coordinate of "ground": ZGRND(2 )
  14   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(1 )
  15   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(2 )
  16   Y     N     N      0    0.00E+00  2.50E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(1 )
  17   Y     N     N      0    0.00E+00  2.50E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(2 )
  18   Y     N     N      0    0.00E+00  2.00E+00 6.7530E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(1 )
  19   Y     N     N      0    0.00E+00  2.00E+00 6.8560E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(2 )
  20   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  height of mid-
tank T-ring web: WEBHI
  21   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring web: WEBTHK
  22   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  width (height) of
mid-tank T-ring flange: FLGHI
  23   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring flange: FLGTHK
  24   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 )
  25   Y     N     N      0    0.00E+00  2.00E-02 8.5550E-01  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  26   Y     N     N      0    0.00E+00  5.00E-02 3.4980E-01  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  27   N     N     Y     26    5.00E+00  0.00E+00 1.7490E+00  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
  28   Y     Y     N      0    0.00E+00  5.00E-03 7.2710E-03  2.00E-01  thickness of a
lamina: THICK(1 )
  29   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  30   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  31   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(4 )
  32   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  33   N     N     Y     28    1.00E+00  0.00E+00 7.2710E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  34   Y     Y     N      0    0.00E+00  5.00E-03 7.2500E-03  2.00E-01  thickness of a
lamina: THICK(7 )
  35   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(8 )
  36   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(9 )
  37   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(10)
```

```
  38   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(11)
  39   N     N     Y     34    1.00E+00  0.00E+00 7.2500E-03  0.00E+00  thickness of a
lamina: THICK(12)
  40   Y     N     N      0    0.00E+00  1.00E+01 1.9920E+01  8.00E+01  layup angle:
ANGLE(1 )
  41   N     N     Y     40   -1.00E+00  0.00E+00-1.9920E+01  0.00E+00  layup angle:
ANGLE(2 )
  42   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(3 )
  43   N     N     Y     42   -1.00E+00  0.00E+00-1.0000E+01  0.00E+00  layup angle:
ANGLE(4 )
  44   Y     N     N      0    0.00E+00  1.00E+01 6.0420E+01  8.00E+01  layup angle:
ANGLE(5 )
  45   N     N     Y     44   -1.00E+00  0.00E+00-6.0420E+01  0.00E+00  layup angle:
ANGLE(6 )
  46   Y     N     N      0    0.00E+00  1.00E+01 1.5370E+01  8.00E+01  layup angle:
ANGLE(7 )
  47   N     N     Y     46   -1.00E+00  0.00E+00-1.5370E+01  0.00E+00  layup angle:
ANGLE(8 )
  48   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(9 )
  49   N     N     Y     48   -1.00E+00  0.00E+00-1.0000E+01  0.00E+00  layup angle:
ANGLE(10)
  50   Y     N     N      0    0.00E+00  1.00E+01 6.4480E+01  8.00E+01  layup angle:
ANGLE(11)
  51   N     N     Y     50   -1.00E+00  0.00E+00-6.4480E+01  0.00E+00  layup angle:
ANGLE(12)
  BEHAVIOR FOR  2 ENVIRONMENT (LOAD SET)

 CONSTRAINT  BEHAVIOR              DEFINITION
   NUMBER     VALUE

  BEHAVIOR FOR LOAD SET NUMBER, ILOADX= 2
 Name of case= test                        ; ITYPEX=  2

 CHAPTER 1 (BEHX01x, x = 1,2,...; x=load case):
 Find the lengths of struts and the axial loads in the
 struts from a BIGBOSOR4 model of the propellant tank
 supported by springs with an arbitrarily assigned spring
 constant. The flexibility of the propellant tank is
 neglected, the strut end fittings are neglected, and the
 propellant tank is loaded by ullage pressure, PRESS, tank
 cool-down, TNKCOOL, axial acceleration, GAXIAL, and lateral
 acceleration, GLATRL. This is a first approximation.
 The BIGBOSOR4 model is stored in *.BEHX01x, x = 1, 2...,
 in which "x" represents the load case.


 BIGBOSOR4 input file for propellant tank supported by struts; Load Case 2
test.BEHX012

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
  6.7730E+04  1.0390E+05  5.3703E+03  4.1538E+04  4.1538E+04
  5.3703E+03  1.0390E+05  6.7730E+04
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
```

```
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
  6.7730E-02  1.0390E-01  5.3703E-03  4.1538E-02  4.1538E-02
  5.3703E-03  1.0390E-01  6.7730E-02

 Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
  6.9511E+04  1.0475E+05  7.3463E+03  4.2583E+04  4.2583E+04
  7.3463E+03  1.0475E+05  6.9511E+04
 Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
  6.9511E-02  1.0475E-01  7.3463E-03  4.2583E-02  4.2583E-02
  7.3463E-03  1.0475E-01  6.9511E-02

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1327E+02  1.0390E+05  0.0000E+00

 Length of strut, max. load, min. load for strut type 2; strut ring no.  2
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1216E+02  1.0475E+05  0.0000E+00
```

CHAPTER 2:
Optain PostScript plot files, *.PL6.ps, *.PL7.ps, *.PL8.ps, which contain a plan view of the AFT set of struts (*.PL6.ps), a plan view of the FORWARD set of struts (*.PL7.ps, if any), and an elevation view of both AFT and FORWARD sets of struts (*.PL8.ps). The FORTRAN software is "borrowed" from the "DEWAR" system (SUBROUTINE STPLOT and the subroutines called by STPLOT). These FORTRAN subroutines are part of the bosdec.tank library.

CHAPTER 3 (BEHX02x, x=1,2,...; x=load case):
1. Fill the "DEWAR" labelled common blocks with the proper quantities so that buckling load factors of the strut launch tubes (buckling as thin shells) and so that the 5 stress components in composite laminate plies can be determined from "PANDA-type" of analyses similar to those analyses that are used in the "DEWAR" system for buckling and stress of the strut launch tubes.

2. Compute from SUBROUTINE GETCIJ the 6 x 6 constitutive stiffness matrix for each type of strut tube. SUBROUTINE GETCIJ is very like a subroutine of the same name in PANDA2.

3. Find the axial stiffnesses of aft and forward strut tubes. These strut tube stiffnesses are to be used in the computation of spring constants associated with each strut in the AFT set of struts and associated with each strut in the FORWARD set of struts (if any). In the "DO 20" loop of SUBROUTINE STRUCT, I = 1 corresponds to the AFT set of struts and I = 2 corresponds to the FORWARD set of struts.

```
 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 1

           COMPOUND SUPPORT TUBE NO. 1:   AFT LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  1.1570E+06  2.1778E+05  0.0000E+00  4.8828E-04  2.4414E-04  1.2207E-04     -5.4605E+02
-3.1910E-04
```

```
  2.1778E+05  4.7805E+05  0.0000E+00  3.6621E-04  4.8828E-04  0.0000E+00     -4.5773E+02
-8.1213E-04
  0.0000E+00  0.0000E+00  2.3458E+05  0.0000E+00  3.0518E-05  2.4414E-04      0.0000E+00
-2.4620E-19
  4.8828E-04  3.6621E-04  0.0000E+00  9.5205E+02  1.1835E+02  6.0078E+01     -9.5367E-07
1.6157E-10
  2.4414E-04  4.8828E-04  3.0518E-05  1.1835E+02  1.2484E+02  1.6337E+01     -1.1921E-06
-6.0313E-09
  1.2207E-04  0.0000E+00  2.4414E-04  6.0078E+01  1.6337E+01  1.2901E+02      0.0000E+00
9.9047E-10


 BIGBOSOR4 input file for Load Case 2:
 axial stiffness of a single launch tube, type 1
test.BEHX022

 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  1.1570E+06  2.1778E+05  4.7805E+05
 C111MD=axial stiffness/circ.length of launch tube type  1
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  1.0577E+06
 Launch tube "EA" and length and "spring constant" for tube type  1
   = TUBEEA,TUBLNG,TUBEK =  2.2730E+07  1.0327E+02  2.2010E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  1 =  1.8040E+05
 The flexibility of the propellant tank is neglected in the
 model that yields SPRCON. See below for model that includes
 the flexibility of the propellant tank and that yields FKTOTL

 Conductance of one strut of type  1 =  1.1615E-04


 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 2

           COMPOUND SUPPORT TUBE NO. 1:   FWD LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  1.1856E+06  1.7820E+05  0.0000E+00  4.8828E-03  7.9346E-04  1.2207E-04     -5.4357E+02
-3.4459E-04
  1.7820E+05  5.2255E+05  0.0000E+00  7.9346E-04  2.4109E-03 -4.5776E-05     -4.5731E+02
-7.5764E-04
  0.0000E+00  0.0000E+00  1.9496E+05  1.2207E-04 -4.5776E-05  9.1553E-04      0.0000E+00
-1.1045E-18
  4.8828E-03  7.9346E-04  1.2207E-04  1.0048E+03  8.8580E+01  5.1870E+01     -2.6226E-06
-3.3702E-10
  7.9346E-04  2.4109E-03 -4.5776E-05  8.8580E+01  1.2024E+02  1.3038E+01     -2.1458E-06
-1.6177E-10
  1.2207E-04 -4.5776E-05  9.1553E-04  5.1870E+01  1.3038E+01  9.9150E+01      0.0000E+00
2.7204E-10

 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  1.1856E+06  1.7820E+05  5.2255E+05
 C111MD=axial stiffness/circ.length of launch tube type  2
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  1.1249E+06
 Launch tube "EA" and length and "spring constant" for tube type  2
   = TUBEEA,TUBLNG,TUBEK =  2.4535E+07  1.0216E+02  2.4018E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  2 =  1.9366E+05
```

The flexibility of the propellant tank is neglected in the model that yields SPRCON. See below for model that includes the flexibility of the propellant tank and that yields FKTOTL

Conductance of one strut of type 2 = 1.1862E-04

CHAPTER 4 (BEHX03x, x = 1,2,...; x=load case):
Compute the linear static response of the propellant tank to concentrated loads applied by the struts (springs) to the tank along the tank support ring no. 1 (aft strut set) and along the tank support ring no. 2 (forward strut set). In this BIGBSOSOR4 model of the propellant tank the springs (struts) are replaced by concentrated loads obtained from the CHAPTER 1 computations. The concentrated loads are modeled in BIGBOSOR4 as line loads with little triangular "pulses" centered about the circumferential angles where the struts are pinned to the propellant tank and at the global axial coordinates that corresponds to the global axial coordinates of the centroids of the aft and forward propellant tank support rings. The circumferential distributions of the line loads are expanded in Fourier series, and the static response to each Fourier component is superposed by BIGBOSOR4 in what is called in BIGBOSOR4 jargon an "INDIC=3" type of analysis. Sixty Fourier terms are used in the Fourier series expansion.

The purpose of this calculation is to find the maximum displacement of the propellant tank wall in the same direction as the axis of one of the struts: 1. the strut associated with the greatest tank wall displacement produced by the AFT strut set and 2. the strut associated with the greatest tank wall displacement produced by the FORWARD strut set. These two maximum local tank wall displacements are used in the determination of the spring constants to be associated with each of the AFT struts and with each of the FORWARD struts in the models in which the flexibility of the propellant tank is accounted for in the computation of the behavior(e.g.vibration)

In this BIGBOSOR4 model there exist "fake" springs, that is, springs with zero axial stiffness. These "fake" springs have no influence on the behavior.

```
 BIGBOSOR4 input file, Load Case 2, for the propellant
 tank with springs replaced by concentrated loads (INDX=5)
test.BEHX032

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 -0.0000E+00 -0.0000E+00  0.0000E+00 -0.0000E+00 -0.0000E+00
  0.0000E+00 -0.0000E+00 -0.0000E+00
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 -1.0059E-01 -3.1919E-01  1.0547E-01 -1.1313E-01 -1.1313E-01
  1.0547E-01 -3.1919E-01 -1.0059E-01
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  8.4000E+01
```

```
Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
-0.0000E+00 -0.0000E+00  0.0000E+00 -0.0000E+00 -0.0000E+00
 0.0000E+00 -0.0000E+00 -0.0000E+00
Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
-1.3036E-01 -3.9865E-01  9.8701E-02 -1.6959E-01 -1.6959E-01
 9.8701E-02 -3.9865E-01 -1.3036E-01
Circ. angle where the maximum concentrated AXIAL load is
applied to the propellant tank by the struts at the tank
support ring no.  2. Circumferential angle =  8.4000E+01

Absolute value of maximum "change in length" of any strut at strut ring no.  1
DISMAX(JRING)=  3.1919E-01
DISMAX is used in the derivation of the strut spring
constant, FKTOTL, that accounts for the flexibility of the
propellant tank.

Absolute value of maximum "change in length" of any strut at strut ring no.  2
DISMAX(JRING)=  3.9865E-01
DISMAX is used in the derivation of the strut spring
constant, FKTOTL, that accounts for the flexibility of the
propellant tank.

Spring constant at ring no.  1: FKTOTL(JRING)=  1.1607E+05
The reduced spring constant, FKTOTL, includes the flexibility
of the propellant tank. Compare with the spring constant
SPRCON=  1.8040E+05 which is the value of the spring
constant obtained neglecting the propellant tank flexibility.

Spring constant at ring no.  2: FKTOTL(JRING)=  1.1149E+05
The reduced spring constant, FKTOTL, includes the flexibility
of the propellant tank. Compare with the spring constant
SPRCON=  1.9366E+05 which is the value of the spring
constant obtained neglecting the propellant tank flexibility.

CHAPTER 5 (BEHX04x, x = 1, 2,...; x = load case):
Repeat the CHAPTER 1 type of computations with the new
(significantly smaller) spring constants that now account
for the flexibility of the propellant tank. The purpose of
this computation is to determine more accurate values of the
loads in each strut (spring) caused by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL. The updated strut loads are
used in the following computations:
1. Buckling of the most highly compressed strut of each type
(type 1 = "AFT"; type 2 = "FORWARD") as a column (BEHX5) and
as a shell (BEHX6).
2. Maximum of each of five stress components in each type
of strut (BEHX2 for AFT struts and BEHX3 for FORWARD struts).
3. Maximum stress in the propellant tank due to loading by
the AFT and FORWARD sets of struts and by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL (BEHX8).
4. Minimum buckling of the propellant tank under the AFT and
FORWARD sets of struts and by the loads, PRESS, GAXIAL,
GLATRL, and TNKCOOL (BEHX9).
```

```
 BIGBOSOR4 input file for propellant tank under
 Load Case 2 supported by struts (second approximation)
test.BEHX042

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
  1.4615E+04  5.9500E+04 -4.0228E+04  4.6574E+03  4.6574E+03
 -4.0228E+04  5.9500E+04  1.4615E+04
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
  1.2592E-01  5.1263E-01 -3.4658E-01  4.0126E-02  4.0126E-02
 -3.4658E-01  5.1262E-01  1.2592E-01
 NOTE: The changes in axial length, SPRDLG, just listed
 are significantly greater than those listed previously
 because the springs are softer in this "BEHX04*" model
 than those in the "BEHX01*" model, NOT because there is
 more local deformation of the tank under these spring
 loads. The change in length of the "effective" spring
 caused by local deformation of the propellant tank is
 listed above as the quantity called "DISMAX", which is
 computed from the "BEHX03*" model in which the springs
 are replaced by concentrated loads acting on the tank.

 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  8.4000E+01

 Maximum load in a strut (NSPTOT,KSTMAX,ANGMAX):
 Ring Number  1: Strut no.  2; Circ. angle to strut=  8.4000E+01
 Minimum load in a strut (NSPTOT,KSTMIN,ANGMIN):
 Ring Number  1: Strut no.  3; Circ. angle to strut=  9.6000E+01
 Strut type =  1; CIRCANG(ITYPE)=  8.4000E+01

 Axial loads in the struts at tank support ring no.  2 SPRLOD(K,NRTOT) =
  1.4490E+04  5.9004E+04 -3.9233E+04  5.2810E+03  5.2810E+03
 -3.9233E+04  5.9004E+04  1.4490E+04
 Circ. angles to strut pinned end at tank ring no.   2 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  2 SPRDLG(K,NRTOT) =
  1.2996E-01  5.2923E-01 -3.5189E-01  4.7367E-02  4.7367E-02
 -3.5189E-01  5.2923E-01  1.2996E-01
 NOTE: The changes in axial length, SPRDLG, just listed
 are significantly greater than those listed previously
 because the springs are softer in this "BEHX04*" model
 than those in the "BEHX01*" model, NOT because there is
 more local deformation of the tank under these spring
 loads. The change in length of the "effective" spring
 caused by local deformation of the propellant tank is
 listed above as the quantity called "DISMAX", which is
 computed from the "BEHX03*" model in which the springs
 are replaced by concentrated loads acting on the tank.

 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  2. Circumferential angle =  8.4000E+01
```

```
 Maximum load in a strut (NSPTOT,KSTMAX,ANGMAX):
 Ring Number  2: Strut no.  2; Circ. angle to strut=  8.4000E+01
 Minimum load in a strut (NSPTOT,KSTMIN,ANGMIN):
 Ring Number  2: Strut no.  3; Circ. angle to strut=  9.6000E+01
 Strut type =  2; CIRCANG(ITYPE)=  8.4000E+01

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1327E+02  5.9500E+04 -4.0228E+04

 Length of strut, max. load, min. load for strut type 2; strut ring no.  2
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1216E+02  5.9004E+04 -3.9233E+04

 Maximum and minimum strut loads using the maximum absolute
 value of any strut load associated with the struts attached
 to propellant tank ring number 1 with plus and minus
 signs attached to that maximum absolute load value. This is
 a conservative model, representing approximately the case in
 which both plus and minus values of the user-specified
 g-loading are accounted for. This conservative approach is
 used only if the absolute value of GLATRL is greater than or
 equal to the absolute value of GAXIAL.
 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMX2(JRING),LODMN2(JRING)=  1.1327E+02  5.9500E+04 -5.9500E+04

 Maximum and minimum strut loads using the maximum absolute
 value of any strut load associated with the struts attached
 to propellant tank ring number 2 with plus and minus
 signs attached to that maximum absolute load value. This is
 a conservative model, representing approximately the case in
 which both plus and minus values of the user-specified
 g-loading are accounted for. This conservative approach is
 used only if the absolute value of GLATRL is greater than or
 equal to the absolute value of GAXIAL.
 Length of strut, max. load, min. load for strut type 2; strut ring no.  2
 LENGTH(ITYPE),LODMX2(JRING),LODMN2(JRING)=  1.1216E+02  5.9004E+04 -5.9004E+04

  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 springs
 (pinned struts) attached. 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
 each set of struts (AFT and FORWARD) are pinned to the tank.
 The strut (spring) stiffness takes into account the
 flexibility of the propellant tank wall.



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

 FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
 Total tank mass including "lumped" propellant, TOTMAS=  8.7338E+01
  1.2043E+01(n= 0 circ.waves)
```

```
  1.2685E+01(n= 1 circ.waves)
  1.2765E+01(n= 2 circ.waves)
  1.3334E+01(n= 3 circ.waves)
  1.6999E+01(n= 4 circ.waves)
    1        12.04332      free vibration frequency (cps): FREQ(2 ,1 )
    2        12.68454      free vibration frequency (cps): FREQ(2 ,2 )
    3        12.76531      free vibration frequency (cps): FREQ(2 ,3 )
    4        13.33366      free vibration frequency (cps): FREQ(2 ,4 )

  BEHAVIOR OVER J =  stress component number

 CHAPTER 7: strut stress analysis-BEHX2x, x=1,2; x=load case)
 This is the stress analysis from both BIGBOSOR4 and from
 a PANDA2-type of laminate analysis of the most highly loaded
 strut of the AFT set of struts (struts of type 1). The struts
 are tubes made of composite laminate. The most highly loaded
 strut under both axial tension and equal axial compression is
 analyzed. The tensile/compressive load to which the most
 highly loaded strut is subjected is derived in the computation
 under CHAPTER 5. The five stress "behavioral" constraints
 computed here correspond to:
 1. tension along the fibers of a ply,
 2. compression along the fibers of a ply,
 3. tension transverse to the fibers of a ply,
 4. compression transverse to the fibers of a ply,
 5. in-plane shear stress in a ply.
 Recorded as 5 behavioral constraints are the maximum values
 of each of the five components just listed from tension or
 compression and from a BIGBOSOR4 or a PANDA2-type of model.
 In other words, only the worst (highest) stress component from
 four computations (tension BIGBOSOR4,compression BIGBOSOR4,
 tension PANDA2, compression PANDA2) is recorded as each
 component behavioral constraint.


 BIGBOSOR4 input file for: maximum stress in a  strut of type 1 for load case 2
test.BEHX22

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  5.8808E+04  fiber tension
  1.4707E+04  fiber compres.
  7.0504E+03  transv tension
  0.0000E+00  transv compres
  2.6250E+03  in-plane shear

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  0.0000E+00  fiber tension
  5.4126E+04  fiber compres.
  3.5984E+03  transv tension
  0.0000E+00  transv compres
  1.9559E+03  in-plane shear

 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
 Corresponding maximum stress components from PANDA-type model:
  5.1975E+04  tensile fiber
  1.2586E+04  compressive fiber
```

```
  6.0305E+03  tensile transverse
  0.0000E+00  compressive transverse
  2.5087E+03  in-plane shear


 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
 Corresponding maximum stress components from PANDA-type model:
  0.0000E+00  tensile fiber
  5.2829E+04  compressive fiber
  3.5535E+03  tensile transverse
  0.0000E+00  compressive transverse
  1.9339E+03  in-plane shear

    5        58808.02      maximum stress in material 1: STRES1(2 ,1 )
    6        54125.80      maximum stress in material 1: STRES1(2 ,2 )
    7        7050.408      maximum stress in material 1: STRES1(2 ,3 )
    8       0.1000000E-09  maximum stress in material 1: STRES1(2 ,4 )
    9        2624.995      maximum stress in material 1: STRES1(2 ,5 )

  BEHAVIOR OVER J =  stress component number

 CHAPTER 8: strut stress analysis-BEHX3x, x=1,2; x=load case)
 This is the stress analysis from both BIGBOSOR4 and from
 a PANDA2-type of laminate analysis of the most highly loaded
 strut of the FWD set of struts (struts of type 2). The struts
 are tubes made of composite laminate. The most highly loaded
 strut under both axial tension and equal axial compression is
 analyzed. The tensile/compressive load to which the most
 highly loaded strut is subjected is derived in the computation
 under CHAPTER 5. The five stress "behavioral" constraints
 computed here correspond to:
 1. tension along the fibers of a ply,
 2. compression along the fibers of a ply,
 3. tension transverse to the fibers of a ply,
 4. compression transverse to the fibers of a ply,
 5. in-plane shear stress in a ply.
 Recorded as 5 behavioral constraints are the maximum values
 of each of the five components just listed from tension or
 compression and from a BIGBOSOR4 or a PANDA2-type of model.
 In other words, only the worst (highest) stress component from
 four computations (tension BIGBOSOR4,compression BIGBOSOR4,
 tension PANDA2, compression PANDA2) is recorded as each
 component behavioral constraint.


 BIGBOSOR4 input file for: maximum stress in a strut of type 2 for load case 2
test.BEHX32

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 2 (BEHX3)
  5.4173E+04  fiber tension
  1.3160E+04  fiber compres.
  7.0383E+03  transv tension
  0.0000E+00  transv compres
  2.0025E+03  in-plane shear

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 2 (BEHX3)
```

```
 0.0000E+00  fiber tension
 4.9575E+04  fiber compres.
 3.1570E+03  transv tension
 0.0000E+00  transv compres
 1.4879E+03  in-plane shear

STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
Corresponding maximum stress components from PANDA-type model:
 4.7557E+04  tensile fiber
 1.1388E+04  compressive fiber
 6.2741E+03  tensile transverse
 0.0000E+00  compressive transverse
 1.9208E+03  in-plane shear


STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
Corresponding maximum stress components from PANDA-type model:
 0.0000E+00  tensile fiber
 4.9337E+04  compressive fiber
 3.1495E+03  tensile transverse
 0.0000E+00  compressive transverse
 1.4846E+03  in-plane shear

  10        54172.56      maximum stress in material 2: STRES2(2 ,1 )
  11        49575.05      maximum stress in material 2: STRES2(2 ,2 )
  12        7038.272      maximum stress in material 2: STRES2(2 ,3 )
  13       0.1000000E-09  maximum stress in material 2: STRES2(2 ,4 )
  14        2002.534      maximum stress in material 2: STRES2(2 ,5 )

 BEHAVIOR OVER J =  stress component number
  15       0.1000000E-09  maximum stress in material 3: STRES3(2 ,1 )
  16       0.1000000E-09  maximum stress in material 3: STRES3(2 ,2 )
  17       0.1000000E-09  maximum stress in material 3: STRES3(2 ,3 )
  18       0.1000000E-09  maximum stress in material 3: STRES3(2 ,4 )
  19       0.1000000E-09  maximum stress in material 3: STRES3(2 ,5 )

 BEHAVIOR OVER J =  strut set number (1 for aft-most set)

CHAPTER 9: Buckling of strut as a column
-BEHX5xy, x=1,2 x=strut type; y=1,2 y=load case
Only the most highly axially compressed strut in the strut
set "x" is included in the analysis. Two models are used:
1. a BIGBOSOR4 model of the strut. n = 1 circumferential wave
   corresponds to buckling of the strut as a column. The
   effect of propellant tank flexibility is NOT included in
   this BIGBOSOR4 model.
2. an Euler buckling model of the strut. This model is
   analogous to the column buckling model used in "DEWAR".
   The effect of propellant tank flexibility IS included.
The Euler buckling model usually gives the lower buckling
load factor, mainly because of propellant tank flexibility.
The buckling constraint is based on the minimum column
buckling load factor obtained from the two models just listed.


BIGBOSOR4 input file for: column buckling of strut of type 1 for load case 2
test.BEHX512
```

```
 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -4.0228E+04 -3.9233E+04

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  1.0000E+01
 JCOL,LODMN2(1),LODMN2(2)=  1 -5.9500E+04 -5.9004E+04

 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  1.6495E+00(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  1; Strut length=  1.1327E+02 Load on strut= -5.9500E+04
 Column buckling of strut from Euler formula, COLBUC=  9.9428E-01
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
 the minimum value obtained from BIGBOSOR4 and the Euler model.
   20       0.9942753      buckling of a strut as a column: COLBUK(2 ,1 )


 BIGBOSOR4 input file for: column buckling of strut of type 2 for load case 2
test.BEHX522

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  2 -4.0228E+04 -3.9233E+04

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  1.0000E+01
 JCOL,LODMN2(1),LODMN2(2)=  2 -5.9500E+04 -5.9004E+04

 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  1.8601E+00(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  2; Strut length=  1.1216E+02 Load on strut= -5.9004E+04
 Column buckling of strut from Euler formula, COLBUC=  1.0021E+00
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
 the minimum value obtained from BIGBOSOR4 and the Euler model.
   21        1.002094      buckling of a strut as a column: COLBUK(2 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 10: Buckling of strut as a shell
 -BEHX6xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of a sub-length of the strut. A search
    is conducted over the number n of circumferential waves in
    the buckling mode to determine the critical buckling load
    factor. The effect of propellant tank flexibility is not
    relevant in this analysis.
 2. a PANDA2-type buckling model of the strut. This model is
```

```
   analogous to the shell buckling model used in "DEWAR".
   The effect of propellant tank flexibility is not relevant.

The PANDA2-type buckling model usually gives the lower
buckling load factor, mainly because of the effect of
transverse shear deformation (t.s.d.) and the effect of the
anisotropic terms, D16 and D26, that BIGBOSOR4 cannot handle.
The buckling constraint is based on the minimum shell
buckling load factor obtained from the two models just listed.


BIGBOSOR4 input file for: shell buckling of strut type 1 for load case 2
test.BEHX612

JCOL=strut type; LODMIN=minimum load for GAXIAL
and GLATRL as specified in the input for BEGIN.
JCOL,LODMIN(1),LODMIN(2)=  1 -4.0228E+04 -3.9233E+04

JCOL=strut type; LODMN2=minimum load for GAXIAL
as specified in the input for BEGIN and for either
plus or minus GLATRL with GLATRL amplitude as
specified in the input for BEGIN: GLATRL=  1.0000E+01
JCOL,LODMN2(1),LODMN2(2)=  1 -5.9500E+04 -5.9004E+04

SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
 4.6887E+00(n= 0 circ.waves (from BIGBOSOR4))
 4.6552E+00(n= 1 circ.waves (from BIGBOSOR4))
 4.5543E+00(n= 2 circ.waves (from BIGBOSOR4))
 4.3829E+00(n= 3 circ.waves (from BIGBOSOR4))
 3.6396E+00(n= 4 circ.waves (from BIGBOSOR4))
 3.0576E+00(n= 5 circ.waves (from BIGBOSOR4))
 3.0098E+00(n= 6 circ.waves (from BIGBOSOR4))
 3.2622E+00(n= 7 circ.waves (from BIGBOSOR4))
 3.7283E+00(n= 8 circ.waves (from BIGBOSOR4))
 4.3260E+00(n= 9 circ.waves (from BIGBOSOR4))
 5.0899E+00(n=10 circ.waves (from BIGBOSOR4))
Critical buckling load factor from BIGBOSOR4, SHLBUK=  3.0098E+00
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    6
Strut type  1; Strut length=  1.1327E+02 Load on strut= -5.9500E+04
Column buckling of strut from Euler formula, COLBUC=  9.9428E-01

INFORMATION PERTAINING TO STRUT TYPE 1:

IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (AFT) ARE:
AFT support member. COLUMN buckling results (Euler formula):
 Effective bending stiffness of LAUNCH tube,      EI =  1.3296E+08
 Length of strut from pinned end to pinned end,    L =  1.1327E+02
 Force in strut tending to buckle it,          FORCE = -5.9500E+04
 Euler (column) buckling strain,    pi**2*I/(A*L**2) =  4.4998E-03
 Average strain in the column (g-loads minus temp.),e= -4.5257E-03
 Effective stiffness of strut for lateral (n=1) motions
   including knockdowns for shell and ring flexibility,
                                                  K1 =  1.1607E+05
 Effective stiffness of strut for axial (n=0) motions
  including only knockdown for axisymmetric shell flexibility,
                                                  K0 =  1.8040E+05
 Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                              COLBUC =  9.9428E-01
```

```
 AFT support member.SHELL buckling results(PANDA):
 Calculations for (1=launch tube,2=orbital tube)= 1
  Main diagonal of shell wall constitutive matrix, C(i,i):
    axial stiffness of shell wall,            C(1,1) =  1.1570E+06
    hoop  stiffness of shell wall,            C(2,2) =  4.7805E+05
    shear stiffness of shell wall,            C(3,3) =  2.3458E+05
    axial bending rigidity of shell wall      C(4,4) =  9.5205E+02
    hoop  bending rigidity of shell wall      C(5,5) =  1.2484E+02
    twisting      rigidity of shell wall      C(6,6) =  1.2901E+02
  Force in tube tending to buckle it,          FORCE = -5.9500E+04
  Length of tube used for SHELL buckling model, FLEFF =  2.0521E+01
  Load factor, shell buckling (PANDA analysis),SHLBC2 =  2.0008E+00
  Number of axial half-waves in buckle pattern,     m =     1
  Number of circumferential full waves in mode,     n =     3
  Slope of nodal lines of buckling pattern,    CSLOPE =  0.0000E+00
   22        2.000810      buckling of strut as a shell: SHLBUK(2 ,1 )


 BIGBOSOR4 input file for: shell buckling of strut type 2 for load case 2
test.BEHX622

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  2 -4.0228E+04 -3.9233E+04

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  1.0000E+01
 JCOL,LODMN2(1),LODMN2(2)=  2 -5.9500E+04 -5.9004E+04

 SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
  5.1748E+00(n= 0 circ.waves (from BIGBOSOR4))
  5.1013E+00(n= 1 circ.waves (from BIGBOSOR4))
  4.8852E+00(n= 2 circ.waves (from BIGBOSOR4))
  4.5144E+00(n= 3 circ.waves (from BIGBOSOR4))
  3.3777E+00(n= 4 circ.waves (from BIGBOSOR4))
  2.7776E+00(n= 5 circ.waves (from BIGBOSOR4))
  2.7056E+00(n= 6 circ.waves (from BIGBOSOR4))
  2.9062E+00(n= 7 circ.waves (from BIGBOSOR4))
  3.2862E+00(n= 8 circ.waves (from BIGBOSOR4))
  3.8249E+00(n= 9 circ.waves (from BIGBOSOR4))
  4.4882E+00(n=10 circ.waves (from BIGBOSOR4))
 Critical buckling load factor from BIGBOSOR4, SHLBUK=  2.7056E+00
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    6
 Strut type  2; Strut length=  1.1216E+02 Load on strut= -5.9004E+04
 Column buckling of strut from Euler formula, COLBUC=  1.0021E+00

 INFORMATION PERTAINING TO STRUT TYPE 2:

 IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (FWD) ARE:
 FWD support member. COLUMN buckling results (Euler formula):
  Effective bending stiffness of LAUNCH tube,      EI =  1.4787E+08
  Length of strut from pinned end to pinned end,    L =  1.1216E+02
  Force in strut tending to buckle it,          FORCE = -5.9004E+04
  Euler (column) buckling strain,    pi**2*I/(A*L**2) =  4.7286E-03
  Average strain in the column (g-loads minus temp.),e= -4.7187E-03
```

```
  Effective stiffness of strut for lateral (n=1) motions
    including knockdowns for shell and ring flexibility,
                                                    K1 =  1.1149E+05
  Effective stiffness of strut for axial (n=0) motions
   including only knockdown for axisymmetric shell flexibility,
                                                    K0 =  1.9366E+05
  Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                                COLBUC =  1.0021E+00

 FWD support member.SHELL buckling results(PANDA):
 Calculations for (1=launch tube,2=orbital tube)= 1
  Main diagonal of shell wall constitutive matrix, C(i,i):
    axial stiffness of shell wall,            C(1,1) =  1.1856E+06
    hoop  stiffness of shell wall,            C(2,2) =  5.2255E+05
    shear stiffness of shell wall,            C(3,3) =  1.9496E+05
    axial bending rigidity of shell wall      C(4,4) =  1.0048E+03
    hoop  bending rigidity of shell wall      C(5,5) =  1.2024E+02
    twisting      rigidity of shell wall      C(6,6) =  9.9150E+01
  Force in tube tending to buckle it,          FORCE = -5.9004E+04
  Length of tube used for SHELL buckling model, FLEFF =  2.0829E+01
  Load factor, shell buckling (PANDA analysis),SHLBC2 =  2.0021E+00
  Number of axial half-waves in buckle pattern,     m =     1
  Number of circumferential full waves in mode,     n =     3
  Slope of nodal lines of buckling pattern,    CSLOPE =  0.0000E+00
   23        2.002097      buckling of strut as a shell: SHLBUK(2 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 11: Launch-hold force in a strut
 -BEHX7x, x=1,2; x=load case
 If the propellant tank is oriented vertically in the launch
 vehicle all the struts in each strut set experience the same
 launch-hold force. The launch-hold force in the AFT struts
 may differ from that in the FORWARD struts. Behavioral
 constraints are computed for each set of struts. The
 behavioral constraint is called "FORCE(i,j)", in which i =
 the load case number and j =the strut set number (strut type).

 FORCE(i,j) is computed from a BIGBOSOR4 model of the
 propellant tank with struts (springs) attached to it. The
 spring constants include the effect of the flexibility of the
 propellant tank. The tank is loaded by PRESS, GAXIAL=1g, and
 TNKCOOL. The maximum allowable strut launch-hold force is
 provided for each load case by the End user. The behavioral
 constraint, FORCE(i,j), must be less than the maximum
 allowable, FORCEA(i,j). The End user must supply FORCEA(i,j)
 at a small enough value so that if the struts contain a
 disconnect feature they will not "short out" during the
 launch-hold phase of a mission.

 BIGBOSOR4 input file for propellant tank supported
 by struts (launch-hold condition for load case 2)
test.BEHX72

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1327E+02  6.2445E+03  0.0000E+00

 Length of strut, max. load, min. load for strut type 2; strut ring no.  2
```

```
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1216E+02  1.4494E+04  0.0000E+00
   24        6244.549      launch-hold force in a strut: FORCE(2 ,1 )
   25        14493.60      launch-hold force in a strut: FORCE(2 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 12: Maximum effective stress in the isotropic
 propellant tank - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The model is analogous to that
 described in CHAPTER 4 (*.BEHX03x, x=1,2; x=load case).
 The propellant tank is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The modeling of the concentrated loads that replace
 the springs (struts) is described in CHAPTER 4. The purpose
 of this model is to compute the maximum effective stress in
 the propellant tank, which is assumed to be fabricated of
 isotropic material. This is an "INDIC=3" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case 2:
 maximum stress in the propellant tank from the prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  8.4000E+01 in which JCOL = 1
test.BEHX812

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  8.8381E-01, LOCATW(1)=1000*ISEG+I=  1001
 *******************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  9.9637E-01 fiber tension : matl=1 ,  A , seg=11, node=6 , layer=1 ,z= -1.01 ;FS=  1.00
  2  1.5043E+00 fiber compres.: matl=1 ,  A , seg=13, node=1 , layer=1 ,z= -1.00 ;FS=  1.00
  3  1.5451E+00 transv tension: matl=1 ,  A , seg=14, node=6 , layer=1 ,z=-0.02  ;FS=  1.00
  4  1.4134E+00 transv compres: matl=1 ,  A , seg=13, node=5 , layer=1 ,z= -1.00 ;FS=  1.00
  5  1.2920E+00 effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
  6  1.3905E+00 effect. stress: matl=3 ,  A , seg=13, node=12, layer=3 ,z= 0.05  ;FS=  1.00
  7  9.9471E-01 effect. stress: matl=4 ,  A , seg=14, node=2 , layer=2 ,z= 0.02  ;FS=  1.00
  8  1.3150E+00 effect. stress: matl=5 ,  A , seg=28, node=8 , layer=2 ,z= 0.03  ;FS=  1.00
 **************************************************
 Maximum stress components for Load Case  2 STRESS2(i),i=1,6=
    5.0182E+04     3.3238E+04     3.2361E+04     3.5375E+04     0.0000E+00     5.0266E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 ****************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0266E+04
effect. stress: matl=4 ,  A , seg=14, node=2 , layer=2 ,z= 0.02  ;FS=  1.00
 ****************************************************
   26        50265.78      maximum stress in the propellant tank: TNKSTR(2 ,1 )


 BIGBOSOR4 input file for load case 2:
 maximum stress in the propellant tank from the prebuckling
```

```
 load distribution on the meridian at angle, CIRCANG(JCOL)=  9.6000E+01 in which JCOL = 2
test.BEHX822

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  8.8381E-01, LOCATW(1)=1000*ISEG+I=  1001
 *******************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  1.4877E+00 fiber tension : matl=1 ,  A , seg=10, node=6 , layer=1 ,z= -1.01 ;FS=  1.00
  2  2.0889E+00 fiber compres.: matl=1 ,  A , seg=1 , node=1 , layer=1 ,z= -1.01 ;FS=  1.00
  3  9.9345E-01 transv tension: matl=1 ,  A , seg=14, node=1 , layer=1 ,z= -1.00 ;FS=  1.00
  4  2.0889E+00 transv compres: matl=1 ,  A , seg=1 , node=1 , layer=1 ,z= -1.01 ;FS=  1.00
  5  1.2904E+00 effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.03  ;FS=  1.00
  6  1.9999E+00 effect. stress: matl=3 ,  A , seg=13, node=12, layer=3 ,z= 0.02  ;FS=  1.00
  7  1.3529E+00 effect. stress: matl=4 ,  A , seg=14, node=8 , layer=2 ,z=-0.02  ;FS=  1.00
  8  1.3134E+00 effect. stress: matl=5 ,  A , seg=28, node=8 , layer=2 ,z= 0.03  ;FS=  1.00
 ****************************************************
 Maximum stress components for Load Case  2 STRESS2(i),i=1,6=
    3.3608E+04     2.3935E+04     5.0330E+04     2.3935E+04     0.0000E+00     3.8747E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0330E+04
transv tension: matl=1 ,  A , seg=14, node=1 , layer=1 ,z= -1.00 ;FS=  1.00
 ******************************************************
   27        50329.60      maximum stress in the propellant tank: TNKSTR(2 ,2 )

  BEHAVIOR OVER J =  strut set number (1 for aft-most set)

 CHAPTER 13: Buckling of the isotropic propellant tank
 - BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The 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 is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The modeling of the concentrated loads that replace
 the springs (struts) is described in CHAPTER 4. The purpose
 of this model is to compute the minimum buckling load of
 the propellant tank, which is assumed to be fabricated of
 isotropic material. This is an "INDIC=4" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case 2: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  8.4000E+01 in which JCOL = 1
test.BEHX912

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  4.6796E+01(n=  10 circ.waves); IFAILD= 0
  1.8527E+01(n=  15 circ.waves); IFAILD= 0
```

```
  1.2112E+01(n=  20 circ.waves); IFAILD= 0
  1.0647E+01(n=  25 circ.waves); IFAILD= 0
  1.0819E+01(n=  30 circ.waves); IFAILD= 0
  1.1826E+01(n=  35 circ.waves); IFAILD= 0
  1.3393E+01(n=  40 circ.waves); IFAILD= 0
  1.5395E+01(n=  45 circ.waves); IFAILD= 0
  1.7765E+01(n=  50 circ.waves); IFAILD= 0
  2.0461E+01(n=  55 circ.waves); IFAILD= 0
  2.3457E+01(n=  60 circ.waves); IFAILD= 0
  2.6732E+01(n=  65 circ.waves); IFAILD= 0
  3.0271E+01(n=  70 circ.waves); IFAILD= 0
  3.4061E+01(n=  75 circ.waves); IFAILD= 0
  3.8091E+01(n=  80 circ.waves); IFAILD= 0
  4.2348E+01(n=  85 circ.waves); IFAILD= 0
  4.6821E+01(n=  90 circ.waves); IFAILD= 0
  5.1499E+01(n=  95 circ.waves); IFAILD= 0
  5.6369E+01(n= 100 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.0647E+01
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
   28        10.64742      propellant tank buckling load factor: TNKBUK(2 ,1 )


 BIGBOSOR4 input file for load case 2: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  9.6000E+01 in which JCOL = 2
test.BEHX922

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  6.5585E+01(n=  10 circ.waves); IFAILD= 0
  3.6983E+01(n=  15 circ.waves); IFAILD= 0
  2.1871E+01(n=  20 circ.waves); IFAILD= 0
  1.8664E+01(n=  25 circ.waves); IFAILD= 0
  1.8948E+01(n=  30 circ.waves); IFAILD= 0
  2.0845E+01(n=  35 circ.waves); IFAILD= 0
  2.3755E+01(n=  40 circ.waves); IFAILD= 0
  2.7423E+01(n=  45 circ.waves); IFAILD= 0
  3.1718E+01(n=  50 circ.waves); IFAILD= 0
  3.6564E+01(n=  55 circ.waves); IFAILD= 0
  4.1910E+01(n=  60 circ.waves); IFAILD= 0
  4.7720E+01(n=  65 circ.waves); IFAILD= 0
  5.3966E+01(n=  70 circ.waves); IFAILD= 0
  6.0625E+01(n=  75 circ.waves); IFAILD= 0
  6.7675E+01(n=  80 circ.waves); IFAILD= 0
  7.5097E+01(n=  85 circ.waves); IFAILD= 0
  8.2868E+01(n=  90 circ.waves); IFAILD= 0
  9.0968E+01(n=  95 circ.waves); IFAILD= 0
  9.9376E+01(n= 100 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  1.8664E+01
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
   29        18.66369      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    1.204E+01    free vibration frequency (cps): FREQ(2 ,1 )
  2    1.268E+01    free vibration frequency (cps): FREQ(2 ,2 )
```

```
 3    1.277E+01    free vibration frequency (cps): FREQ(2 ,3 )
 4    1.333E+01    free vibration frequency (cps): FREQ(2 ,4 )
 5    5.881E+04    maximum stress in material 1: STRES1(2 ,1 )
 6    5.413E+04    maximum stress in material 1: STRES1(2 ,2 )
 7    7.050E+03    maximum stress in material 1: STRES1(2 ,3 )
 8    1.000E-10    maximum stress in material 1: STRES1(2 ,4 )
 9    2.625E+03    maximum stress in material 1: STRES1(2 ,5 )
10    5.417E+04    maximum stress in material 2: STRES2(2 ,1 )
11    4.958E+04    maximum stress in material 2: STRES2(2 ,2 )
12    7.038E+03    maximum stress in material 2: STRES2(2 ,3 )
13    1.000E-10    maximum stress in material 2: STRES2(2 ,4 )
14    2.003E+03    maximum stress in material 2: STRES2(2 ,5 )
15    1.000E-10    maximum stress in material 3: STRES3(2 ,1 )
16    1.000E-10    maximum stress in material 3: STRES3(2 ,2 )
17    1.000E-10    maximum stress in material 3: STRES3(2 ,3 )
18    1.000E-10    maximum stress in material 3: STRES3(2 ,4 )
19    1.000E-10    maximum stress in material 3: STRES3(2 ,5 )
20    9.943E-01    buckling of a strut as a column: COLBUK(2 ,1 )
21    1.002E+00    buckling of a strut as a column: COLBUK(2 ,2 )
22    2.001E+00    buckling of strut as a shell: SHLBUK(2 ,1 )
23    2.002E+00    buckling of strut as a shell: SHLBUK(2 ,2 )
24    6.245E+03    launch-hold force in a strut: FORCE(2 ,1 )
25    1.449E+04    launch-hold force in a strut: FORCE(2 ,2 )
26    5.027E+04    maximum stress in the propellant tank: TNKSTR(2 ,1 )
27    5.033E+04    maximum stress in the propellant tank: TNKSTR(2 ,2 )
28    1.065E+01    propellant tank buckling load factor: TNKBUK(2 ,1 )
29    1.866E+01    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    3.610E-03  (FREQ(2 ,1 )/FREQA(2 ,1 )) / FREQF(2 ,1 )-1; F.S.=  1.20
 2    5.705E-02  (FREQ(2 ,2 )/FREQA(2 ,2 )) / FREQF(2 ,2 )-1; F.S.=  1.20
 3    6.378E-02  (FREQ(2 ,3 )/FREQA(2 ,3 )) / FREQF(2 ,3 )-1; F.S.=  1.20
 4    1.111E-01  (FREQ(2 ,4 )/FREQA(2 ,4 )) / FREQF(2 ,4 )-1; F.S.=  1.20
 5    5.936E-01  (STRES1A(2 ,1 )/STRES1(2 ,1 )) / STRES1F(2 ,1 )-1; F.S.=  1.50
 6    2.898E-01  (STRES1A(2 ,2 )/STRES1(2 ,2 )) / STRES1F(2 ,2 )-1; F.S.=  1.50
 7   -1.760E-03  (STRES1A(2 ,3 )/STRES1(2 ,3 )) / STRES1F(2 ,3 )-1; F.S.=  1.50
 8    5.975E-01  (STRES1A(2 ,5 )/STRES1(2 ,5 )) / STRES1F(2 ,5 )-1; F.S.=  1.50
 9    7.299E-01  (STRES2A(2 ,1 )/STRES2(2 ,1 )) / STRES2F(2 ,1 )-1; F.S.=  1.50
10    4.082E-01  (STRES2A(2 ,2 )/STRES2(2 ,2 )) / STRES2F(2 ,2 )-1; F.S.=  1.50
11   -3.868E-05  (STRES2A(2 ,3 )/STRES2(2 ,3 )) / STRES2F(2 ,3 )-1; F.S.=  1.50
12    1.094E+00  (STRES2A(2 ,5 )/STRES2(2 ,5 )) / STRES2F(2 ,5 )-1; F.S.=  1.50
13   -5.725E-03  (COLBUK(2 ,1 )/COLBUKA(2 ,1 )) / COLBUKF(2 ,1 )-1; F.S.=  1.00
14    2.094E-03  (COLBUK(2 ,2 )/COLBUKA(2 ,2 )) / COLBUKF(2 ,2 )-1; F.S.=  1.00
15    4.052E-04  (SHLBUK(2 ,1 )/SHLBUKA(2 ,1 )) / SHLBUKF(2 ,1 )-1; F.S.=  2.00
16    1.048E-03  (SHLBUK(2 ,2 )/SHLBUKA(2 ,2 )) / SHLBUKF(2 ,2 )-1; F.S.=  2.00
17    1.402E+00  (FORCEA(2 ,1 )/FORCE(2 ,1 )) / FORCEF(2 ,1 )-1; F.S.=  1.00
18    3.494E-02  (FORCEA(2 ,2 )/FORCE(2 ,2 )) / FORCEF(2 ,2 )-1; F.S.=  1.00
19   -5.288E-03  (TNKSTRA(2 ,1 )/TNKSTR(2 ,1 )) / TNKSTRF(2 ,1 )-1; F.S.=  1.00
```

```
20   -6.549E-03  (TNKSTRA(2 ,2 )/TNKSTR(2 ,2 )) / TNKSTRF(2 ,2 )-1; F.S.=  1.00
21    9.647E+00  (TNKBUK(2 ,1 )/TNKBUKA(2 ,1 )) / TNKBUKF(2 ,1 )-1; F.S.=  1.00
22    1.766E+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    1.021E+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.   CURRENT
NO.     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    5.000E+00  length of end fitting attached to tank ring: FITTNK(1 )
16    5.000E+00  length of end fitting attached to tank ring: FITTNK(2 )
17    1.000E+07  axial "EA" stiffness of tank-end strut fitting: FEATNK(1 )
18    1.000E+07  axial "EA" stiffness of tank-end strut fitting: FEATNK(2 )
19    1.000E-05  Coef.of thermal expansion of tank end fitting: ALFITT(1 )
20    1.000E-05  Coef.of thermal expansion of tank end fitting: ALFITT(2 )
21    5.000E+00  length of strut end fitting attached to "ground": FITVEH(1 )
22    5.000E+00  length of strut end fitting attached to "ground": FITVEH(2 )
23    1.000E+07  axial "EA" stiffness of "ground" end strut fitting: FEAVEH(1 )
24    1.000E+07  axial "EA" stiffness of "ground" end strut fitting: FEAVEH(2 )
25    1.000E-05  coef.of thermal expan. of "ground" end fitting: ALFITV(1 )
26    1.000E-05  coef.of thermal expan. of "ground" end fitting: ALFITV(2 )
27    1.000E-01  length factor for strut buckling as a shell: FACLEN(1 )
28    1.000E-01  length factor for strut buckling as a shell: FACLEN(2 )
29   -1.000E+02  Average strut temperature minus ambient: DTSUP(1 )
30   -1.000E+02  Average strut temperature minus ambient: DTSUP(2 )
31    2.000E+00  outer diam.of the orbital tube assembly: ODINNR(1 )
32    2.000E+00  outer diam.of the orbital tube assembly: ODINNR(2 )
33    4.000E+00  Length of the orbital tube assembly: FLINNR(1 )
34    4.000E+00  Length of the orbital tube assembly: FLINNR(2 )
```

```
35     1.000E+07  hoop modulus of the tank ring: TRNGE(1 )
36     1.000E-05  coef.of thermal expansion of the tank ring: ALRNGT(1 )
37     2.100E+07  modulus in the fiber direction: E1(1 )
38     1.600E+06  modulus transverse to fibers: E2(1 )
39     6.790E+05  in-plane shear modulus: G12(1 )
40     2.300E-02  small Poisson's ratio: NU(1 )
41     6.270E+05  x-z out-of-plane shear modulus: G13(1 )
42     3.340E+05  y-z out-of-plane shear modulus: G23(1 )
43     1.000E-06  coef.of thermal expansion along fibers: ALPHA1(1 )
44     1.000E-05  coef.of thermal expan.transverse to fibers: ALPHA2(1 )
45     1.700E+02  curing delta temperature (positive): TEMTUR(1 )
46     7.270E-03  conductivity along the fibers: COND1(1 )
47     4.370E-03  conductivity transverse to fibers: COND2(1 )
48     5.700E-02  weight density of the material: DENSTY(1 )
49     5.000E-01  objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
50     1.000E+01  normalizing empty tank mass: TNKNRM
51     2.000E-03  normalizing total strut conductance: CONNRM
PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR.   CURRENT
NO.     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.   CURRENT
NO.     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     1.406E+05  maximum allowable stress in material 3: STRES3A(1 ,1 )
30     1.406E+05  maximum allowable stress in material 3: STRES3A(2 ,1 )
31     1.047E+05  maximum allowable stress in material 3: STRES3A(1 ,2 )
32     1.047E+05  maximum allowable stress in material 3: STRES3A(2 ,2 )
33     1.056E+04  maximum allowable stress in material 3: STRES3A(1 ,3 )
34     1.056E+04  maximum allowable stress in material 3: STRES3A(2 ,3 )
35     1.453E+04  maximum allowable stress in material 3: STRES3A(1 ,4 )
36     1.453E+04  maximum allowable stress in material 3: STRES3A(2 ,4 )
37     6.290E+03  maximum allowable stress in material 3: STRES3A(1 ,5 )
38     6.290E+03  maximum allowable stress in material 3: STRES3A(2 ,5 )
39     1.000E+00  allowable for column buckling of strut: COLBUKA(1 ,1 )
40     1.000E+00  allowable for column buckling of strut: COLBUKA(2 ,1 )
41     1.000E+00  allowable for column buckling of strut: COLBUKA(1 ,2 )
42     1.000E+00  allowable for column buckling of strut: COLBUKA(2 ,2 )
43     1.000E+00  allowable for shell buckling of strut: SHLBUKA(1 ,1 )
44     1.000E+00  allowable for shell buckling of strut: SHLBUKA(2 ,1 )
45     1.000E+00  allowable for shell buckling of strut: SHLBUKA(1 ,2 )
46     1.000E+00  allowable for shell buckling of strut: SHLBUKA(2 ,2 )
47     1.500E+04  maximum allowable launch-hold force in strut: FORCEA(1 ,1 )
48     1.500E+04  maximum allowable launch-hold force in strut: FORCEA(2 ,1 )
49     1.500E+04  maximum allowable launch-hold force in strut: FORCEA(1 ,2 )
50     1.500E+04  maximum allowable launch-hold force in strut: FORCEA(2 ,2 )
51     5.000E+04  allowable for propellant tank stress: TNKSTRA(1 ,1 )
52     5.000E+04  allowable for propellant tank stress: TNKSTRA(2 ,1 )
53     5.000E+04  allowable for propellant tank stress: TNKSTRA(1 ,2 )
54     5.000E+04  allowable for propellant tank stress: TNKSTRA(2 ,2 )
55     1.000E+00  allowable for propellant tank buckling: TNKBUKA(1 ,1 )
56     1.000E+00  allowable for propellant tank buckling: TNKBUKA(2 ,1 )
57     1.000E+00  allowable for propellant tank buckling: TNKBUKA(1 ,2 )
58     1.000E+00  allowable for propellant tank buckling: TNKBUKA(2 ,2 )
PARAMETERS WHICH ARE FACTORS OF SAFETY

VAR.   CURRENT
NO.     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     1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,1 )
30     1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,1 )
31     1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,2 )
32     1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,2 )
33     1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,3 )
34     1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,3 )
35     1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,4 )
36     1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,4 )
37     1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,5 )
38     1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,5 )
39     1.000E+00  factor of safety for Euler strut buckling: COLBUKF(1 ,1 )
40     1.000E+00  factor of safety for Euler strut buckling: COLBUKF(2 ,1 )
41     1.000E+00  factor of safety for Euler strut buckling: COLBUKF(1 ,2 )
42     1.000E+00  factor of safety for Euler strut buckling: COLBUKF(2 ,2 )
43     2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(1 ,1 )
44     2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(2 ,1 )
45     2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(1 ,2 )
46     2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(2 ,2 )
47     1.000E+00  factor of safety for launch-hold force: FORCEF(1 ,1 )
48     1.000E+00  factor of safety for launch-hold force: FORCEF(2 ,1 )
49     1.000E+00  factor of safety for launch-hold force: FORCEF(1 ,2 )
50     1.000E+00  factor of safety for launch-hold force: FORCEF(2 ,2 )
51     1.000E+00  factor of safety for tank stress: TNKSTRF(1 ,1 )
52     1.000E+00  factor of safety for tank stress: TNKSTRF(2 ,1 )
53     1.000E+00  factor of safety for tank stress: TNKSTRF(1 ,2 )
54     1.000E+00  factor of safety for tank stress: TNKSTRF(2 ,2 )
55     1.000E+00  factor of safety for tank buckling: TNKBUKF(1 ,1 )
56     1.000E+00  factor of safety for tank buckling: TNKBUKF(2 ,1 )
57     1.000E+00  factor of safety for tank buckling: TNKBUKF(1 ,2 )
58     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:

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

For further information about files used and generated
```

```
 during operation of GENOPT, give the command HELPG FILES.

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

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

Table 8b: For the same optimized design, that obtained with the "constant density" option (addbosor4.regular and bosdec.tank) (a different optimum design from that listed in Table 8):
Listed below is the "test.diff" file obtained from the command:
"diff ..genoptcase/test.OPM ..work3/test.constdensity.opm > test.diff"
in which the ..genoptcase/test.OPM file is generated via the "varying density" option (addbosor4.density.var and bosdec.density.var), and the ..work3/test.constdensity.opm file is generated with the "constant density" option (addbosor4.regular and bosdec.tank). Notice that the "shell" vibration eigenvalues (n = 2,3,4 circ. waves; Figs. 22b,c,d) hardly depend at all on which of the two different propellant "lumping" density models is used.

Load Case 1:

```
458,467c458,467
<  Total tank mass including "lumped" propellant, TOTMAS=  8.7453E+01
<   1.3050E+01(n= 0 circ.waves)
<   1.2902E+01(n= 1 circ.waves)
<   1.3055E+01(n= 2 circ.waves)
<   1.3397E+01(n= 3 circ.waves)
<   1.7007E+01(n= 4 circ.waves)
<     1        13.04973      free vibration frequency (cps): FREQ(1 ,1 )
<     2        12.90214      free vibration frequency (cps): FREQ(1 ,2 )
<     3        13.05469      free vibration frequency (cps): FREQ(1 ,3 )
<     4        13.39659      free vibration frequency (cps): FREQ(1 ,4 )
---
>  Total tank mass including "lumped" propellant, TOTMAS=  1.0230E+02
>   1.2042E+01(n= 0 circ.waves)
>   1.2081E+01(n= 1 circ.waves)
>   1.3046E+01(n= 2 circ.waves)
>   1.3395E+01(n= 3 circ.waves)
>   1.7006E+01(n= 4 circ.waves)
>     1        12.04152      free vibration frequency (cps): FREQ(1 ,1 )
>     2        12.08118      free vibration frequency (cps): FREQ(1 ,2 )
>     3        13.04610      free vibration frequency (cps): FREQ(1 ,3 )
>     4        13.39474      free vibration frequency (cps): FREQ(1 ,4 )
1057,1058c1057,1058
<   1    1.305E+01    free vibration frequency (cps): FREQ(1 ,1 )
<   2    1.290E+01    free vibration frequency (cps): FREQ(1 ,2 )
---
>   1    1.204E+01    free vibration frequency (cps): FREQ(1 ,1 )
>   2    1.208E+01    free vibration frequency (cps): FREQ(1 ,2 )
1060c1060
<   4    1.340E+01    free vibration frequency (cps): FREQ(1 ,4 )
---
>   4    1.339E+01    free vibration frequency (cps): FREQ(1 ,4 )
```

```
1098,1101c1098,1101
<   1    8.748E-02  (FREQ(1 ,1 )/FREQA(1 ,1 )) / FREQF(1 ,1 )-1; F.S.=  1.20
<   2    7.518E-02  (FREQ(1 ,2 )/FREQA(1 ,2 )) / FREQF(1 ,2 )-1; F.S.=  1.20
<   3    8.789E-02  (FREQ(1 ,3 )/FREQA(1 ,3 )) / FREQF(1 ,3 )-1; F.S.=  1.20
<   4    1.164E-01  (FREQ(1 ,4 )/FREQA(1 ,4 )) / FREQF(1 ,4 )-1; F.S.=  1.20
---
>   1    3.460E-03  (FREQ(1 ,1 )/FREQA(1 ,1 )) / FREQF(1 ,1 )-1; F.S.=  1.20
>   2    6.765E-03  (FREQ(1 ,2 )/FREQA(1 ,2 )) / FREQF(1 ,2 )-1; F.S.=  1.20
>   3    8.717E-02  (FREQ(1 ,3 )/FREQA(1 ,3 )) / FREQF(1 ,3 )-1; F.S.=  1.20
>   4    1.162E-01  (FREQ(1 ,4 )/FREQA(1 ,4 )) / FREQF(1 ,4 )-1; F.S.=  1.20
```

Load Case 2:

```
1537,1546c1537,1546
<  Total tank mass including "lumped" propellant, TOTMAS=  8.7453E+01
<   1.3073E+01(n= 0 circ.waves)
<   1.3031E+01(n= 1 circ.waves)
<   1.3064E+01(n= 2 circ.waves)
<   1.3400E+01(n= 3 circ.waves)
<   1.7008E+01(n= 4 circ.waves)
<     1        13.07314      free vibration frequency (cps): FREQ(2 ,1 )
<     2        13.03073      free vibration frequency (cps): FREQ(2 ,2 )
<     3        13.06399      free vibration frequency (cps): FREQ(2 ,3 )
<     4        13.39973      free vibration frequency (cps): FREQ(2 ,4 )
---
>  Total tank mass including "lumped" propellant, TOTMAS=  1.0230E+02
>   1.2063E+01(n= 0 circ.waves)
>   1.2194E+01(n= 1 circ.waves)
>   1.3055E+01(n= 2 circ.waves)
>   1.3398E+01(n= 3 circ.waves)
>   1.7007E+01(n= 4 circ.waves)
>     1        12.06301      free vibration frequency (cps): FREQ(2 ,1 )
>     2        12.19379      free vibration frequency (cps): FREQ(2 ,2 )
>     3        13.05541      free vibration frequency (cps): FREQ(2 ,3 )
>     4        13.39788      free vibration frequency (cps): FREQ(2 ,4 )
2117,2118c2117,2118
<   1    1.307E+01    free vibration frequency (cps): FREQ(2 ,1 )
<   2    1.303E+01    free vibration frequency (cps): FREQ(2 ,2 )
---
>   1    1.206E+01    free vibration frequency (cps): FREQ(2 ,1 )
>   2    1.219E+01    free vibration frequency (cps): FREQ(2 ,2 )
2158,2161c2158,2161
<   1    8.943E-02  (FREQ(2 ,1 )/FREQA(2 ,1 )) / FREQF(2 ,1 )-1; F.S.=  1.20
<   2    8.589E-02  (FREQ(2 ,2 )/FREQA(2 ,2 )) / FREQF(2 ,2 )-1; F.S.=  1.20
<   3    8.867E-02  (FREQ(2 ,3 )/FREQA(2 ,3 )) / FREQF(2 ,3 )-1; F.S.=  1.20
<   4    1.166E-01  (FREQ(2 ,4 )/FREQA(2 ,4 )) / FREQF(2 ,4 )-1; F.S.=  1.20
---
>   1    5.251E-03  (FREQ(2 ,1 )/FREQA(2 ,1 )) / FREQF(2 ,1 )-1; F.S.=  1.20
>   2    1.615E-02  (FREQ(2 ,2 )/FREQA(2 ,2 )) / FREQF(2 ,2 )-1; F.S.=  1.20
>   3    8.795E-02  (FREQ(2 ,3 )/FREQA(2 ,3 )) / FREQF(2 ,3 )-1; F.S.=  1.20
>   4    1.165E-01  (FREQ(2 ,4 )/FREQA(2 ,4 )) / FREQF(2 ,4 )-1; F.S.=  1.20
================================================================================
```

Table 9 Input data for the GENOPT processor, CHANGE, by means of which optimized designs can be archived (test.CHG file).
(These data are provided by the End user, long propellant tank)

```
=========================================================================
      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, . .)
  0.5188000E-01 $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         2      $ Number of parameter to change (1, 2, 3, . .)
  0.4527000E-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, . .)
  0.5320000E-01 $ New value of the parameter
      Y         $ Want to change any other parameters in this set?
         4      $ Number of parameter to change (1, 2, 3, . .)
   3.639000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         5      $ Number of parameter to change (1, 2, 3, . .)
   4.446000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         6      $ Number of parameter to change (1, 2, 3, . .)
  0.1028000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         7      $ Number of parameter to change (1, 2, 3, . .)
  0.9806000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
  0.1762000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         9      $ Number of parameter to change (1, 2, 3, . .)
  0.9806000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        10      $ Number of parameter to change (1, 2, 3, . .)
   150.0000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        11      $ Number of parameter to change (1, 2, 3, . .)
   450.0000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        12      $ Number of parameter to change (1, 2, 3, . .)
   89.39000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        13      $ Number of parameter to change (1, 2, 3, . .)
   508.5000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
```

```
     14        $ Number of parameter to change (1, 2, 3, . .)
 6.000000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     15        $ Number of parameter to change (1, 2, 3, . .)
 6.000000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     16        $ Number of parameter to change (1, 2, 3, . .)
 45.00000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     17        $ Number of parameter to change (1, 2, 3, . .)
 45.00000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     18        $ Number of parameter to change (1, 2, 3, . .)
 6.753000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     19        $ Number of parameter to change (1, 2, 3, . .)
 6.856000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     20        $ Number of parameter to change (1, 2, 3, . .)
 0.000001      $ New value of the parameter
    Y          $ Want to change any other parameters in this set?
     21        $ Number of parameter to change (1, 2, 3, . .)
 0.000001      $ New value of the parameter
    Y          $ Want to change any other parameters in this set?
     22        $ Number of parameter to change (1, 2, 3, . .)
 0.000001      $ New value of the parameter
    Y          $ Want to change any other parameters in this set?
     23        $ Number of parameter to change (1, 2, 3, . .)
 0.000001      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     24        $ 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?
     25        $ Number of parameter to change (1, 2, 3, . .)
0.8555000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     26        $ Number of parameter to change (1, 2, 3, . .)
0.3498000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     27        $ Number of parameter to change (1, 2, 3, . .)
1.7490000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
     28        $ Number of parameter to change (1, 2, 3, . .)
0.7271000E-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, . .)
0.7271000E-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, . .)
0.7271000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      31       $ Number of parameter to change (1, 2, 3, . .)
0.7271000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      32       $ Number of parameter to change (1, 2, 3, . .)
0.7271000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      33       $ Number of parameter to change (1, 2, 3, . .)
0.7271000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      34       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      35       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      36       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      37       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      38       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      39       $ Number of parameter to change (1, 2, 3, . .)
0.7250000E-02 $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      40       $ Number of parameter to change (1, 2, 3, . .)
 19.92000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      41       $ Number of parameter to change (1, 2, 3, . .)
-19.92000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      42       $ Number of parameter to change (1, 2, 3, . .)
 10.00000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      43       $ Number of parameter to change (1, 2, 3, . .)
-10.00000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      44       $ Number of parameter to change (1, 2, 3, . .)
 60.42000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      45       $ Number of parameter to change (1, 2, 3, . .)
-60.42000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
```

```
      46       $ Number of parameter to change (1, 2, 3, . .)
   15.37000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      47       $ Number of parameter to change (1, 2, 3, . .)
  -15.37000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      48       $ Number of parameter to change (1, 2, 3, . .)
   10.00000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      49       $ Number of parameter to change (1, 2, 3, . .)
  -10.00000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      50       $ Number of parameter to change (1, 2, 3, . .)
   64.48000    $ New value of the parameter
     y         $ Want to change any other parameters in this set?
      51       $ Number of parameter to change (1, 2, 3, . .)
  -64.48000    $ 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 10 Input data for the GENOPT processor, CHOOSEPLOT (test.CPL file). This type of input leads to a plot analogous to those displayed in Fig 30 or Fig. 31 or Fig. 84 or Fig. 85, for examples

```
================================================================================
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) ?
        12      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        25      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        26      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        30      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        31      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        36      $ 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) ?
        50      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        51      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        52      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        54      $ Choose a margin to be plotted v. iterations (1,2,3,..)
      y         $ Any more margins to be plotted (Y or N) ?
        55      $ 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.
================================================================================
```

Table 11 Valid input files for the "stand-alone" version of BIGBOSOR4 Generated automatically by the GENOPT processor, OPTIMIZE, run with the analysis type index, ITYPE = 2, in the test.OPT file (input for MAINSETUP)

```
THE FOLLOWING FILES ARE GENERATED IF itype = 2 IN THE *.OPT FILE,
THAT IS, IF THE "FIXED DESIGN OPTION" IS USED in *.OPT.
(Each of these files contains valid input data for BIGBOSOR4.
NOTE: The following list was generated with an earlier version
of the "tank" capability that existed on Nov. 17, 2011, but the
file names, test.BEHX011, test.BEHX012, etc. remain the same.)

1   -rw-rw-r-- 1 bush bush 54216 Nov 17 07:29 test.BEHX011
2   -rw-rw-r-- 1 bush bush 54216 Nov 17 07:29 test.BEHX012
3   -rw-rw-r-- 1 bush bush  5130 Nov 17 07:29 test.BEHX021
4   -rw-rw-r-- 1 bush bush  5130 Nov 17 07:29 test.BEHX022
5   -rw-rw-r-- 1 bush bush 60605 Nov 17 07:29 test.BEHX031
6   -rw-rw-r-- 1 bush bush 60605 Nov 17 07:29 test.BEHX032
7   -rw-rw-r-- 1 bush bush 54216 Nov 17 07:29 test.BEHX041
8   -rw-rw-r-- 1 bush bush 54216 Nov 17 07:29 test.BEHX042

9   -rw-rw-r-- 1 bush bush 51560 Nov 17 07:29 test.BEHX11
10  -rw-rw-r-- 1 bush bush 51560 Nov 17 07:29 test.BEHX12
11  -rw-rw-r-- 1 bush bush  4942 Nov 17 07:29 test.BEHX21
12  -rw-rw-r-- 1 bush bush  4942 Nov 17 07:29 test.BEHX22
13  -rw-rw-r-- 1 bush bush  5176 Nov 17 07:29 test.BEHX31
14  -rw-rw-r-- 1 bush bush  5176 Nov 17 07:29 test.BEHX32

15  -rw-rw-r-- 1 bush bush  5119 Nov 17 07:29 test.BEHX511
16  -rw-rw-r-- 1 bush bush  5119 Nov 17 07:29 test.BEHX512
17  -rw-rw-r-- 1 bush bush  5353 Nov 17 07:29 test.BEHX521
18  -rw-rw-r-- 1 bush bush  5353 Nov 17 07:29 test.BEHX522
19  -rw-rw-r-- 1 bush bush  5406 Nov 17 07:29 test.BEHX611
20  -rw-rw-r-- 1 bush bush  5406 Nov 17 07:29 test.BEHX612
21  -rw-rw-r-- 1 bush bush  5640 Nov 17 07:29 test.BEHX621
22  -rw-rw-r-- 1 bush bush  5640 Nov 17 07:29 test.BEHX622

23  -rw-rw-r-- 1 bush bush 93086 Nov 17 07:29 test.BEHX71
24  -rw-rw-r-- 1 bush bush 93086 Nov 17 07:29 test.BEHX72

25  -rw-rw-r-- 1 bush bush 99487 Nov 17 07:29 test.BEHX811
26  -rw-rw-r-- 1 bush bush 99487 Nov 17 07:29 test.BEHX812
27  -rw-rw-r-- 1 bush bush 99487 Nov 17 07:29 test.BEHX821
28  -rw-rw-r-- 1 bush bush 99487 Nov 17 07:29 test.BEHX822
29  -rw-rw-r-- 1 bush bush 99662 Nov 17 07:29 test.BEHX911
30  -rw-rw-r-- 1 bush bush 99662 Nov 17 07:29 test.BEHX912
```

```
31  -rw-rw-r-- 1 bush bush 99662 Nov 17 07:29 test.BEHX921
32  -rw-rw-r-- 1 bush bush 99662 Nov 17 07:29 test.BEHX922

---------------------------------------------------------

What the *.BEHXxxx files are for:

FILES 1 - 8, BEHX i j k:

i = 0 means "preliminary model used in SUBROUTINE STRUCT"
j = 1 means "propellant tank supported by struts"
j = 2 means "get axial stiffness of a single launch tube
j = 3 means "propellant tank with struts replaced by
             concentrated loads"
j = 4 means "propellant tank with struts, second approximation"
k = 1 means "Load Case 1"; k = 2 means "Load Case 2"


FILES 9 - 14, BEHX j k:

j = 1 means "vibration frequencies and mode shapes"
j = 2 means "5 maximum stress components in composite strut type 1
j = 3 means "5 maximum stress components in composite strut type 2
k = 1 means "Load Case 1"; k = 2 means "Load Case 2"


FILES 15 - 22, BEHX i j k:

i = 5 means "strut buckling as a column"
i = 6 means "strut buckling as a shell"
j = 1 means "strut type 1"
j = 2 means "strut type 2"
k = 1 means "Load Case 1"; k = 2 means "Load Case 2"


FILES 23 and 24, BEHX j k:

j = 7 means "propellant tank supported by struts, launch-hold
             condition
k = 1 means "Load Case 1"; k = 2 means "Load Case 2"


FILES 25 - 32, BEHX i j k:

i = 8 means "maximum stress in the propellant tank"
i = 9 means "buckling of the propellant tank"
j = 1 means "prebuckling stress distribution on meridian no. 1"
j = 2 means "prebuckling stress distribution on meridian no. 2"
```

k = 1 means "Load Case 1"; k = 2 means "Load Case 2"

****
NOTE: THE FOLLOWING CAN BE DONE ONLY IF ITYPE = 2 IN THE *.opt
file, that is, only if the *.OPT file contains the line:
 2 $ Choose type of analysis (1=opt., 2=fixed, 3=sensit.) ITYPE
****

HOW TO OPTAIN PLOTS OF THE PROPELLANT TANK WITH ATTACHED STRUTS
(Input from the End user is printed in 16pt **boldface**.)

1. Elevation view from the file called "test.PL8":

'rm' test.ps
/home/progs/bin/plotps.x86_64 < test.PL8 > test.ps
gv test.ps (Note: "gv" means "ghost view")

2. Plan view of the aft struts from the file, "test.PL6":

'rm' test.ps
/home/progs/bin/plotps.x86_64 < test.PL6 > test.ps
gv test.ps

3. Plan view of the forward struts from the file, "test.PL7":

'rm' test.ps
/home/progs/bin/plotps.x86_64 < test.PL7 > test.ps
gv test.ps

NOTE: The End user commands typed above are based on the assumption that the plotting utility called "plotps.x86_64" is stored in the directory, /home/progs/bin, which is the case on the writer's computer.

HOW TO OBTAIN PLOTS FROM BIGBOSOR4 WITH USE OF THE test.BEHXxxx
FILES AS INPUT FILES FOR BIGBOSOR4

1, Establish a working directory for BIGBOSOR4 executions:

mkdir /home/progs/work5 (NOTE: "home/progs" is the "home" directory on the writer's computer)

2. Copy one of the test.BEHX* files to the working directory, changing the suffix, .BEHX*, to .ALL because all BIGBOSOR4 input files must have the suffix, .ALL .

cp /home/progs/genoptcase/test.BEHX12   /home/progs/work5/test.ALL

(test.BEHX12 is a BIGBOSOR4 input file for free vibration
 of the spring-supported, propellant-filled tank under Load Case 2.)

3. Go to the working directory for BIGBOSOR4 runs.

cd /home/progs/work5

4. Activate the BIGBOSOR4 commands:

bigbosor4log

(You will see on your screen the following:)

```
--------------------------------------------------
BIGBOSOR4 COMMANDS HAVE BEEN ACTIVATED.

The BIGBOSOR4 commands, in the general order in which
you would probably use them, are:

help4           (get information on BOSOR4.)
input           (you provide segment-by-seg. input)
assemble        (concatenates segment data files)
bigbosorall     (batch run of pre, main, post proc.)
bosorplot       (batch run for generating plot files)
resetup         (input for restart run, same model)
bigrestart              (batch run of main & postprocessors)
cleanup         (delete all except for .DOC file)
getsegs         (generate segment files from .DOC)
modify          (modify a segment file)
------------------------------------------------------
```

5. Execute BIGBOSOR4 with the file, test.ALL, as input.

bigbosorall

Case Name: **test**

6. Inspect the output file from the execution of BIGBOSOR4.

vi test.OUT

(for vibration and buckling cases search for the string,
"EIGENVALUE(", including the "(" in that string. You will
see the following on your screen; ; NOTE..These are results from a
Nov.2011 version of “tank”:)

```
----------------------------------------------------------
 VIBRATION FREQUENCIES (CPS) FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =       1

 EIGENVALUES =
    1.19982E+01    1.40950E+01
```

```
 JUST LEFT SUBROUTINE OUT2

 **** CRITICAL EIGENVALUE AND WAVENUMBER ****
 EIGCRT=  1.1998E+01; NO. OF CIRC. WAVES, NWVCRT=    1
 ****************************************************

 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 ========================================
    1.2000E+01(     0)
    1.1998E+01(     1)
 ========================================
---------------------------------------------------------------
(The two eigenvalues for n = 0 circumferential waves are
listed somewhat above those just given as follows:)
---------------------------------------------------------------
 VIBRATION FREQUENCIES (CPS) FOLLOW
 CIRCUMFERENTIAL WAVE NUMBER, N =       0

 EIGENVALUES =
    1.19996E+01    1.83293E+01
---------------------------------------------------------------

(The four free vibration eigenvalues, 2 for n=0 and
2 for n=1, correspond to the first four behavioral
constraints in the GENOPT output corresponding to
Load Case 2:)
---------------------------------------------------------------------
 ***** RESULTS FOR LOAD SET NO.  2  ******
 PARAMETERS WHICH DESCRIBE BEHAVIOR (e.g. stress, buckling load)

 BEH.   CURRENT
 NO.     VALUE            DEFINITION
  1    1.200E+01    free vibration frequency (cps): FREQ(2 ,1 )
  2    1.200E+01    free vibration frequency (cps): FREQ(2 ,2 )
  3    1.833E+01    free vibration frequency (cps): FREQ(2 ,3 )
  4    1.409E+01    free vibration frequency (cps): FREQ(2 ,4 )
---------------------------------------------------------------------

(These four behaviors correspond to the first four margins for
Load Case 2; NOTE..These are results from Nov.2011 version of “tank”:)
--------------------------------------------------------------------
 MARGINS CORRESPONDING TO CURRENT DESIGN (F.S.= FACTOR OF SAFETY)
MARGIN CURRENT
 NO.   VALUE            DEFINITION
 1 -3.332E-05  (FREQ(2 ,1 )/FREQA(2,1 ))/FREQF(2,1 )-1; F.S.=1.2
 2 -1.504E-04  (FREQ(2 ,2 )/FREQA(2,2 ))/FREQF(2,2 )-1; F.S.=1.2
```

```
 3  5.274E-01  (FREQ(2 ,3 )/FREQA(2,3 ))/FREQF(2,3 )-1; F.S.=1.2
 4  1.746E-01  (FREQ(2 ,4 )/FREQA(2,4 ))/FREQF(2,4 )-1; F.S.=1.2
----------------------------------------------------------------
```

[Next, we want to get plots of the 2 vibration modes for n = 0 circumferential waves (axial motion and rolling), and we want to get plots of the 2 vibration modes for n = 1 circumferential wave (lateral-pitching mode no. 1 and lateral-pitching mode no. 2, not necessarily in that order. Here is what we do:]

bosorplot

```
Please enter the BIGBOSOR4 case name: test

Do you want to use Xgraph or create a PostScript file? (Choose X or P) p

One, maybe Two moments please...

Text file(s) have been created containing plot data.  The names of the
files explain to a greater or lesser extent what the data represent.
Some plot files contain data for more than one plot.
1)      test..R,Z_EIGENMODE_1--N_0
2)      test..R,Z_EIGENMODE_1--N_1
3)      test..R,Z_EIGENMODE_2--N_0
4)      test..R,Z_EIGENMODE_2--N_1
5)      test..R,Z_RingLocation
CR)     to QUIT
Please choose the number of the file you wish to plot: 1
Plotting: Undeformed & Deformed Axial Station as a function of Radius

The PostScript file, metafile.ps, has been created.
Please choose one of the three options below:

   1) Rename the PostScript file.  This is useful if
      you don't have access to a PostScript printer on your
      machine, but you wish to save to a file so you can later
      transfer it to a different machine for printing.

         Example:  mv metafile.ps plot1.ps

   2) Enter an "lpr" command.  This is useful if your default
      printer is not PostScript, but there is a PostScript
      printer available on your system.

         Example:  lpr -PApplelaser metafile.ps

   3) Press the return key.  This executes the command:
```

lpr metafile.ps

This assumes that your default printer is a PostScript printer.

Enter your command> <hit "enter">
Printing PostScript plot on the default printer...
lpr: Error - no default destination available.

Text file(s) have been created containing plot data. The names of the files explain to a greater or lesser extent what the data represent. Some plot files contain data for more than one plot.
1) test..R,Z_EIGENMODE_1--N_0
2) test..R,Z_EIGENMODE_1--N_1
3) test..R,Z_EIGENMODE_2--N_0
4) test..R,Z_EIGENMODE_2--N_1
5) test..R,Z_RingLocation
CR) to QUIT
Please choose the number of the file you wish to plot: <hit "**enter**">

[Edit the file called "metafile.ps". On the line with the string, "(Radius)", you can add the string, " (inches)", so that you have the total string, "(Radius (inches))". On the line with the string, "(Axial Station)", you can add the string, " (inches)", so that you have the total string, "(Axial Station (inches))". On the line that contains the string, "(test..R,Z_EIGENMODE_1--N_0)", you can add the string, "; eigenvalue=11.9996", so that you have the total string, "(test..R,Z_EIGENMODE_1--N_0; eigenvalue=11.9996). Then you can view the modified metafile.ps file on your screen by typing the command:]
gv metafile.ps
in which the command, "gv", means "ghost view", a utility that you must have on your computer in order to view the plots on your screen.

(Next, save the modified metafile.ps file as follows:)
cp /home/progs/work5/metafile.ps /home/progs/archive/test.vib.load2.n=0.axial.ps
(in which "archive" is a library in which you are collecting results from the case called "test", and "test.vib.load2.n=0.axial.ps" is the final name of the postscript file that contains enough information to specify what that file represents physically. In this report the file, test.vib.load2.n=0.axial.ps = Fig. 19.)

(The other three vibration modes can be plotted in an analogous manner. The 4 vibration eigenvalues and modes that act as behavioral constraints during optimization are contained in the four postscript files:)

---

test.vib.load2.n=0.axial.ps (Fig.19)

```
 test.vib.load2.n=0.rolling.ps                            (Fig.20)
 test.vib.load2.n=1.lateralpitch1.ps                      (Fig.21)
 test.vib.load2.n=1.lateralpitch2.ps                      (Fig.22)
-------------------------------------------------------------------
```

In an analogous manner BIGBOSOR4 results and plots can be obtained corresponding to other test.BEHX* files.

For example, use of the file, test.BEHX911, leads to the plot,
test.tankbuck.load1.ps (Fig.23)

Use of the file, test.BEHX912, leads to the plot,
test.tankbuck.load2.ps (Fig.24)

Use of the file, test.BEHX512, leads to the plot,
test.strutbuck.column.load2.struttype1.ps (Fig.25)

Use of the file, test.BEHX612, leads to the plot,
test.strutbuck.shell.load2.struttype1.ps (Fig.26)

Use of the file, test.BEHX812, leads to the plot,
test.tankstress.load1.ps (Fig.27)

Use of the file, test.BEHX812, leads to the plot,
test.tankstress.load2.ps (Fig.28)

==

Table 12 Input for BEGIN (test2.BEG file) for the short propellant tank with one set of struts

```
========================================================================
      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
       150      $ 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
       175      $ 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
       175      $ global axial coordinate of tank support ring: ZTANK(  1)
        50      $ global axial coordinate of "ground": ZGRND(  1)
         1      $ type of strut arrangement: STRTYP(  1)
         1      $ Number INPAIRS of rows in the array  NPAIRS: INPAIRS
         4      $ number of strut pairs: NPAIRS(  1)
         5      $ length of end fitting attached to tank ring: FITTNK(  1)
  0.1000000E+08 $ axial "EA" stiffness of tank-end strut fitting: FEATNK(  1)
  0.1000000E-04 $ Coef.of thermal expansion of tank end fitting: ALFITT(  1)
         5      $ length of strut end fitting attached to "ground": FITVEH(  1)
  0.1000000E+08 $ axial "EA" stiffness of "ground" end strut fitting: FEAVEH(  1)
  0.1000000E-04 $ coef.of thermal expan. of "ground" end fitting: ALFITV(  1)
        10      $ circ.angle (deg.) to pinned tank end of strut: ATANK(  1)
        35      $ circ.angle to pinned "ground" end of strut: AGRND(  1)
         5      $ inner diam. of support tube active at launch: IDTUBE(  1)
  0.1000000     $ length factor for strut buckling as a shell: FACLEN(  1)
      -100      $ Average strut temperature minus ambient: DTSUP(  1)
         2      $ outer diam.of the orbital tube assembly: ODINNR(  1)
         4      $ Length of the orbital tube assembly: FLINNR(  1)
         1      $ Choose 1 or 2 tubes in the orbital tube assembly: NTUBES
         1      $ index for simple strut (1), "PODS" strut (2): ISTRUT
         1      $ type of wall constructions in strut type STRTYP: WALTYP(  1)
```

```
 0.000001      $ height of mid-tank T-ring web: WEBHI
 0.000001      $ thickness of mid-tank T-ring web: WEBTHK
 0.000001      $ width (height) of mid-tank T-ring flange: FLGHI
 0.000001      $ thickness of mid-tank T-ring flange: FLGTHK
      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)
0.5000000      $ thickness of the tank reinforcement ring: TRNGTH(  1)
2.5000000      $ 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)
      6        $ Number ITHICK  of rows in the array  THICK: ITHICK
0.1000000      $ thickness of a lamina: THICK(  1)
0.1000000      $ thickness of a lamina: THICK(  2)
0.1000000      $ thickness of a lamina: THICK(  3)
0.1000000      $ thickness of a lamina: THICK(  4)
0.1000000      $ thickness of a lamina: THICK(  5)
0.1000000      $ 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)
 0.5          $ objective=WGT*(empty tank weight) +(1-WGT)*(conductance): WGT
 3.000        $ normalizing empty tank weight: TNKNRM
0.600E-03     $ normalizing total strut conductance: CONNRM
      1       $ IPHASE=1=launch phase; IPHASE=2=orbital phase: IPHASE
      2       $ Number NCASES  of load cases (environments): NCASES
 25.00000     $ propellant tank ullage pressure: PRESS(  1)
 25.00000     $ 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)
-200.0000     $ propellant tank cool-down from cryogen: TNKCOOL(  1)
-200.0000     $ 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)
 140571       $ maximum allowable stress in material 3: STRES3A(  1,  1)
 140571       $ maximum allowable stress in material 3: STRES3A(  2,  1)
 104714       $ maximum allowable stress in material 3: STRES3A(  1,  2)
 104714       $ maximum allowable stress in material 3: STRES3A(  2,  2)
  10557       $ maximum allowable stress in material 3: STRES3A(  1,  3)
  10557       $ maximum allowable stress in material 3: STRES3A(  2,  3)
  14529       $ maximum allowable stress in material 3: STRES3A(  1,  4)
  14529       $ maximum allowable stress in material 3: STRES3A(  2,  4)
   6290       $ maximum allowable stress in material 3: STRES3A(  1,  5)
   6290       $ maximum allowable stress in material 3: STRES3A(  2,  5)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  1)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  1)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  2)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  2)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  3)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  3)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  4)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  4)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  1,  5)
1.500000      $ factor of safety for stress, matl 3: STRES3F(  2,  5)
       1      $ Number JCOLBUK of columns in the array, COLBUK: JCOLBUK
       1      $ allowable for column buckling of strut: COLBUKA(  1,  1)
       1      $ allowable for column buckling of strut: COLBUKA(  2,  1)
       1      $ factor of safety for Euler strut buckling: COLBUKF(  1,  1)
       1      $ factor of safety for Euler strut buckling: COLBUKF(  2,  1)
       1      $ allowable for shell buckling of strut: SHLBUKA(  1,  1)
       1      $ allowable for shell buckling of strut: SHLBUKA(  2,  1)
       2      $ factor of safety for shell buckling of strut: SHLBUKF(  1,  1)
       2      $ factor of safety for shell buckling of strut: SHLBUKF(  2,  1)
  15000       $ maximum allowable launch-hold force in strut: FORCEA(  1,  1)
```

```
     15000      $ maximum allowable launch-hold force in strut: FORCEA(  2,  1)
         1      $ factor of safety for launch-hold force: FORCEF(  1,  1)
         1      $ factor of safety for launch-hold force: FORCEF(  2,  1)
  50000.00      $ allowable for propellant tank stress: TNKSTRA(  1,  1)
  50000.00      $ allowable for propellant tank stress: TNKSTRA(  2,  1)
         1      $ factor of safety for tank stress: TNKSTRF(  1,  1)
         1      $ factor of safety for tank stress: TNKSTRF(  2,  1)
         1      $ allowable for propellant tank buckling: TNKBUKA(  1,  1)
         1      $ allowable for propellant tank buckling: TNKBUKA(  2,  1)
         1      $ factor of safety for tank buckling: TNKBUKF(  1,  1)
         1      $ factor of safety for tank buckling: TNKBUKF(  2,  1)
==============================================================================
```

Table 13 Input for DECIDE (test2.DEC file) for the short propellant tank with one set of struts

```
==============================================================================
     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) ?
        5       $ Choose a decision variable (1,2,3,...)
   3.000000     $ Lower bound of variable no.(  5)
   10.00000     $ Upper bound of variable no.(  5)
     N          $ Do you want especially to restrict variable no.(  5)
     Y          $ Any more decision variables (Y or N) ?
        6       $ Choose a decision variable (1,2,3,...)
  0.1000000     $ 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) ?
        8       $ Choose a decision variable (1,2,3,...)
  0.1000000     $ Lower bound of variable no.(  8)
   1.000000     $ Upper bound of variable no.(  8)
     N          $ Do you want especially to restrict variable no.(  8)
     Y          $ Any more decision variables (Y or N) ?
       11       $ Choose a decision variable (1,2,3,...)
       20       $ Lower bound of variable no.( 11)
```

```
     160       $ Upper bound of variable no.( 11)
    N          $ Do you want especially to restrict variable no.( 11)
    Y          $ Any more decision variables (Y or N) ?
      12       $ Choose a decision variable (1,2,3,...)
 6.000000      $ Lower bound of variable no.( 12)
      20       $ Upper bound of variable no.( 12)
    N          $ Do you want especially to restrict variable no.( 12)
    Y          $ Any more decision variables (Y or N) ?
      13       $ Choose a decision variable (1,2,3,...)
      30       $ Lower bound of variable no.( 13)
      45       $ Upper bound of variable no.( 13)
    N          $ Do you want especially to restrict variable no.( 13)
    Y          $ Any more decision variables (Y or N) ?
      14       $ Choose a decision variable (1,2,3,...)
       2       $ Lower bound of variable no.( 14)
      20       $ Upper bound of variable no.( 14)
    N          $ Do you want especially to restrict variable no.( 14)
    Y          $ Any more decision variables (Y or N) ?
      20       $ Choose a decision variable (1,2,3,...)
0.2000000E-01  $ Lower bound of variable no.( 20)
 2.000000      $ 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,...)
0.1000000      $ Lower bound of variable no.( 21)
 2.000000      $ Upper bound of variable no.( 21)
    N          $ Do you want especially to restrict variable no.( 21)
    Y          $ Any more decision variables (Y or N) ?
      23       $ Choose a decision variable (1,2,3,...)
0.5000000E-02  $ Lower bound of variable no.( 23)
0.2000000      $ Upper bound of variable no.( 23)
    N          $ Do you want especially to restrict variable no.( 23)
    Y          $ Any more decision variables (Y or N) ?
      29       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 29)
      80       $ Upper bound of variable no.( 29)
    Y          $ Do you want especially to restrict variable no.( 29)
       2       $ Maximum permitted change in variable no.( 29)
    Y          $ Any more decision variables (Y or N) ?
      31       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 31)
      80       $ Upper bound of variable no.( 31)
    Y          $ Do you want especially to restrict variable no.( 31)
       2       $ Maximum permitted change in variable no.( 31)
    Y          $ Any more decision variables (Y or N) ?
      33       $ Choose a decision variable (1,2,3,...)
      10       $ Lower bound of variable no.( 33)
      80       $ Upper bound of variable no.( 33)
```

```
Y         $ Do you want especially to restrict variable no.( 33)
   2      $ Maximum permitted change in variable no.( 33)
N         $ Any more decision variables (Y or N) ?
Y         $ Any 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) ?
  22      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  21      $ 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) ?
  24      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  23      $ 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) ?
  25      $ Choose a linked variable (1,2,3,...)
   1      $ Choose type of linking (1=polynomial; 2=user-defined)
  23      $ 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)
  23      $ 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)
  23      $ 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)
    23      $ 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) ?
    30      $ Choose a linked variable (1,2,3,...)
     1      $ Choose type of linking (1=polynomial; 2=user-defined)
    29      $ 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) ?
    32      $ Choose a linked variable (1,2,3,...)
     1      $ Choose type of linking (1=polynomial; 2=user-defined)
    31      $ 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) ?
    34      $ Choose a linked variable (1,2,3,...)
     1      $ Choose type of linking (1=polynomial; 2=user-defined)
    33      $ 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 14 Input for the GENOPT processor, MAINSETUP (test2.OPT file) for analysis type 2 (fixed design). This input leads to output such as listed in the next table.

```
=====================================================================
 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 15 Output from the GENOPT processor, OPTIMIZE, for a fixed, optimized design. The specific case is called "test2" (short propellant tank with only one set of struts, 4 strut pairs. (test2.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  test2.OPT  FILE ***********
 ************ AUGUST, 2010 VERSION OF GENOPT ****************
 ******** BEGINNING OF THE  test2.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 test2.  Results are stored in the file  test2.OPM.
 Please inspect test2.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 2.1350E-02  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 6.6720E-02  2.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 2.7570E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 3.0000E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   Y     N     N      0    0.00E+00  3.00E+00 3.0000E+00  1.00E+01  spacing of the
tank orthogrid rings: RNGSPC
   6   Y     N     N      0    0.00E+00  1.00E-01 1.5950E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
   7   Y     N     N      0    0.00E+00  2.00E-01 1.0000E+00  1.00E+00  height of the
tank orthogrid stringers: STRHI
```

```
   8   Y     N     N      0    0.00E+00  1.00E-01 1.6340E-01  1.00E+00  thickness of the
tank orthogrid rings: RNGTHK
   9   N     N     Y      7    1.00E+00  0.00E+00 1.0000E+00  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 1.7500E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   Y     N     N      0    0.00E+00  2.00E+01 1.0660E+02  1.60E+02  global axial
coordinate of "ground": ZGRND(1 )
  12   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(1 )
  13   Y     N     N      0    0.00E+00  3.00E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(1 )
  14   Y     N     N      0    0.00E+00  2.00E+00 6.2770E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(1 )
  15   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  height of mid-
tank T-ring web: WEBHI
  16   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring web: WEBTHK
  17   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  width (height) of
mid-tank T-ring flange: FLGHI
  18   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring flange: FLGTHK
  19   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 )
  20   Y     Y     N      0    0.00E+00  2.00E-02 1.8100E-01  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  21   Y     Y     N      0    0.00E+00  1.00E-01 1.0000E-01  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  22   N     N     Y     21    5.00E+00  0.00E+00 5.0000E-01  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
  23   Y     Y     N      0    0.00E+00  5.00E-03 5.0000E-03  2.00E-01  thickness of a
lamina: THICK(1 )
  24   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  25   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  26   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(4 )
  27   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  28   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  29   Y     N     N      0    0.00E+00  1.00E+01 1.7260E+01  8.00E+01  layup angle:
ANGLE(1 )
  30   N     N     Y     29   -1.00E+00  0.00E+00-1.7260E+01  0.00E+00  layup angle:
ANGLE(2 )
  31   Y     N     N      0    0.00E+00  1.00E+01 6.7010E+01  8.00E+01  layup angle:
ANGLE(3 )
  32   N     N     Y     31   -1.00E+00  0.00E+00-6.7010E+01  0.00E+00  layup angle:
ANGLE(4 )
  33   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(5 )
  34   N     N     Y     33   -1.00E+00  0.00E+00-1.0000E+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
Name of case= test2                       ; ITYPEX=  2

CHAPTER 1 (BEHX01x, x = 1,2,...; x=load case):
Find the lengths of struts and the axial loads in the
struts from a BIGBOSOR4 model of the propellant tank
supported by springs with an arbitrarily assigned spring
constant. The flexibility of the propellant tank is
neglected, the strut end fittings are neglected, and the
propellant tank is loaded by ullage pressure, PRESS, tank
cool-down, TNKCOOL, axial acceleration, GAXIAL, and lateral
acceleration, GLATRL. This is a first approximation.
The BIGBOSOR4 model is stored in *.BEHX01x, x = 1, 2...,
in which "x" represents the load case.


BIGBOSOR4 input file for propellant tank supported by struts; Load Case 1
test2.BEHX011

Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
-2.4062E+04 -2.4061E+04 -2.4062E+04 -2.4062E+04 -2.4062E+04
-2.4062E+04 -2.4061E+04 -2.4062E+04
Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
 6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
 2.6400E+02  2.7600E+02  3.5400E+02
Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
-2.4062E-02 -2.4061E-02 -2.4062E-02 -2.4062E-02 -2.4062E-02
-2.4062E-02 -2.4061E-02 -2.4062E-02

Length of strut, max. load, min. load for strut type 1; strut ring no.  1
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1771E+02  0.0000E+00 -2.4062E+04

CHAPTER 2:
Optain PostScript plot files, *.PL6.ps, *.PL7.ps, *.PL8.ps,
which contain a plan view of the AFT set of struts (*.PL6.ps),
a plan view of the FORWARD set of struts (*.PL7.ps, if any),
and an elevation view of both AFT and FORWARD sets of struts
(*.PL8.ps). The FORTRAN software is "borrowed" from the
"DEWAR" system (SUBROUTINE STPLOT and the subroutines called
by STPLOT). These FORTRAN subroutines are part of the
bosdec.tank library.

CHAPTER 3 (BEHX02x, x=1,2,...; x=load case):
1. Fill the "DEWAR" labelled common blocks with the
proper quantities so that buckling load factors of
the strut launch tubes (buckling as thin shells) and
so that the 5 stress components in composite laminate
plies can be determined from "PANDA-type" of analyses
similar to those analyses that are used in the "DEWAR"
system for buckling and stress of the strut launch tubes.

2. Compute from SUBROUTINE GETCIJ the 6 x 6 constitutive
stiffness matrix for each type of strut tube. SUBROUTINE
GETCIJ is very like a subroutine of the same name in PANDA2.

3. Find the axial stiffnesses of aft and forward strut
tubes. These strut tube stiffnesses are to be used in the
```

computation of spring constants associated with each strut in the AFT set of struts and associated with each strut in the FORWARD set of struts (if any). In the "DO 20" loop of SUBROUTINE STRUCT, I = 1 corresponds to the AFT set of struts and I = 2 corresponds to the FORWARD set of struts.

Composite laminate layup of the wall of strut tube type 1

```
WALL PROPERTIES. . .
AFT/ TYPE TUBE   LAYER  LAYER  THICKNESS   WINDING     MATERAL    CRACKING
FWD        NO.    NO.   TYPE               ANGLE       TYPE       RATIO

AFT  TUBE   1      1      1   5.0000E-03  1.7260E+01     1        1.0000E+00
AFT  TUBE   1      2      2   5.0000E-03 -1.7260E+01     1        1.0000E+00
AFT  TUBE   1      3      3   5.0000E-03  6.7010E+01     1        1.0000E+00
AFT  TUBE   1      4      4   5.0000E-03 -6.7010E+01     1        1.0000E+00
AFT  TUBE   1      5      5   5.0000E-03  1.0000E+01     1        1.0000E+00
AFT  TUBE   1      6      6   5.0000E-03 -1.0000E+01     1        1.0000E+00
AFT  TUBE   1      7      6   5.0000E-03 -1.0000E+01     1        1.0000E+00
AFT  TUBE   1      8      5   5.0000E-03  1.0000E+01     1        1.0000E+00
AFT  TUBE   1      9      4   5.0000E-03 -6.7010E+01     1        1.0000E+00
AFT  TUBE   1     10      3   5.0000E-03  6.7010E+01     1        1.0000E+00
AFT  TUBE   1     11      2   5.0000E-03 -1.7260E+01     1        1.0000E+00
AFT  TUBE   1     12      1   5.0000E-03  1.7260E+01     1        1.0000E+00
```

```
 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 1

           COMPOUND SUPPORT TUBE NO. 1:   AFT LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  8.0044E+05  1.2026E+05  0.0000E+00 -7.3242E-04 -1.2207E-04  6.1035E-05     -3.7229E+02
-3.5719E-04
  1.2026E+05  3.8288E+05  0.0000E+00 -1.2207E-04 -8.2397E-04 -4.5776E-05     -3.1797E+02
-7.1828E-04
  0.0000E+00  0.0000E+00  1.3182E+05  1.2207E-04 -4.5776E-05 -1.5259E-04      0.0000E+00
-2.9815E-18
 -7.3242E-04 -1.2207E-04  1.2207E-04  2.4994E+02  4.0023E+01  1.5780E+01      7.1526E-07
1.8660E-09
 -1.2207E-04 -8.2397E-04 -4.5776E-05  4.0023E+01  9.7170E+01  1.0265E+01      4.7684E-07
-2.3613E-09
  6.1035E-05 -4.5776E-05 -1.5259E-04  1.5780E+01  1.0265E+01  4.3490E+01      0.0000E+00
-3.7446E-10
```

BIGBOSOR4 input file for Load Case 1:
axial stiffness of a single launch tube, type 1
test2.BEHX021

```
 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  8.0044E+05  1.2026E+05  3.8288E+05
 C111MD=axial stiffness/circ.length of launch tube type  1
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  7.6267E+05
 Launch tube "EA" and length and "spring constant" for tube type  1
   = TUBEEA,TUBLNG,TUBEK =  1.5183E+07  1.0771E+02  1.4097E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  1 =  1.2355E+05
 The flexibility of the propellant tank is neglected in the
```

model that yields SPRCON. See below for model that includes the flexibility of the propellant tank and that yields FKTOTL

Conductance of one strut of type 1 = 7.0274E-05

CHAPTER 4 (BEHX03x, x = 1,2,...; x=load case):
Compute the linear static response of the propellant tank to concentrated loads applied by the struts (springs) to the tank along the tank support ring no. 1 (aft strut set) and along the tank support ring no. 2 (forward strut set). In this BIGBSOSOR4 model of the propellant tank the springs (struts) are replaced by concentrated loads obtained from the CHAPTER 1 computations. The concentrated loads are modeled in BIGBOSOR4 as line loads with little triangular "pulses" centered about the circumferential angles where the struts are pinned to the propellant tank and at the global axial coordinates that corresponds to the global axial coordinates of the centroids of the aft and forward propellant tank support rings. The circumferential distributions of the line loads are expanded in Fourier series, and the static response to each Fourier component is superposed by BIGBOSOR4 in what is called in BIGBOSOR4 jargon an "INDIC=3" type of analysis. Sixty Fourier terms are used in the Fourier series expansion.

The purpose of this calculation is to find the maximum displacement of the propellant tank wall in the same direction as the axis of one of the struts: 1. the strut associated with the greatest tank wall displacement produced by the AFT strut set and 2. the strut associated with the greatest tank wall displacement produced by the FORWARD strut set. These two maximum local tank wall displacements are used in the determination of the spring constants to be associated with each of the AFT struts and with each of the FORWARD struts in the models in which the flexibility of the propellant tank is accounted for in the computation of the behavior(e.g.vibration)

In this BIGBOSOR4 model there exist "fake" springs, that is, springs with zero axial stiffness. These "fake" springs have no influence on the behavior.

BIGBOSOR4 input file, Load Case 1, for the propellant tank with springs replaced by concentrated loads (INDX=5)
test2.BEHX031

```
 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
  2.3530E-02  2.3531E-02  2.3530E-02  2.3530E-02  2.3530E-02
  2.3530E-02  2.3531E-02  2.3530E-02
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  6.0000E+00
```

Absolute value of maximum "change in length" of any strut at strut ring no. 1
DISMAX(JRING)= 2.3531E-02
DISMAX is used in the derivation of the strut spring
constant, FKTOTL, that accounts for the flexibility of the
propellant tank.

Spring constant at ring no. 1: FKTOTL(JRING)= 1.1023E+05
The reduced spring constant, FKTOTL, includes the flexibility
of the propellant tank. Compare with the spring constant
SPRCON= 1.2355E+05 which is the value of the spring
constant obtained neglecting the propellant tank flexibility.

CHAPTER 5 (BEHX04x, x = 1, 2,...; x = load case):
Repeat the CHAPTER 1 type of computations with the new
(significantly smaller) spring constants that now account
for the flexibility of the propellant tank. The purpose of
this computation is to determine more accurate values of the
loads in each strut (spring) caused by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL. The updated strut loads are
used in the following computations:
1. Buckling of the most highly compressed strut of each type
(type 1 = "AFT"; type 2 = "FORWARD") as a column (BEHX5) and
as a shell (BEHX6).
2. Maximum of each of five stress components in each type
of strut (BEHX2 for AFT struts and BEHX3 for FORWARD struts).
3. Maximum stress in the propellant tank due to loading by
the AFT and FORWARD sets of struts and by the loads, PRESS,
GAXIAL, GLATRL, and TNKCOOL (BEHX8).
4. Minimum buckling of the propellant tank under the AFT and
FORWARD sets of struts and by the loads, PRESS, GAXIAL,
GLATRL, and TNKCOOL (BEHX9).

```
 BIGBOSOR4 input file for propellant tank under
 Load Case 1 supported by struts (second approximation)
test2.BEHX041

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 -2.4061E+04 -2.4061E+04 -2.4061E+04 -2.4061E+04 -2.4061E+04
 -2.4061E+04 -2.4061E+04 -2.4061E+04
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
   6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
   2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 -2.1827E-01 -2.1827E-01 -2.1827E-01 -2.1827E-01 -2.1827E-01
 -2.1827E-01 -2.1827E-01 -2.1827E-01
 NOTE: The changes in axial length, SPRDLG, just listed
 are significantly greater than those listed previously
 because the springs are softer in this "BEHX04*" model
 than those in the "BEHX01*" model, NOT because there is
 more local deformation of the tank under these spring
 loads. The change in length of the "effective" spring
 caused by local deformation of the propellant tank is
 listed above as the quantity called "DISMAX", which is
 computed from the "BEHX03*" model in which the springs
 are replaced by concentrated loads acting on the tank.

 Circ. angle where the maximum concentrated AXIAL load is
```

applied to the propellant tank by the struts at the tank
support ring no. 1. Circumferential angle = 6.0000E+00
Minimum load in a strut (NSPTOT,KSTMIN,ANGMIN):
Ring Number 1: Strut no. 1; Circ. angle to strut= 6.0000E+00
Strut type = 1; CIRCANG(ITYPE)= 6.0000E+00

Length of strut, max. load, min. load for strut type 1; strut ring no. 1
LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)= 1.1771E+02 0.0000E+00 -2.4061E+04

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 springs
(pinned struts) attached. 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
each set of struts (AFT and FORWARD) are pinned to the tank.
The strut (spring) stiffness takes into account the
flexibility of the propellant tank wall.

BIGBOSOR4 input file for: free vibration frequencies for Load Case 1
test2.BEHX11

FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
Total tank mass including "lumped" propellant, TOTMAS= 2.8950E+01
1.6003E+01(n= 0 circ.waves)
1.3893E+01(n= 1 circ.waves)
4.1437E+01(n= 2 circ.waves)
4.1448E+01(n= 3 circ.waves)
4.0200E+01(n= 4 circ.waves)

```
  1       16.00277      free vibration frequency (cps): FREQ(1 ,1 )
  2       13.89297      free vibration frequency (cps): FREQ(1 ,2 )
  3       41.43726      free vibration frequency (cps): FREQ(1 ,3 )
  4       41.44757      free vibration frequency (cps): FREQ(1 ,4 )
```

BEHAVIOR OVER J = stress component number

CHAPTER 7: strut stress analysis-BEHX2x, x=1,2; x=load case)
This is the stress analysis from both BIGBOSOR4 and from
a PANDA2-type of laminate analysis of the most highly loaded
strut of the AFT set of struts (struts of type 1). The struts
are tubes made of composite laminate. The most highly loaded
strut under both axial tension and equal axial compression is
analyzed. The tensile/compressive load to which the most
highly loaded strut is subjected is derived in the computation
under CHAPTER 5. The five stress "behavioral" constraints
computed here correspond to:
1. tension along the fibers of a ply,
2. compression along the fibers of a ply,
3. tension transverse to the fibers of a ply,
4. compression transverse to the fibers of a ply,
5. in-plane shear stress in a ply.
Recorded as 5 behavioral constraints are the maximum values
of each of the five components just listed from tension or

compression and from a BIGBOSOR4 or a PANDA2-type of model.
In other words, only the worst (highest) stress component from
four computations (tension BIGBOSOR4,compression BIGBOSOR4,
tension PANDA2, compression PANDA2) is recorded as each
component behavioral constraint.

```
 BIGBOSOR4 input file for: maximum stress in a  strut of type 1 for load case 1
test2.BEHX21

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  5.3308E+03  fiber tension
  8.0618E+03  fiber compres.
  4.2395E+03  transv tension
  0.0000E+00  transv compres
  2.2710E+02  in-plane shear

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  0.0000E+00  fiber tension
  3.3689E+04  fiber compres.
  3.4539E+03  transv tension
  0.0000E+00  transv compres
  9.6434E+02  in-plane shear

 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
 Corresponding maximum stress components from PANDA-type model:
  0.0000E+00  tensile fiber
  7.2021E+03  compressive fiber
  3.4947E+03  tensile transverse
  0.0000E+00  compressive transverse
  1.7631E+02  in-plane shear


 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
 Corresponding maximum stress components from PANDA-type model:
  0.0000E+00  tensile fiber
  3.3077E+04  compressive fiber
  3.1233E+03  tensile transverse
  0.0000E+00  compressive transverse
  8.4047E+02  in-plane shear

    5        5330.790      maximum stress in material 1: STRES1(1 ,1 )
    6        33689.14      maximum stress in material 1: STRES1(1 ,2 )
    7        4239.534      maximum stress in material 1: STRES1(1 ,3 )
    8       0.1000000E-09  maximum stress in material 1: STRES1(1 ,4 )
    9        964.3354      maximum stress in material 1: STRES1(1 ,5 )

  BEHAVIOR OVER J =  stress component number
```

CHAPTER 8: strut stress analysis-BEHX3x, x=1,2; x=load case)
This is the stress analysis from both BIGBOSOR4 and from
a PANDA2-type of laminate analysis of the most highly loaded
strut of the FWD set of struts (struts of type 2). The struts
are tubes made of composite laminate. The most highly loaded
strut under both axial tension and equal axial compression is
analyzed. The tensile/compressive load to which the most

```
 highly loaded strut is subjected is derived in the computation
 under CHAPTER 5. The five stress "behavioral" constraints
 computed here correspond to:
 1. tension along the fibers of a ply,
 2. compression along the fibers of a ply,
 3. tension transverse to the fibers of a ply,
 4. compression transverse to the fibers of a ply,
 5. in-plane shear stress in a ply.
 Recorded as 5 behavioral constraints are the maximum values
 of each of the five components just listed from tension or
 compression and from a BIGBOSOR4 or a PANDA2-type of model.
 In other words, only the worst (highest) stress component from
 four computations (tension BIGBOSOR4,compression BIGBOSOR4,
 tension PANDA2, compression PANDA2) is recorded as each
 component behavioral constraint.
   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 =  stress component number
   15       0.1000000E-09  maximum stress in material 3: STRES3(1 ,1 )
   16       0.1000000E-09  maximum stress in material 3: STRES3(1 ,2 )
   17       0.1000000E-09  maximum stress in material 3: STRES3(1 ,3 )
   18       0.1000000E-09  maximum stress in material 3: STRES3(1 ,4 )
   19       0.1000000E-09  maximum stress in material 3: STRES3(1 ,5 )

 CHAPTER 9: Buckling of strut as a column
 -BEHX5xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of the strut. n = 1 circumferential wave
    corresponds to buckling of the strut as a column. The
    effect of propellant tank flexibility is NOT included in
    this BIGBOSOR4 model.
 2. an Euler buckling model of the strut. This model is
    analogous to the column buckling model used in "DEWAR".
    The effect of propellant tank flexibility IS included.
 The Euler buckling model usually gives the lower buckling
 load factor, mainly because of propellant tank flexibility.
 The buckling constraint is based on the minimum column
 buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: column buckling of strut of type 1 for load case 1
test2.BEHX511

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -2.4061E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  1 -2.4061E+04  0.0000E+00
```

```
 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  2.1638E+00(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  1; Strut length=  1.1771E+02 Load on strut= -2.4061E+04
 Column buckling of strut from Euler formula, COLBUC=  1.9285E+00
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
 the minimum value obtained from BIGBOSOR4 and the Euler model.
   20        1.928481      buckling of a strut as a column: COLBUK(1 ,1 )

 CHAPTER 10: Buckling of strut as a shell
 -BEHX6xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of a sub-length of the strut. A search
    is conducted over the number n of circumferential waves in
    the buckling mode to determine the critical buckling load
    factor. The effect of propellant tank flexibility is not
    relevant in this analysis.
 2. a PANDA2-type buckling model of the strut. This model is
    analogous to the shell buckling model used in "DEWAR".
    The effect of propellant tank flexibility is not relevant.

 The PANDA2-type buckling model usually gives the lower
 buckling load factor, mainly because of the effect of
 transverse shear deformation (t.s.d.) and the effect of the
 anisotropic terms, D16 and D26, that BIGBOSOR4 cannot handle.
 The buckling constraint is based on the minimum shell
 buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: shell buckling of strut type 1 for load case 1
test2.BEHX611

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -2.4061E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  0.0000E+00
 JCOL,LODMN2(1),LODMN2(2)=  1 -2.4061E+04  0.0000E+00

 SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
  5.5904E+00(n= 0 circ.waves (from BIGBOSOR4))
  5.5453E+00(n= 1 circ.waves (from BIGBOSOR4))
  5.4096E+00(n= 2 circ.waves (from BIGBOSOR4))
  5.1797E+00(n= 3 circ.waves (from BIGBOSOR4))
  4.8154E+00(n= 4 circ.waves (from BIGBOSOR4))
  4.0478E+00(n= 5 circ.waves (from BIGBOSOR4))
  3.8093E+00(n= 6 circ.waves (from BIGBOSOR4))
  3.9315E+00(n= 7 circ.waves (from BIGBOSOR4))
  4.3184E+00(n= 8 circ.waves (from BIGBOSOR4))
  4.9174E+00(n= 9 circ.waves (from BIGBOSOR4))
  5.6943E+00(n=10 circ.waves (from BIGBOSOR4))
 Critical buckling load factor from BIGBOSOR4, SHLBUK=  3.8093E+00
```

```
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    6
Strut type  1; Strut length=  1.1771E+02 Load on strut= -2.4061E+04
Column buckling of strut from Euler formula, COLBUC=  1.9285E+00

INFORMATION PERTAINING TO STRUT TYPE 1:

IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (AFT) ARE:
AFT support member. COLUMN buckling results (Euler formula):
 Effective bending stiffness of LAUNCH tube,      EI =  7.6223E+07
 Length of strut from pinned end to pinned end,    L =  1.1771E+02
 Force in strut tending to buckle it,          FORCE = -2.4061E+04
 Euler (column) buckling strain,    pi**2*I/(A*L**2) =  3.5761E-03
 Average strain in the column (g-loads minus temp.),e= -1.8544E-03
 Effective stiffness of strut for lateral (n=1) motions
   including knockdowns for shell and ring flexibility,
                                                  K1 =  1.1023E+05
 Effective stiffness of strut for axial (n=0) motions
  including only knockdown for axisymmetric shell flexibility,
                                                  K0 =  1.2355E+05
 Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                              COLBUC =  1.9285E+00

AFT support member.SHELL buckling results(PANDA):
Calculations for (1=launch tube,2=orbital tube)= 1
 Main diagonal of shell wall constitutive matrix, C(i,i):
   axial stiffness of shell wall,             C(1,1) =  8.0044E+05
   hoop  stiffness of shell wall,             C(2,2) =  3.8288E+05
   shear stiffness of shell wall,             C(3,3) =  1.3182E+05
   axial bending rigidity of shell wall       C(4,4) =  2.4994E+02
   hoop  bending rigidity of shell wall       C(5,5) =  9.7170E+01
   twisting      rigidity of shell wall       C(6,6) =  4.3490E+01
 Force in tube tending to buckle it,           FORCE = -2.4061E+04
 Length of tube used for SHELL buckling model, FLEFF =  1.9011E+01
 Load factor, shell buckling (PANDA analysis),SHLBC2 =  2.8869E+00
 Number of axial half-waves in buckle pattern,     m =     1
 Number of circumferential full waves in mode,     n =     7
 Slope of nodal lines of buckling pattern,    CSLOPE =  7.1667E-01
  21        2.886882      buckling of strut as a shell: SHLBUK(1 ,1 )
```

CHAPTER 11: Launch-hold force in a strut
-BEHX7x, x=1,2; x=load case

If the propellant tank is oriented vertically in the launch vehicle all the struts in each strut set experience the same launch-hold force. The launch-hold force in the AFT struts may differ from that in the FORWARD struts. Behavioral constraints are computed for each set of struts. The behavioral constraint is called "FORCE(i,j)", in which i = the load case number and j =the strut set number (strut type).

FORCE(i,j) is computed from a BIGBOSOR4 model of the propellant tank with struts (springs) attached to it. The spring constants include the effect of the flexibility of the propellant tank. The tank is loaded by PRESS, GAXIAL=1g, and TNKCOOL. The maximum allowable strut launch-hold force is provided for each load case by the End user. The behavioral constraint, FORCE(i,j), must be less than the maximum allowable, FORCEA(i,j). The End user must supply FORCEA(i,j) at a small enough value so that if the struts contain a

```
 disconnect feature they will not "short out" during the
 launch-hold phase of a mission.

 BIGBOSOR4 input file for propellant tank supported
 by struts (launch-hold condition for load case 1)
test2.BEHX71

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1771E+02  0.0000E+00 -2.4050E+03
   22        2404.973      launch-hold force in a strut: FORCE(1 ,1 )

 CHAPTER 12: Maximum effective stress in the isotropic
 propellant tank - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The model is analogous to that
 described in CHAPTER 4 (*.BEHX03x, x=1,2; x=load case).
 The propellant tank is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The modeling of the concentrated loads that replace
 the springs (struts) is described in CHAPTER 4. The purpose
 of this model is to compute the maximum effective stress in
 the propellant tank, which is assumed to be fabricated of
 isotropic material. This is an "INDIC=3" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case 1:
 maximum stress in the propellant tank from the prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 1
test2.BEHX811

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  1.0613E+00, LOCATW(1)=1000*ISEG+I=  1001
 *****************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  1.0062E+00 fiber tension : matl=1 ,  A , seg=15, node=1 , layer=1 ,z= -1.03 ;FS=  1.00
  2  2.9790E+00 fiber compres.: matl=1 ,  A , seg=13, node=46, layer=1 ,z= -1.03 ;FS=  1.00
  3  1.4287E+00 transv tension: matl=1 ,  A , seg=1 , node=5 , layer=1 ,z=-0.01  ;FS=  1.00
  4  1.8451E+00 transv compres: matl=1 ,  A , seg=11, node=5 , layer=1 ,z=-0.01  ;FS=  1.00
  5  9.9525E-01 effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.01  ;FS=  1.00
  6  2.3426E+00 effect. stress: matl=3 ,  A , seg=14, node=2 , layer=3 ,z= 0.04  ;FS=  1.00
  7  2.2407E+00 effect. stress: matl=4 ,  A , seg=14, node=1 , layer=2 ,z= 0.03  ;FS=  1.00
  8  1.2847E+00 effect. stress: matl=5 ,  A , seg=28, node=9 , layer=2 ,z= 0.01  ;FS=  1.00
 ****************************************************
 Maximum stress components for Load Case  1 STRESS2(i),i=1,6=
     4.9693E+04     1.6784E+04     3.4996E+04     2.7098E+04     0.0000E+00     5.0239E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 ******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0239E+04
effect. stress: matl=2 ,  A , seg=1 , node=6 , layer=2 ,z= 0.01  ;FS=  1.00
 ******************************************************
```

```
   23        50238.52      maximum stress in the propellant tank: TNKSTR(1 ,1 )
```

CHAPTER 13: Buckling of the isotropic propellant tank
- BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
This is a BIGBOSOR4 model in which the springs (struts) are
replaced by concentrated loads. The 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 is loaded by PRESS, GAXIAL, GLATRL, and
TNKCOOL. The modeling of the concentrated loads that replace
the springs (struts) is described in CHAPTER 4. The purpose
of this model is to compute the minimum buckling load of
the propellant tank, which is assumed to be fabricated of
isotropic material. This is an "INDIC=4" BIGBOSOR4 model.

```
 BIGBOSOR4 input file for load case 1: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  6.0000E+00 in which JCOL = 1
test2.BEHX911

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  2.7832E+01(n=  10 circ.waves); IFAILD= 0
  1.1779E+01(n=  15 circ.waves); IFAILD= 0
  8.2541E+00(n=  20 circ.waves); IFAILD= 0
  7.6763E+00(n=  25 circ.waves); IFAILD= 0
  8.1071E+00(n=  30 circ.waves); IFAILD= 0
  9.0921E+00(n=  35 circ.waves); IFAILD= 0
  1.0472E+01(n=  40 circ.waves); IFAILD= 0
  1.2164E+01(n=  45 circ.waves); IFAILD= 0
  1.4121E+01(n=  50 circ.waves); IFAILD= 0
  1.6306E+01(n=  55 circ.waves); IFAILD= 0
  1.8693E+01(n=  60 circ.waves); IFAILD= 0
  2.1260E+01(n=  65 circ.waves); IFAILD= 0
  2.3988E+01(n=  70 circ.waves); IFAILD= 0
  2.6858E+01(n=  75 circ.waves); IFAILD= 0
  2.9850E+01(n=  80 circ.waves); IFAILD= 0
  3.2945E+01(n=  85 circ.waves); IFAILD= 0
  3.6121E+01(n=  90 circ.waves); IFAILD= 0
  3.9352E+01(n=  95 circ.waves); IFAILD= 0
  4.2595E+01(n= 100 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  7.6763E+00
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
   24        7.676278      propellant tank buckling load factor: TNKBUK(1 ,1 )
```

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

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

 in which (normalized weight of empty tank) =    TOTMAS/TNKNRM
 and      (normalized total strut 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 strut conductance, CONDCT. Note that the listed definition of the objective is always "total conductance into the tank: CONDCT".

```
WGT,TOTMAS,TNKNRM,CONDCT,CONNRM=
 5.0000E-01  4.6675E+00  3.0000E+00  5.6219E-04  6.0000E-04

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

BEH.   CURRENT
NO.     VALUE            DEFINITION
 1     1.600E+01    free vibration frequency (cps): FREQ(1 ,1 )
 2     1.389E+01    free vibration frequency (cps): FREQ(1 ,2 )
 3     4.144E+01    free vibration frequency (cps): FREQ(1 ,3 )
 4     4.145E+01    free vibration frequency (cps): FREQ(1 ,4 )
 5     5.331E+03    maximum stress in material 1: STRES1(1 ,1 )
 6     3.369E+04    maximum stress in material 1: STRES1(1 ,2 )
 7     4.240E+03    maximum stress in material 1: STRES1(1 ,3 )
 8     1.000E-10    maximum stress in material 1: STRES1(1 ,4 )
 9     9.643E+02    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    maximum stress in material 3: STRES3(1 ,1 )
16     1.000E-10    maximum stress in material 3: STRES3(1 ,2 )
17     1.000E-10    maximum stress in material 3: STRES3(1 ,3 )
18     1.000E-10    maximum stress in material 3: STRES3(1 ,4 )
19     1.000E-10    maximum stress in material 3: STRES3(1 ,5 )
20     1.928E+00    buckling of a strut as a column: COLBUK(1 ,1 )
21     2.887E+00    buckling of strut as a shell: SHLBUK(1 ,1 )
22     2.405E+03    launch-hold force in a strut: FORCE(1 ,1 )
23     5.024E+04    maximum stress in the propellant tank: TNKSTR(1 ,1 )
24     7.676E+00    propellant tank buckling load factor: TNKBUK(1 ,1 )

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


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

MARGIN CURRENT
NO.     VALUE            DEFINITION
 1     3.336E-01  (FREQ(1 ,1 )/FREQA(1 ,1 )) / FREQF(1 ,1 )-1; F.S.=  1.20
 2     1.577E-01  (FREQ(1 ,2 )/FREQA(1 ,2 )) / FREQF(1 ,2 )-1; F.S.=  1.20
 3     2.453E+00  (FREQ(1 ,3 )/FREQA(1 ,3 )) / FREQF(1 ,3 )-1; F.S.=  1.20
 4     2.454E+00  (FREQ(1 ,4 )/FREQA(1 ,4 )) / FREQF(1 ,4 )-1; F.S.=  1.20
 5     1.658E+01  (STRES1A(1 ,1 )/STRES1(1 ,1 )) / STRES1F(1 ,1 )-1; F.S.=  1.50
 6     1.072E+00  (STRES1A(1 ,2 )/STRES1(1 ,2 )) / STRES1F(1 ,2 )-1; F.S.=  1.50
 7     6.601E-01  (STRES1A(1 ,3 )/STRES1(1 ,3 )) / STRES1F(1 ,3 )-1; F.S.=  1.50
 8     3.348E+00  (STRES1A(1 ,5 )/STRES1(1 ,5 )) / STRES1F(1 ,5 )-1; F.S.=  1.50
 9     9.285E-01  (COLBUK(1 ,1 )/COLBUKA(1 ,1 )) / COLBUKF(1 ,1 )-1; F.S.=  1.00
10     4.434E-01  (SHLBUK(1 ,1 )/SHLBUKA(1 ,1 )) / SHLBUKF(1 ,1 )-1; F.S.=  2.00
11     5.237E+00  (FORCEA(1 ,1 )/FORCE(1 ,1 )) / FORCEF(1 ,1 )-1; F.S.=  1.00
```

```
 12   -4.748E-03  (TNKSTRA(1 ,1 )/TNKSTR(1 ,1 )) / TNKSTRF(1 ,1 )-1; F.S.=  1.00
 13    6.676E+00  (TNKBUK(1 ,1 )/TNKBUKA(1 ,1 )) / TNKBUKF(1 ,1 )-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 2.1350E-02  2.00E-01  thickness of the
tank aft dome skin: THKAFT
   2   Y     N     N      0    0.00E+00  2.00E-02 6.6720E-02  2.00E-01  thickness of the
tank cylinder skin: THKMID
   3   Y     N     N      0    0.00E+00  2.00E-02 2.7570E-02  2.00E-01  thickness of the
forward tank dome skin: THKFWD
   4   Y     N     N      0    0.00E+00  3.00E+00 3.0000E+00  1.00E+01  spacing of the
tank orthogrid stringers: STRSPC
   5   Y     N     N      0    0.00E+00  3.00E+00 3.0000E+00  1.00E+01  spacing of the
tank orthogrid rings: RNGSPC
   6   Y     N     N      0    0.00E+00  1.00E-01 1.5950E-01  1.00E+00  thickness of the
tank orthogrid stringers: STRTHK
   7   Y     N     N      0    0.00E+00  2.00E-01 1.0000E+00  1.00E+00  height of the
tank orthogrid stringers: STRHI
   8   Y     N     N      0    0.00E+00  1.00E-01 1.6340E-01  1.00E+00  thickness of the
tank orthogrid rings: RNGTHK
   9   N     N     Y      7    1.00E+00  0.00E+00 1.0000E+00  0.00E+00  height of the
tank orthogrid rings: RNGHI
  10   N     N     N      0    0.00E+00  0.00E+00 1.7500E+02  0.00E+00  global axial
coordinate of tank support ring: ZTANK(1 )
  11   Y     N     N      0    0.00E+00  2.00E+01 1.0660E+02  1.60E+02  global axial
coordinate of "ground": ZGRND(1 )
  12   Y     N     N      0    0.00E+00  6.00E+00 6.0000E+00  2.00E+01  circ.angle (deg.)
to pinned tank end of strut: ATANK(1 )
  13   Y     N     N      0    0.00E+00  3.00E+01 4.5000E+01  4.50E+01  circ.angle to
pinned "ground" end of strut: AGRND(1 )
  14   Y     N     N      0    0.00E+00  2.00E+00 6.2770E+00  2.00E+01  inner diam. of
support tube active at launch: IDTUBE(1 )
  15   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  height of mid-
tank T-ring web: WEBHI
  16   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring web: WEBTHK
  17   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  width (height) of
mid-tank T-ring flange: FLGHI
  18   N     N     N      0    0.00E+00  0.00E+00 1.0000E-06  0.00E+00  thickness of mid-
tank T-ring flange: FLGTHK
  19   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 )
  20   Y     Y     N      0    0.00E+00  2.00E-02 1.8100E-01  2.00E+00  max.thickness of
the propellant tank doubler: DUBTHK(1 )
  21   Y     Y     N      0    0.00E+00  1.00E-01 1.0000E-01  2.00E+00  thickness of the
tank reinforcement ring: TRNGTH(1 )
  22   N     N     Y     21    5.00E+00  0.00E+00 5.0000E-01  0.00E+00  height of the
tank reinforcement ring: TRNGHI(1 )
  23   Y     Y     N      0    0.00E+00  5.00E-03 5.0000E-03  2.00E-01  thickness of a
lamina: THICK(1 )
  24   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(2 )
  25   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(3 )
  26   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(4 )
```

```
  27   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(5 )
  28   N     N     Y     23    1.00E+00  0.00E+00 5.0000E-03  0.00E+00  thickness of a
lamina: THICK(6 )
  29   Y     N     N      0    0.00E+00  1.00E+01 1.7260E+01  8.00E+01  layup angle:
ANGLE(1 )
  30   N     N     Y     29   -1.00E+00  0.00E+00-1.7260E+01  0.00E+00  layup angle:
ANGLE(2 )
  31   Y     N     N      0    0.00E+00  1.00E+01 6.7010E+01  8.00E+01  layup angle:
ANGLE(3 )
  32   N     N     Y     31   -1.00E+00  0.00E+00-6.7010E+01  0.00E+00  layup angle:
ANGLE(4 )
  33   Y     N     N      0    0.00E+00  1.00E+01 1.0000E+01  8.00E+01  layup angle:
ANGLE(5 )
  34   N     N     Y     33   -1.00E+00  0.00E+00-1.0000E+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
 Name of case= test2                       ; ITYPEX=  2

 CHAPTER 1 (BEHX01x, x = 1,2,...; x=load case):
 Find the lengths of struts and the axial loads in the
 struts from a BIGBOSOR4 model of the propellant tank
 supported by springs with an arbitrarily assigned spring
 constant. The flexibility of the propellant tank is
 neglected, the strut end fittings are neglected, and the
 propellant tank is loaded by ullage pressure, PRESS, tank
 cool-down, TNKCOOL, axial acceleration, GAXIAL, and lateral
 acceleration, GLATRL. This is a first approximation.
 The BIGBOSOR4 model is stored in *.BEHX01x, x = 1, 2...,
 in which "x" represents the load case.


 BIGBOSOR4 input file for propellant tank supported by struts; Load Case 2
test2.BEHX012

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 -3.5834E+03  3.4678E+04 -3.4675E+04  3.5863E+03  3.5863E+03
 -3.4675E+04  3.4678E+04 -3.5834E+03
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 -3.5834E-03  3.4678E-02 -3.4675E-02  3.5863E-03  3.5863E-03
 -3.4675E-02  3.4678E-02 -3.5834E-03

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1771E+02  3.4678E+04 -3.4675E+04

 CHAPTER 2:
 Optain PostScript plot files, *.PL6.ps, *.PL7.ps, *.PL8.ps,
 which contain a plan view of the AFT set of struts (*.PL6.ps),
 a plan view of the FORWARD set of struts (*.PL7.ps, if any),
 and an elevation view of both AFT and FORWARD sets of struts
```

```
 (*.PL8.ps). The FORTRAN software is "borrowed" from the
 "DEWAR" system (SUBROUTINE STPLOT and the subroutines called
 by STPLOT). These FORTRAN subroutines are part of the
 bosdec.tank library.

 CHAPTER 3 (BEHX02x, x=1,2,...; x=load case):
 1. Fill the "DEWAR" labelled common blocks with the
 proper quantities so that buckling load factors of
 the strut launch tubes (buckling as thin shells) and
 so that the 5 stress components in composite laminate
 plies can be determined from "PANDA-type" of analyses
 similar to those analyses that are used in the "DEWAR"
 system for buckling and stress of the strut launch tubes.

 2. Compute from SUBROUTINE GETCIJ the 6 x 6 constitutive
 stiffness matrix for each type of strut tube. SUBROUTINE
 GETCIJ is very like a subroutine of the same name in PANDA2.

 3. Find the axial stiffnesses of aft and forward strut
 tubes. These strut tube stiffnesses are to be used in the
 computation of spring constants associated with each strut
 in the AFT set of struts and associated with each strut in
 the FORWARD set of struts (if any). In the "DO 20" loop of
 SUBROUTINE STRUCT, I = 1 corresponds to the AFT set of struts
 and I = 2 corresponds to the FORWARD set of struts.


 CONSTITUTIVE MATRIX C(i,j) FOR STRUT TUBE TYPE 1

           COMPOUND SUPPORT TUBE NO. 1:   AFT LAUNCH  TUBE               THERMAL {NT}
ETHERM {ET}
  8.0044E+05  1.2026E+05  0.0000E+00 -7.3242E-04 -1.2207E-04  6.1035E-05     -3.7229E+02
-3.5719E-04
  1.2026E+05  3.8288E+05  0.0000E+00 -1.2207E-04 -8.2397E-04 -4.5776E-05     -3.1797E+02
-7.1828E-04
  0.0000E+00  0.0000E+00  1.3182E+05  1.2207E-04 -4.5776E-05 -1.5259E-04      0.0000E+00
-2.9815E-18
 -7.3242E-04 -1.2207E-04  1.2207E-04  2.4994E+02  4.0023E+01  1.5780E+01      7.1526E-07
1.8660E-09
 -1.2207E-04 -8.2397E-04 -4.5776E-05  4.0023E+01  9.7170E+01  1.0265E+01      4.7684E-07
-2.3613E-09
  6.1035E-05 -4.5776E-05 -1.5259E-04  1.5780E+01  1.0265E+01  4.3490E+01      0.0000E+00
-3.7446E-10


 BIGBOSOR4 input file for Load Case 2:
 axial stiffness of a single launch tube, type 1
test2.BEHX022

 In SUBROUTINE STRUCT after 2nd CALL B4READ
 CSKIN1(1,1,1),CSKIN1(1,2,1),CSKIN1(2,2,1)=  8.0044E+05  1.2026E+05  3.8288E+05
 C111MD=axial stiffness/circ.length of launch tube type  1
   =CSKIN1(1,1,1)-CSKIN1(1,2,1)**2/CSKIN1(2,2,1)=  7.6267E+05
 Launch tube "EA" and length and "spring constant" for tube type  1
   = TUBEEA,TUBLNG,TUBEK =  1.5183E+07  1.0771E+02  1.4097E+05
 "Spring constants" for tank end and launch vehicle end
 fittings, FITK1 and FITK2 =  2.0000E+06  2.0000E+06
 Spring constant for compound strut type  1 =  1.2355E+05
```

The flexibility of the propellant tank is neglected in the model that yields SPRCON. See below for model that includes the flexibility of the propellant tank and that yields FKTOTL

Conductance of one strut of type 1 = 7.0274E-05

CHAPTER 4 (BEHX03x, x = 1,2,...; x=load case):
Compute the linear static response of the propellant tank to concentrated loads applied by the struts (springs) to the tank along the tank support ring no. 1 (aft strut set) and along the tank support ring no. 2 (forward strut set). In this BIGBSOSOR4 model of the propellant tank the springs (struts) are replaced by concentrated loads obtained from the CHAPTER 1 computations. The concentrated loads are modeled in BIGBOSOR4 as line loads with little triangular "pulses" centered about the circumferential angles where the struts are pinned to the propellant tank and at the global axial coordinates that corresponds to the global axial coordinates of the centroids of the aft and forward propellant tank support rings. The circumferential distributions of the line loads are expanded in Fourier series, and the static response to each Fourier component is superposed by BIGBOSOR4 in what is called in BIGBOSOR4 jargon an "INDIC=3" type of analysis. Sixty Fourier terms are used in the Fourier series expansion.

The purpose of this calculation is to find the maximum displacement of the propellant tank wall in the same direction as the axis of one of the struts: 1. the strut associated with the greatest tank wall displacement produced by the AFT strut set and 2. the strut associated with the greatest tank wall displacement produced by the FORWARD strut set. These two maximum local tank wall displacements are used in the determination of the spring constants to be associated with each of the AFT struts and with each of the FORWARD struts in the models in which the flexibility of the propellant tank is accounted for in the computation of the behavior(e.g.vibration)

In this BIGBOSOR4 model there exist "fake" springs, that is, springs with zero axial stiffness. These "fake" springs have no influence on the behavior.

BIGBOSOR4 input file, Load Case 2, for the propellant tank with springs replaced by concentrated loads (INDX=5)

```
test2.BEHX032

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
  0.0000E+00 -0.0000E+00  0.0000E+00 -0.0000E+00 -0.0000E+00
  0.0000E+00 -0.0000E+00  0.0000E+00
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
  8.8706E-03 -1.4149E-01  1.4133E-01 -9.0229E-03 -9.0230E-03
  1.4133E-01 -1.4149E-01  8.8706E-03
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  8.4000E+01
```

```
 Absolute value of maximum "change in length" of any strut at strut ring no.  1
 DISMAX(JRING)=  1.4149E-01
 DISMAX is used in the derivation of the strut spring
 constant, FKTOTL, that accounts for the flexibility of the
 propellant tank.

 Spring constant at ring no.  1: FKTOTL(JRING)=  8.2144E+04
 The reduced spring constant, FKTOTL, includes the flexibility
 of the propellant tank. Compare with the spring constant
 SPRCON=  1.2355E+05 which is the value of the spring
 constant obtained neglecting the propellant tank flexibility.

 CHAPTER 5 (BEHX04x, x = 1, 2,...; x = load case):
 Repeat the CHAPTER 1 type of computations with the new
 (significantly smaller) spring constants that now account
 for the flexibility of the propellant tank. The purpose of
 this computation is to determine more accurate values of the
 loads in each strut (spring) caused by the loads, PRESS,
 GAXIAL, GLATRL, and TNKCOOL. The updated strut loads are
 used in the following computations:
 1. Buckling of the most highly compressed strut of each type
 (type 1 = "AFT"; type 2 = "FORWARD") as a column (BEHX5) and
 as a shell (BEHX6).
 2. Maximum of each of five stress components in each type
 of strut (BEHX2 for AFT struts and BEHX3 for FORWARD struts).
 3. Maximum stress in the propellant tank due to loading by
 the AFT and FORWARD sets of struts and by the loads, PRESS,
 GAXIAL, GLATRL, and TNKCOOL (BEHX8).
 4. Minimum buckling of the propellant tank under the AFT and
 FORWARD sets of struts and by the loads, PRESS, GAXIAL,
 GLATRL, and TNKCOOL (BEHX9).


 BIGBOSOR4 input file for propellant tank under
 Load Case 2 supported by struts (second approximation)
test2.BEHX042

 Axial loads in the struts at tank support ring no.  1 SPRLOD(K,NRTOT) =
 -3.5834E+03  3.4678E+04 -3.4675E+04  3.5863E+03  3.5863E+03
 -3.4675E+04  3.4678E+04 -3.5834E+03
 Circ. angles to strut pinned end at tank ring no.   1 SPRANG(K,ISEG) =
  6.0000E+00  8.4000E+01  9.6000E+01  1.7400E+02  1.8600E+02
  2.6400E+02  2.7600E+02  3.5400E+02
 Axial length change in struts at tank support ring no.  1 SPRDLG(K,NRTOT) =
 -4.3624E-02  4.2216E-01 -4.2212E-01  4.3658E-02  4.3658E-02
 -4.2212E-01  4.2216E-01 -4.3624E-02
 NOTE: The changes in axial length, SPRDLG, just listed
 are significantly greater than those listed previously
 because the springs are softer in this "BEHX04*" model
 than those in the "BEHX01*" model, NOT because there is
 more local deformation of the tank under these spring
 loads. The change in length of the "effective" spring
 caused by local deformation of the propellant tank is
 listed above as the quantity called "DISMAX", which is
 computed from the "BEHX03*" model in which the springs
 are replaced by concentrated loads acting on the tank.
```

```
 Circ. angle where the maximum concentrated AXIAL load is
 applied to the propellant tank by the struts at the tank
 support ring no.  1. Circumferential angle =  8.4000E+01

 Maximum load in a strut (NSPTOT,KSTMAX,ANGMAX):
 Ring Number  1: Strut no.  2; Circ. angle to strut=  8.4000E+01
 Minimum load in a strut (NSPTOT,KSTMIN,ANGMIN):
 Ring Number  1: Strut no.  3; Circ. angle to strut=  9.6000E+01
 Strut type =  1; CIRCANG(ITYPE)=  8.4000E+01

 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMAX(JRING),LODMIN(JRING)=  1.1771E+02  3.4678E+04 -3.4675E+04

 Maximum and minimum strut loads using the maximum absolute
 value of any strut load associated with the struts attached
 to propellant tank ring number 1 with plus and minus
 signs attached to that maximum absolute load value. This is
 a conservative model, representing approximately the case in
 which both plus and minus values of the user-specified
 g-loading are accounted for. This conservative approach is
 used only if the absolute value of GLATRL is greater than or
 equal to the absolute value of GAXIAL.
 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),LODMX2(JRING),LODMN2(JRING)=  1.1771E+02  3.4678E+04 -3.4678E+04

  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 springs
 (pinned struts) attached. 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
 each set of struts (AFT and FORWARD) are pinned to the tank.
 The strut (spring) stiffness takes into account the
 flexibility of the propellant tank wall.



 BIGBOSOR4 input file for: free vibration frequencies for Load Case 2
test2.BEHX12

 FREE VIBRATION FREQUENCIES AND MODES (BEHX1)
 Total tank mass including "lumped" propellant, TOTMAS=  2.8950E+01
  1.3845E+01(n= 0 circ.waves)
  1.2049E+01(n= 1 circ.waves)
  4.0955E+01(n= 2 circ.waves)
  4.1090E+01(n= 3 circ.waves)
  3.9907E+01(n= 4 circ.waves)
    1        13.84504      free vibration frequency (cps): FREQ(2 ,1 )
    2        12.04862      free vibration frequency (cps): FREQ(2 ,2 )
    3        40.95461      free vibration frequency (cps): FREQ(2 ,3 )
    4        41.09015      free vibration frequency (cps): FREQ(2 ,4 )

  BEHAVIOR OVER J =  stress component number

 CHAPTER 7: strut stress analysis-BEHX2x, x=1,2; x=load case)
```

This is the stress analysis from both BIGBOSOR4 and from a PANDA2-type of laminate analysis of the most highly loaded strut of the AFT set of struts (struts of type 1). The struts are tubes made of composite laminate. The most highly loaded strut under both axial tension and equal axial compression is analyzed. The tensile/compressive load to which the most highly loaded strut is subjected is derived in the computation under CHAPTER 5. The five stress "behavioral" constraints computed here correspond to:

1. tension along the fibers of a ply,
2. compression along the fibers of a ply,
3. tension transverse to the fibers of a ply,
4. compression transverse to the fibers of a ply,
5. in-plane shear stress in a ply.

Recorded as 5 behavioral constraints are the maximum values of each of the five components just listed from tension or compression and from a BIGBOSOR4 or a PANDA2-type of model. In other words, only the worst (highest) stress component from four computations (tension BIGBOSOR4,compression BIGBOSOR4, tension PANDA2, compression PANDA2) is recorded as each component behavioral constraint.

```
 BIGBOSOR4 input file for: maximum stress in a  strut of type 1 for load case 2
test2.BEHX22

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM TENSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  5.0598E+04  fiber tension
  1.3520E+04  fiber compres.
  7.0426E+03  transv tension
  0.0000E+00  transv compres
  1.7385E+03  in-plane shear

 BIGBOSOR4 MODEL: STRUT LOADED BY MAXIMUM COMPRESSION FORCE
 MAXIMUM STRESS COMPONENTS IN A STRUT OF TYPE 1 (BEHX2)
  0.0000E+00  fiber tension
  4.7186E+04  fiber compres.
  3.1073E+03  transv tension
  0.0000E+00  transv compres
  1.2896E+03  in-plane shear

 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER TENSION...
 Corresponding maximum stress components from PANDA-type model:
  4.4974E+04  tensile fiber
  1.1802E+04  compressive fiber
  6.3106E+03  tensile transverse
  0.0000E+00  compressive transverse
  1.6417E+03  in-plane shear


 STRESSES FROM PANDA THEORY FOR THE STRUT TUBE UNDER COMPRESSN..
 Corresponding maximum stress components from PANDA-type model:
  0.0000E+00  tensile fiber
  4.7184E+04  compressive fiber
  3.1059E+03  tensile transverse
  0.0000E+00  compressive transverse
  1.2891E+03  in-plane shear
```

```
   5        50598.19      maximum stress in material 1: STRES1(2 ,1 )
   6        47186.20      maximum stress in material 1: STRES1(2 ,2 )
   7        7042.618      maximum stress in material 1: STRES1(2 ,3 )
   8       0.1000000E-09  maximum stress in material 1: STRES1(2 ,4 )
   9        1738.535      maximum stress in material 1: STRES1(2 ,5 )

 BEHAVIOR OVER J =  stress component number

CHAPTER 8: strut stress analysis-BEHX3x, x=1,2; x=load case)
This is the stress analysis from both BIGBOSOR4 and from
a PANDA2-type of laminate analysis of the most highly loaded
strut of the FWD set of struts (struts of type 2). The struts
are tubes made of composite laminate. The most highly loaded
strut under both axial tension and equal axial compression is
analyzed. The tensile/compressive load to which the most
highly loaded strut is subjected is derived in the computation
under CHAPTER 5. The five stress "behavioral" constraints
computed here correspond to:
1. tension along the fibers of a ply,
2. compression along the fibers of a ply,
3. tension transverse to the fibers of a ply,
4. compression transverse to the fibers of a ply,
5. in-plane shear stress in a ply.
Recorded as 5 behavioral constraints are the maximum values
of each of the five components just listed from tension or
compression and from a BIGBOSOR4 or a PANDA2-type of model.
In other words, only the worst (highest) stress component from
four computations (tension BIGBOSOR4,compression BIGBOSOR4,
tension PANDA2, compression PANDA2) is recorded as each
component behavioral constraint.
  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 =  stress component number
  15       0.1000000E-09  maximum stress in material 3: STRES3(2 ,1 )
  16       0.1000000E-09  maximum stress in material 3: STRES3(2 ,2 )
  17       0.1000000E-09  maximum stress in material 3: STRES3(2 ,3 )
  18       0.1000000E-09  maximum stress in material 3: STRES3(2 ,4 )
  19       0.1000000E-09  maximum stress in material 3: STRES3(2 ,5 )

CHAPTER 9: Buckling of strut as a column
-BEHX5xy, x=1,2 x=strut type; y=1,2 y=load case
Only the most highly axially compressed strut in the strut
set "x" is included in the analysis. Two models are used:
1. a BIGBOSOR4 model of the strut. n = 1 circumferential wave
   corresponds to buckling of the strut as a column. The
   effect of propellant tank flexibility is NOT included in
   this BIGBOSOR4 model.
2. an Euler buckling model of the strut. This model is
   analogous to the column buckling model used in "DEWAR".
   The effect of propellant tank flexibility IS included.
The Euler buckling model usually gives the lower buckling
load factor, mainly because of propellant tank flexibility.
The buckling constraint is based on the minimum column
```

```
 buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: column buckling of strut of type 1 for load case 2
test2.BEHX512

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -3.4675E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
 specified in the input for BEGIN: GLATRL=  1.0000E+01
 JCOL,LODMN2(1),LODMN2(2)=  1 -3.4678E+04  0.0000E+00

 COLUMN BUCKLING OF STRUT FROM BIGBOSOR4. The flexibility of
 the propellant tank is not accounted for in the BIGBOSOR4
 model of column buckling. (BEHX5)
  1.5012E+00(n= 1 circ.waves (from the BIGBOSOR4 model))
 Strut type  1; Strut length=  1.1771E+02 Load on strut= -3.4678E+04
 Column buckling of strut from Euler formula, COLBUC=  9.9711E-01
 The flexibility of the propellant tank IS accounted for in
 this Euler buckling model. The column buckling constraint is
 the minimum value obtained from BIGBOSOR4 and the Euler model.
   20       0.9971097      buckling of a strut as a column: COLBUK(2 ,1 )

 CHAPTER 10: Buckling of strut as a shell
 -BEHX6xy, x=1,2 x=strut type; y=1,2 y=load case
 Only the most highly axially compressed strut in the strut
 set "x" is included in the analysis. Two models are used:
 1. a BIGBOSOR4 model of a sub-length of the strut. A search
    is conducted over the number n of circumferential waves in
    the buckling mode to determine the critical buckling load
    factor. The effect of propellant tank flexibility is not
    relevant in this analysis.
 2. a PANDA2-type buckling model of the strut. This model is
    analogous to the shell buckling model used in "DEWAR".
    The effect of propellant tank flexibility is not relevant.

 The PANDA2-type buckling model usually gives the lower
 buckling load factor, mainly because of the effect of
 transverse shear deformation (t.s.d.) and the effect of the
 anisotropic terms, D16 and D26, that BIGBOSOR4 cannot handle.
 The buckling constraint is based on the minimum shell
 buckling load factor obtained from the two models just listed.


 BIGBOSOR4 input file for: shell buckling of strut type 1 for load case 2
test2.BEHX612

 JCOL=strut type; LODMIN=minimum load for GAXIAL
 and GLATRL as specified in the input for BEGIN.
 JCOL,LODMIN(1),LODMIN(2)=  1 -3.4675E+04  0.0000E+00

 JCOL=strut type; LODMN2=minimum load for GAXIAL
 as specified in the input for BEGIN and for either
 plus or minus GLATRL with GLATRL amplitude as
```

```
specified in the input for BEGIN: GLATRL=  1.0000E+01
JCOL,LODMN2(1),LODMN2(2)=  1 -3.4678E+04  0.0000E+00

SHELL BUCKLING OF STRUT FROM BIGBOSOR4 (BEHX6)
 3.8788E+00(n= 0 circ.waves (from BIGBOSOR4))
 3.8475E+00(n= 1 circ.waves (from BIGBOSOR4))
 3.7533E+00(n= 2 circ.waves (from BIGBOSOR4))
 3.5937E+00(n= 3 circ.waves (from BIGBOSOR4))
 3.3423E+00(n= 4 circ.waves (from BIGBOSOR4))
 2.8097E+00(n= 5 circ.waves (from BIGBOSOR4))
 2.6440E+00(n= 6 circ.waves (from BIGBOSOR4))
 2.7284E+00(n= 7 circ.waves (from BIGBOSOR4))
 2.9965E+00(n= 8 circ.waves (from BIGBOSOR4))
 3.4118E+00(n= 9 circ.waves (from BIGBOSOR4))
 3.9498E+00(n=10 circ.waves (from BIGBOSOR4))
Critical buckling load factor from BIGBOSOR4, SHLBUK=  2.6440E+00
Critical number of axial half-waves (BIGBOSOR4), NWVCRT=    6
Strut type  1; Strut length=  1.1771E+02 Load on strut= -3.4678E+04
Column buckling of strut from Euler formula, COLBUC=  9.9711E-01

INFORMATION PERTAINING TO STRUT TYPE 1:

IMPORTANT ELEMENTS IN THE BUCKLING CONSTRAINTS FOR SUPPORT SET (AFT) ARE:
AFT support member. COLUMN buckling results (Euler formula):
 Effective bending stiffness of LAUNCH tube,      EI =  7.6223E+07
 Length of strut from pinned end to pinned end,    L =  1.1771E+02
 Force in strut tending to buckle it,          FORCE = -3.4678E+04
 Euler (column) buckling strain,    pi**2*I/(A*L**2) =  3.5761E-03
 Average strain in the column (g-loads minus temp.),e= -3.5865E-03
 Effective stiffness of strut for lateral (n=1) motions
   including knockdowns for shell and ring flexibility,
                                                  K1 =  8.2144E+04
 Effective stiffness of strut for axial (n=0) motions
  including only knockdown for axisymmetric shell flexibility,
                                                  K0 =  1.2355E+05
 Load factor for column buckling: COLBUC=(Euler/e)*(K1/K0),
                                              COLBUC =  9.9711E-01

AFT support member.SHELL buckling results(PANDA):
Calculations for (1=launch tube,2=orbital tube)= 1
 Main diagonal of shell wall constitutive matrix, C(i,i):
   axial stiffness of shell wall,             C(1,1) =  8.0044E+05
   hoop  stiffness of shell wall,             C(2,2) =  3.8288E+05
   shear stiffness of shell wall,             C(3,3) =  1.3182E+05
   axial bending rigidity of shell wall       C(4,4) =  2.4994E+02
   hoop  bending rigidity of shell wall       C(5,5) =  9.7170E+01
   twisting      rigidity of shell wall       C(6,6) =  4.3490E+01
 Force in tube tending to buckle it,           FORCE = -3.4678E+04
 Length of tube used for SHELL buckling model, FLEFF =  1.9011E+01
 Load factor, shell buckling (PANDA analysis),SHLBC2 =  2.0031E+00
 Number of axial half-waves in buckle pattern,     m =     1
 Number of circumferential full waves in mode,     n =     7
 Slope of nodal lines of buckling pattern,    CSLOPE =  7.1667E-01
  21        2.003065      buckling of strut as a shell: SHLBUK(2 ,1 )

CHAPTER 11: Launch-hold force in a strut
-BEHX7x, x=1,2; x=load case
If the propellant tank is oriented vertically in the launch
```

vehicle all the struts in each strut set experience the same launch-hold force. The launch-hold force in the AFT struts may differ from that in the FORWARD struts. Behavioral constraints are computed for each set of struts. The behavioral constraint is called "FORCE(i,j)", in which i = the load case number and j =the strut set number (strut type).

FORCE(i,j) is computed from a BIGBOSOR4 model of the propellant tank with struts (springs) attached to it. The spring constants include the effect of the flexibility of the propellant tank. The tank is loaded by PRESS, GAXIAL=1g, and TNKCOOL. The maximum allowable strut launch-hold force is provided for each load case by the End user. The behavioral constraint, FORCE(i,j), must be less than the maximum allowable, FORCEA(i,j). The End user must supply FORCEA(i,j) at a small enough value so that if the struts contain a disconnect feature they will not "short out" during the launch-hold phase of a mission.

BIGBOSOR4 input file for propellant tank supported by struts (launch-hold condition for load case 2)
test2.BEHX72

```
 Length of strut, max. load, min. load for strut type 1; strut ring no.  1
 LENGTH(ITYPE),FCEMAX(JRING),FCEMIN(JRING)=  1.1771E+02  0.0000E+00 -2.4050E+03
   22        2404.957      launch-hold force in a strut: FORCE(2 ,1 )
```

CHAPTER 12: Maximum effective stress in the isotropic propellant tank - BEHX8xy, x=1,2 x=meridian; y=1,2 y=load case This is a BIGBOSOR4 model in which the springs (struts) are replaced by concentrated loads. The model is analogous to that described in CHAPTER 4 (*.BEHX03x, x=1,2; x=load case). The propellant tank is loaded by PRESS, GAXIAL, GLATRL, and TNKCOOL. The modeling of the concentrated loads that replace the springs (struts) is described in CHAPTER 4. The purpose of this model is to compute the maximum effective stress in the propellant tank, which is assumed to be fabricated of isotropic material. This is an "INDIC=3" BIGBOSOR4 model.

BIGBOSOR4 input file for load case 2:
maximum stress in the propellant tank from the prebuckling load distribution on the meridian at angle, CIRCANG(JCOL)= 8.4000E+01 in which JCOL = 1
test2.BEHX812

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

 ****** MAX. NORMAL DISPLACEMENT, LOAD SET A ************
 WWWMAX(1)=  9.9028E-01, LOCATW(1)=1000*ISEG+I=  1001
 ********************************************************

 ****** (ALLOWABLE STRESS)/(ACTUAL STRESS) ********
  1  9.9202E-01 fiber tension : matl=1 ,  A , seg=18, node=2 , layer=1 ,z= -1.01 ;FS=  1.00
  2  9.9813E-01 fiber compres.: matl=1 ,  A , seg=15, node=1 , layer=1 ,z= -1.03 ;FS=  1.00
  3  1.5031E+00 transv tension: matl=1 ,  A , seg=1 , node=5 , layer=1 ,z=-0.01  ;FS=  1.00
  4  1.2157E+00 transv compres: matl=1 ,  A , seg=15, node=3 , layer=1 ,z= -1.03 ;FS=  1.00
  5  1.0476E+00 effect. stress: matl=2 ,  A , seg=1 , node=5 , layer=2 ,z= 0.01  ;FS=  1.00
  6  1.5298E+00 effect. stress: matl=3 ,  A , seg=15, node=12, layer=3 ,z= 0.04  ;FS=  1.00
  7  1.4595E+00 effect. stress: matl=4 ,  A , seg=15, node=13, layer=2 ,z= 0.03  ;FS=  1.00
```

```
  8  1.1484E+00 effect. stress: matl=5 ,  A , seg=17, node=1 , layer=2 ,z=-0.01  ;FS=  1.00
 ***************************************************
 Maximum stress components for Load Case  2 STRESS2(i),i=1,6=
     5.0402E+04     5.0094E+04     3.3264E+04     4.1127E+04     0.0000E+00     4.7729E+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)=  0.0000E+00, LOCATS(1)=1000*ISEG+I=     0
 *******************************************************

 ****** MAX. EFF. STRESS IN NWALL =9 SEGS, LOAD A ******
 STRESS=     5.0402E+04
fiber tension : matl=1 ,  A , seg=18, node=2 , layer=1 ,z= -1.01 ;FS=  1.00
 *******************************************************
   23        50402.36      maximum stress in the propellant tank: TNKSTR(2 ,1 )

 CHAPTER 13: Buckling of the isotropic propellant tank
 - BEHX9xy, x=1,2 x=meridian; y=1,2 y=load case
 This is a BIGBOSOR4 model in which the springs (struts) are
 replaced by concentrated loads. The 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 is loaded by PRESS, GAXIAL, GLATRL, and
 TNKCOOL. The modeling of the concentrated loads that replace
 the springs (struts) is described in CHAPTER 4. The purpose
 of this model is to compute the minimum buckling load of
 the propellant tank, which is assumed to be fabricated of
 isotropic material. This is an "INDIC=4" BIGBOSOR4 model.


 BIGBOSOR4 input file for load case 2: buckling of the propellant tank from the
prebuckling
 load distribution on the meridian at angle, CIRCANG(JCOL)=  8.4000E+01 in which JCOL = 1
test2.BEHX912

 BUCKLING OF THE PROPELLANT TANK (BEHX9)
  2.8727E+01(n=  10 circ.waves); IFAILD= 0
  1.2205E+01(n=  15 circ.waves); IFAILD= 0
  8.5354E+00(n=  20 circ.waves); IFAILD= 0
  7.9269E+00(n=  25 circ.waves); IFAILD= 0
  8.3666E+00(n=  30 circ.waves); IFAILD= 0
  9.3804E+00(n=  35 circ.waves); IFAILD= 0
  1.0802E+01(n=  40 circ.waves); IFAILD= 0
  1.2547E+01(n=  45 circ.waves); IFAILD= 0
  1.4564E+01(n=  50 circ.waves); IFAILD= 0
  1.6816E+01(n=  55 circ.waves); IFAILD= 0
  1.9277E+01(n=  60 circ.waves); IFAILD= 0
  2.1924E+01(n=  65 circ.waves); IFAILD= 0
  2.4736E+01(n=  70 circ.waves); IFAILD= 0
  2.7694E+01(n=  75 circ.waves); IFAILD= 0
  3.0779E+01(n=  80 circ.waves); IFAILD= 0
  3.3969E+01(n=  85 circ.waves); IFAILD= 0
  3.7244E+01(n=  90 circ.waves); IFAILD= 0
  4.0574E+01(n=  95 circ.waves); IFAILD= 0
  4.3920E+01(n= 100 circ.waves); IFAILD= 0
 Critical buckling load factor from BIGBOSOR4, TNKBUK=  7.9269E+00
 Critical number of axial half-waves (BIGBOSOR4), NWVCRT=   25
```

```
  24        7.926853      propellant tank buckling load factor: TNKBUK(2 ,1 )

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

BEH.   CURRENT
NO.     VALUE            DEFINITION
 1    1.385E+01    free vibration frequency (cps): FREQ(2 ,1 )
 2    1.205E+01    free vibration frequency (cps): FREQ(2 ,2 )
 3    4.095E+01    free vibration frequency (cps): FREQ(2 ,3 )
 4    4.109E+01    free vibration frequency (cps): FREQ(2 ,4 )
 5    5.060E+04    maximum stress in material 1: STRES1(2 ,1 )
 6    4.719E+04    maximum stress in material 1: STRES1(2 ,2 )
 7    7.043E+03    maximum stress in material 1: STRES1(2 ,3 )
 8    1.000E-10    maximum stress in material 1: STRES1(2 ,4 )
 9    1.739E+03    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    maximum stress in material 3: STRES3(2 ,1 )
16    1.000E-10    maximum stress in material 3: STRES3(2 ,2 )
17    1.000E-10    maximum stress in material 3: STRES3(2 ,3 )
18    1.000E-10    maximum stress in material 3: STRES3(2 ,4 )
19    1.000E-10    maximum stress in material 3: STRES3(2 ,5 )
20    9.971E-01    buckling of a strut as a column: COLBUK(2 ,1 )
21    2.003E+00    buckling of strut as a shell: SHLBUK(2 ,1 )
22    2.405E+03    launch-hold force in a strut: FORCE(2 ,1 )
23    5.040E+04    maximum stress in the propellant tank: TNKSTR(2 ,1 )
24    7.927E+00    propellant tank buckling load factor: TNKBUK(2 ,1 )

******* 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    1.538E-01  (FREQ(2 ,1 )/FREQA(2 ,1 )) / FREQF(2 ,1 )-1; F.S.=  1.20
 2    4.052E-03  (FREQ(2 ,2 )/FREQA(2 ,2 )) / FREQF(2 ,2 )-1; F.S.=  1.20
 3    2.413E+00  (FREQ(2 ,3 )/FREQA(2 ,3 )) / FREQF(2 ,3 )-1; F.S.=  1.20
 4    2.424E+00  (FREQ(2 ,4 )/FREQA(2 ,4 )) / FREQF(2 ,4 )-1; F.S.=  1.20
 5    8.521E-01  (STRES1A(2 ,1 )/STRES1(2 ,1 )) / STRES1F(2 ,1 )-1; F.S.=  1.50
 6    4.794E-01  (STRES1A(2 ,2 )/STRES1(2 ,2 )) / STRES1F(2 ,2 )-1; F.S.=  1.50
 7   -6.558E-04  (STRES1A(2 ,3 )/STRES1(2 ,3 )) / STRES1F(2 ,3 )-1; F.S.=  1.50
 8    1.412E+00  (STRES1A(2 ,5 )/STRES1(2 ,5 )) / STRES1F(2 ,5 )-1; F.S.=  1.50
 9   -2.890E-03  (COLBUK(2 ,1 )/COLBUKA(2 ,1 )) / COLBUKF(2 ,1 )-1; F.S.=  1.00
10    1.532E-03  (SHLBUK(2 ,1 )/SHLBUKA(2 ,1 )) / SHLBUKF(2 ,1 )-1; F.S.=  2.00
11    5.237E+00  (FORCEA(2 ,1 )/FORCE(2 ,1 )) / FORCEF(2 ,1 )-1; F.S.=  1.00
12   -7.983E-03  (TNKSTRA(2 ,1 )/TNKSTR(2 ,1 )) / TNKSTRF(2 ,1 )-1; F.S.=  1.00
13    6.927E+00  (TNKBUK(2 ,1 )/TNKBUKA(2 ,1 )) / TNKBUKF(2 ,1 )-1; F.S.=  1.00

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

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

VAR.   CURRENT
NO.     VALUE            DEFINITION
 1    1.246E+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.   CURRENT
NO.     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    1.500E+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    1.750E+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    5.000E+00  length of end fitting attached to tank ring: FITTNK(1 )
16    1.000E+07  axial "EA" stiffness of tank-end strut fitting: FEATNK(1 )
17    1.000E-05  Coef.of thermal expansion of tank end fitting: ALFITT(1 )
18    5.000E+00  length of strut end fitting attached to "ground": FITVEH(1 )
19    1.000E+07  axial "EA" stiffness of "ground" end strut fitting: FEAVEH(1 )
20    1.000E-05  coef.of thermal expan. of "ground" end fitting: ALFITV(1 )
21    1.000E-01  length factor for strut buckling as a shell: FACLEN(1 )
22   -1.000E+02  Average strut temperature minus ambient: DTSUP(1 )
23    2.000E+00  outer diam.of the orbital tube assembly: ODINNR(1 )
24    4.000E+00  Length of the orbital tube assembly: FLINNR(1 )
25    1.000E+07  hoop modulus of the tank ring: TRNGE(1 )
26    1.000E-05  coef.of thermal expansion of the tank ring: ALRNGT(1 )
27    2.100E+07  modulus in the fiber direction: E1(1 )
28    1.600E+06  modulus transverse to fibers: E2(1 )
29    6.790E+05  in-plane shear modulus: G12(1 )
30    2.300E-02  small Poisson's ratio: NU(1 )
31    6.270E+05  x-z out-of-plane shear modulus: G13(1 )
32    3.340E+05  y-z out-of-plane shear modulus: G23(1 )
33    1.000E-06  coef.of thermal expansion along fibers: ALPHA1(1 )
34    1.000E-05  coef.of thermal expan.transverse to fibers: ALPHA2(1 )
35    1.700E+02  curing delta temperature (positive): TEMTUR(1 )
36    7.270E-03  conductivity along the fibers: COND1(1 )
37    4.370E-03  conductivity transverse to fibers: COND2(1 )
38    5.700E-02  weight density of the material: DENSTY(1 )
39    5.000E-01  objective=WGT*(empty tank mass) +(1-WGT)*(conductance): WGT
```

```
40    3.000E+00  normalizing empty tank mass: TNKNRM
41    6.000E-04  normalizing total strut conductance: CONNRM
PARAMETERS WHICH ARE ENVIRONMENTAL FACTORS (e.g. loads, temps.)

VAR.   CURRENT
NO.     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.   CURRENT
NO.     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    1.406E+05  maximum allowable stress in material 3: STRES3A(1 ,1 )
30    1.406E+05  maximum allowable stress in material 3: STRES3A(2 ,1 )
31    1.047E+05  maximum allowable stress in material 3: STRES3A(1 ,2 )
32    1.047E+05  maximum allowable stress in material 3: STRES3A(2 ,2 )
33    1.056E+04  maximum allowable stress in material 3: STRES3A(1 ,3 )
34    1.056E+04  maximum allowable stress in material 3: STRES3A(2 ,3 )
35    1.453E+04  maximum allowable stress in material 3: STRES3A(1 ,4 )
36    1.453E+04  maximum allowable stress in material 3: STRES3A(2 ,4 )
37    6.290E+03  maximum allowable stress in material 3: STRES3A(1 ,5 )
38    6.290E+03  maximum allowable stress in material 3: STRES3A(2 ,5 )
39    1.000E+00  allowable for column buckling of strut: COLBUKA(1 ,1 )
40    1.000E+00  allowable for column buckling of strut: COLBUKA(2 ,1 )
```

```
41    1.000E+00  allowable for shell buckling of strut: SHLBUKA(1 ,1 )
42    1.000E+00  allowable for shell buckling of strut: SHLBUKA(2 ,1 )
43    1.500E+04  maximum allowable launch-hold force in strut: FORCEA(1 ,1 )
44    1.500E+04  maximum allowable launch-hold force in strut: FORCEA(2 ,1 )
45    5.000E+04  allowable for propellant tank stress: TNKSTRA(1 ,1 )
46    5.000E+04  allowable for propellant tank stress: TNKSTRA(2 ,1 )
47    1.000E+00  allowable for propellant tank buckling: TNKBUKA(1 ,1 )
48    1.000E+00  allowable for propellant tank buckling: TNKBUKA(2 ,1 )
PARAMETERS WHICH ARE FACTORS OF SAFETY

VAR.   CURRENT
NO.     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    1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,1 )
30    1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,1 )
31    1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,2 )
32    1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,2 )
33    1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,3 )
34    1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,3 )
35    1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,4 )
36    1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,4 )
37    1.500E+00  factor of safety for stress, matl 3: STRES3F(1 ,5 )
38    1.500E+00  factor of safety for stress, matl 3: STRES3F(2 ,5 )
39    1.000E+00  factor of safety for Euler strut buckling: COLBUKF(1 ,1 )
40    1.000E+00  factor of safety for Euler strut buckling: COLBUKF(2 ,1 )
41    2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(1 ,1 )
42    2.000E+00  factor of safety for shell buckling of strut: SHLBUKF(2 ,1 )
43    1.000E+00  factor of safety for launch-hold force: FORCEF(1 ,1 )
44    1.000E+00  factor of safety for launch-hold force: FORCEF(2 ,1 )
45    1.000E+00  factor of safety for tank stress: TNKSTRF(1 ,1 )
46    1.000E+00  factor of safety for tank stress: TNKSTRF(2 ,1 )
```

```
47    1.000E+00  factor of safety for tank buckling: TNKBUKF(1 ,1 )
48    1.000E+00  factor of safety for tank buckling: TNKBUKF(2 ,1 )

   0 INEQUALITY CONSTRAINTS WHICH MUST BE SATISFIED



DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

test2.NAM = This file contains only the name of the case.
test2.OPM = Output data. Please list this file and inspect
           carefully before proceeding.
test2.OPP = Output file containing evolution of design and
           margins since the beginning of optimization cycles.
test2.CBL = Labelled common blocks for analysis.
           (This is an unformatted sequential file.)
test2.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 test2.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 test2.OPM FILE ****************
=====================================================================
```

Table 16 Input data for the GENOPT processor, CHANGE, by means of which optimized designs can be archived (test2.CHG file).
(These data are provided by the End user, short propellant tank)

```
===========================================================
      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, . .)
  0.2135000E-01 $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         2      $ Number of parameter to change (1, 2, 3, . .)
  0.6672000E-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, . .)
  0.2757000E-01 $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         4      $ Number of parameter to change (1, 2, 3, . .)
   3.000000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         5      $ Number of parameter to change (1, 2, 3, . .)
   3.000000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         6      $ Number of parameter to change (1, 2, 3, . .)
  0.1595000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         7      $ Number of parameter to change (1, 2, 3, . .)
   1.000000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         8      $ Number of parameter to change (1, 2, 3, . .)
  0.1634000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
         9      $ Number of parameter to change (1, 2, 3, . .)
   1.000000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        10      $ Number of parameter to change (1, 2, 3, . .)
       175      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        11      $ Number of parameter to change (1, 2, 3, . .)
   106.6000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        12      $ Number of parameter to change (1, 2, 3, . .)
         6      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        13      $ Number of parameter to change (1, 2, 3, . .)
        45      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        14      $ Number of parameter to change (1, 2, 3, . .)
```

```
 6.277000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      15      $ Number of parameter to change (1, 2, 3, . .)
0.1000000E-05 $ New value of the parameter
    Y         $ Want to change any other parameters in this set?
      16      $ Number of parameter to change (1, 2, 3, . .)
0.1000000E-05 $ New value of the parameter
    Y         $ Want to change any other parameters in this set?
      17      $ Number of parameter to change (1, 2, 3, . .)
0.1000000E-05 $ New value of the parameter
    Y         $ Want to change any other parameters in this set?
      18      $ Number of parameter to change (1, 2, 3, . .)
0.1000000E-05 $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      19      $ Number of parameter to change (1, 2, 3, . .)
      30      $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      20      $ Number of parameter to change (1, 2, 3, . .)
0.1810000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      21      $ Number of parameter to change (1, 2, 3, . .)
0.1000000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      22      $ Number of parameter to change (1, 2, 3, . .)
0.5000000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      23      $ Number of parameter to change (1, 2, 3, . .)
0.5000000E-02 $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      24      $ Number of parameter to change (1, 2, 3, . .)
0.5000000E-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, . .)
0.5000000E-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, . .)
0.5000000E-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, . .)
0.5000000E-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, . .)
0.5000000E-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, . .)
 17.26000     $ New value of the parameter
    y         $ Want to change any other parameters in this set?
      30      $ Number of parameter to change (1, 2, 3, . .)
```

```
  -17.26000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        31      $ Number of parameter to change (1, 2, 3, . .)
   67.01000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        32      $ Number of parameter to change (1, 2, 3, . .)
  -67.01000     $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        33      $ Number of parameter to change (1, 2, 3, . .)
        10      $ New value of the parameter
      y         $ Want to change any other parameters in this set?
        34      $ Number of parameter to change (1, 2, 3, . .)
       -10      $ 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?
========================================================================
```