25 February, 2009

Dear Allen,

This is probably the final chapter in my study of your case, "testcase2", which I call "allen" and "allen2".

The page numbering starts where the material I sent to you some time ago ends. You can just add this material to the other for a complete documentation of this project.

This long chapter is based on use of the PANDA2 conservativeness index, ICONSV = 0 and IQUICK = 0 . There are many comparisons with STAGS models.

In the course of this work I have made several modifications to PANDA2, documented in new ITEMS, ITEM 754 - 769 (dated February, 2009) in my "documentation" file, .../panda2/doc/panda2.news.

You will have to install this latest version of PANDA2 at your facility if you want to get results that agree with those presented here.

I think I have explained everything in the many tables and figures, and I have two introductory lists that give the run streams I used:

1. pp. 55 - 59 give the run stream and some explanation for the case I have called "allen". "allen" is the case in which there exist sub-stringers.

2. p. 185 gives the run stream and some explanation for the case I have called "allen2". "allen2" is the case in which there are no sub-stringers.

In this package, pp. 55 - 183 pertain to the case with sub-stringers present: "allen". Pages 184 - 212 pertain to the case without sub-stringers: "allen2".

There is one very important aspect of this work, in my opinion. That important aspect is described on p. 57. I have extracted that section and repeat it here for emphasis:

******************** IMPORTANT **

"Next, we want to address two important questions:

1. The very slender rings [thickness = 0.065 inch; height = 6.7093 inches see the end of Table 28]. The height of the optimized ring is more than 100 times its thickness. This ring is too flimsy for practical designs, designs for which there always exists SOME imperfection shape. The ring gets very slender during optimization cycles because there is only hoop tension in it if the shell is perfect. With a general buckling modal imperfection of reasonably conservative amplitude, part of the ring will experience hoop compression because of prebuckling circumferential bending of the imperfect shell that occurs as the imperfect shell is subjected to uniform axial compression. The flimsy ring will buckle by itself if there is any hoop compression in it at all.

2. the factors of safety for buckling. Once we assume that a general buckling modal imperfection is present, we can set the factors of safety for buckling equal to 0.999 (essentially unity), provided that a reasonably conservative value is used for the amplitude of the initial general buckling modal imperfection. Here we use 0.999 instead of 1.0 for the buckling factors of safety because in PANDA2, if the user sets the buckling factors of safety equal to 1.0, PANDA2 automatically revises them to 1.1. If the user sets the buckling factors of safety to 0.999 PANDA2 does not change them."

******************* IMPORTANT ***

In my opinion the best way to obtain robust optimum designs is always to have the presence of a general buckling modal imperfection in load sets that are buckling-critical. It may be difficult to assign an appropriate amplitude for the general buckling modal imperfection, but try! Always optimize with the plus and minus amplitudes of the general buckling modal imperfection in two different load sets. Don't ever bother with what I call "panel" buckling modal imperfections or "local" buckling modal imperfections. ("panel" here means inter-ring buckling modal imperfections; "local" means buckling modal imperfections between adjacent stringers and rings.)

I very much prefer the optimum design for "allen" listed in Table 49 over that listed in Table 28, even though the Table 49 design is somewhat heavier. The Table 49 design is better because it is optimized under the realistic assumption that there exists an overall imperfection shape. The imperfect shell behaves significantly differently from the perfect shell. This significant difference in behavior leads to significantly different and, in my opinion, more robust designs than those obtained for perfect shells in which the effect of a neglected imperfection is compensated for by application of factors of safety for buckling that are larger than unity. I describe the main effects of an initial general buckling modal imperfection in my 2007 AIAA paper on the optimum design of imperfect stiffened cylindrical shells under uniform axial compression. (See Section 7 of AIAA Paper 2007-2216, AIAA 48th SDM meeting, April 2007). Table 54 lists the margins for the shell optimized with a general buckling modal imperfection with plus and minus amplitude, Wimp = 0.5 inch. In Table 54 the amplitude of the general buckling modal imperfection has been set equal to zero. We see that the optimum design obtained WITH the general buckling modal imperfection present exhibits a factor of safety for local buckling equal to about 1.33 and a factor of safety for general buckling equal to about 2.46 when the amplitude of the general buckling modal imperfection is set to zero. (See Margins 1 and 12, respectively on page 1 of Table 54.) These factors of safety are not horribly different from those you assigned, 1.55 and 2.15, respectively, yet I end up with an optimum design that does not have those flimsy rings.

Another main conclusion of all this work: The presence of sub-stringers does not lead to a significantly lower weight. However, it does lead to a significantly larger spacing of the major stringers. Perhaps, therefore, the configuration with sub-stringers might be easier to fabricate. I don't know, since I don't know anything about modern fabrication methods. This conclusion holds only for your particular loading case and type of major stiffeners. However, I found the same for a cylindrical shell with different loading and with major stringers and rings that had Tee cross sections (one of my AIAA papers, the one with "substiffeners" in the title). It may just be that substiffeners never improve the design significantly.

Another point: It is not a good idea overly to constrain the design because of what you know about the structure from previous experience and from certain previously conceived "design rules". When you start using PANDA2 on a case that has been worked on previously, give the design plenty of design space to evolve in. I've noticed that in some of the cases you have sent to me there are certain design rules and bounds that you probably inherited from previous work on the project. These previously conceived design rules and bounds may well prevent PANDA2 from finding a good optimum design. Give the design lots of freedom at first and then start imposing constraints and rules after you already know how good an alternative might be if those constraints and rules had not been present. The powers that be might change their rules and constraints once they appreciate how much they cost in weight.

I hope all this is useful, Allen. Please look it over carefully and let me know where more explanation is needed.

If you have any questions, do not hesitate to ask!

With best regards,

Dave

Dave

February 25, 2009

RUN STREAM

RUN STREAM USED TO OBTAIN "allen" RESULTS WITH ICONSV = 0 AND IQUICK = 0 AND A NEW INEQUALITY CONSTRAINT IN DECIDE .

The new PANDA2 model, skin-substringer discretized single module, is used. Please read Item 764 in .../panda2/doc/panda2.news. The runs indicated in this list were made including the changes to PANDA2 described in the ITEMS listed in the file, .../panda2/doc/panda2.news up through Item 769.

(First, re-run the "allen" case, no optimization just the fixed (optimum) design, as follows:)

```
panda2log
begin           table 24
change          table 15(b) (same as Table 25 here)
setup
decide          table 26
mainsetup       table 27, except ITYPE=2
pandaopt
```

(Next, find a new optimum design with ICONSV = 0) (First, edit the allen.OPT file by setting NPRINT equal to zero and ITYPE equal to one, as is listed in Table 27).

```
superopt        (use 5 pandaopts per autochange)
```

(After superopt finishes (about 12 hours later) inspect the allen.OPP file, especially near the bottom of that file, and get a plot of the objective vs design iterations).

```
chooseplot
diplot
```

(inspect the allen.5.ps file, shown as Fig. 6 here).

(Next, edit the allen.OPT file by changing NPRINT from zero to 2 and by changing ITYPE from 1 to 2).

```
mainsetup       (Table 27 with NPRINT=2 & ITYPE=2)
pandaopt
```

(Inspect the allen.OPM file. Table 28 is an abridged version of allen.OPM).

(Next, save the optimum design by using "CHANGE").

```
change          (Table 29)
```

(Next, generate a "STAGSworthy" model. A "STAGSworthy" model is one in which the following holds:

1. There must be an integral number of major stringers in the 360-degree cylindrical shell. Change the spacing of the major stringers, B(STR), from the optimum value to the closest value that corresponds to an integral number of major stringers in the 360-degree cylindrical shell.

2. If the base under each major stringer is linked to the stringer spacing, change B2(STR) so that the linking expression is satisfied for the new value of B(STR).

3. There must be an integral number of substringers between adjacent major stringers. Change BSUB(substringers) to the nearest value that satisfies this requirement.

4. There must be an integral number of major rings over the axial length of the cylindrical shell. Change the spacing of the major rings, B(RNG), so that there are an integral number of major rings over the axial length of the shell.

5. If there are subrings, change their spacing to the nearest value so that there are an integral number of subrings between adjacent major rings.

These changes are accomplished by suitable editing of the allen.CHG file.)

```
change          (Table 30)
setup
```

(Next, execute PANDAOPT for a "fixed" design (ITYPE=2). Edit the allen.OPT file, if necessary)

```
mainsetup
pandaopt        (Table 31)
```

(Next we want to check the PANDA2 predictions by running STAGS. To do this, we first decide for which load set we want to obtain verification by STAGS. Here we choose Load Set 1. We edit the allen.OPT file to remove the input related to Load Set 2)

```
mainsetup       (Table 32)
pandaopt        (Table 33 and 34)
```

(Next, we use the PANDA2 processor called "STAGSUNIT" to set up a linear buckling STAGS model. First, we want to generate a STAGS model that includes 3 major stringer bays and 3 major ring bays. We want all the structural parts to be modeled as flexible shell units, which is the most accurate model.)

```
stagsunit       (Table 35; 3 bay x 3 bay STAGS model)
```

(STAGSMODEL generates the STAGS input files, allen.bin and allen.inp. We transfer these two files to a directory where we want to run STAGS and then execute STAGS, using the command:)

```
stags -b allen
```

(NOTE: we may want to edit the allen.bin file to change the number of eigenvalues and the eigenvalue shift. The unedited STAGS input file, allen.bin, is listed at the top of Table 36 and an edited version of allen.bin is listed at the bottom of page 1 of Table 36. Whenever a STAGS run is finished we inspect the allen.out2 file. We are especially interested in whether or not "roots" have been skipped (search for "roots") and what the eigenvalues are (search for "CONV"). Two examples of abridged allen.out2 files appear in Table 36.

(Next, run the STAGS post-processor, STAPL, in order to produce linear buckling mode shapes, such as that displayed in Figs. 7 and 8:)

```
stapl allen      (input data for STAPL are listed in Table 37).
acroread allen.pdf       (See Figs. 7 and 8, for examples)
etc.
```

(STAPL/acroread generate plots such as shown in Figs. 7 and 8).

(Next we run STAGS repeatedly with different models of the same design in order thoroughly to evaluate the predictions by PANDA2. These various STAGS runs are documented in Tables 38 - 41 and results are displayed in Figs. 9 - 13.)

(Next, we want to set up a BIGBOSOR4 model for buckling between adjacent major rings of the cylindrical shell with smeared substringers and major stringers as shell branches. First we execute the PANDA2 processor called "PANEL", then we go to a directory where we want to execute BIGBOSOR4 and copy the allen.ALL file into that directory. Finally we execute BIGBOSOR4, perhaps several times.)

```
panel            (Table 42)
cp allen.ALL ../bigbosor4/work/allen.ALL
cd ../bigbosor4/work
bigbosor4log             (activate bigbosor4 command set)
```

```
bigbosorall              (execute bigbosor4)
(inspect the allen.OUT file. Search for the string, "EIGENVALUE(".)
bosorplot
(obtain plots such as shown in Figs. 14 - 16).
```

(Next, we want to set up another BIGBOSOR4 model for buckling of the entire cylindrical shell with smeared substringers and smeared stringers. The rings are modeled as flexible shell branches. First we execute the PANDA2 processor called "PANEL2". Then we go to the directory where we want to execute BIGBOSOR4 and copy the allen.ALL file into that directory. Finally we execute BIGBOSOR4, perhaps several times.)

```
panel2          (Table 43, top)
cp allen.ALL ../bigbosor4/work/allen.ALL
cd ../bigbosor4/work
bigbosor4log
bigbosorall
(inspect the allen.OUT file. Search for the string, "EIGENVALUE(".)
(See Table 43, bottom)
bosorplot
(obtain plots such as shown in Fig. 17).
```

IMPORTANT!!

Next, we want to address two important questions:

1. The very slender rings [thickness = 0.065 inch; height = 6.7093 inches see the end of Table 28]. The height of the optimized ring is more than 100 times its thickness. This ring is too flimsy for practical designs, designs for which there always exists SOME imperfection shape. The ring gets very slender during optimization cycles because there is only hoop tension in it if the shell is perfect. With a general buckling modal imperfection of reasonably conservative amplitude, part of the ring will experience hoop compression because of prebuckling circumferential bending of the imperfect shell that occurs as the imperfect shell is subjected to uniform axial compression. The flimsy ring will buckle by itself if there is any hoop compression in it at all.

2. the factors of safety for buckling. Once we assume that a general buckling modal imperfection is present, we can set the factors of safety for buckling equal to 0.999 (essentially unity), provided that a reasonably conservative value is used for the amplitude of the initial general buckling modal imperfection. Here we use 0.999 instead of 1.0 for the buckling factors of safety because in PANDA2, if the user sets the buckling factors of safety equal to 1.0, PANDA2 automatically revises them to 1.1. If the user sets the buckling factors of safety to 0.999 PANDA2 does not change them.

(First, we want to investigate the effect of a very small general buckling modal imperfection on the design margins corresponding to Load set 1 only. For the design, we use the design listed at the bottom of Table 28, that is the optimum design determined by PANDA2 for the perfect shell).

```
panda2log       (activate the PANDA2 command set)
begin           (Table 24)
change          (Table 29)
setup
decide          (Table 26)
mainsetup       (Table 44)
pandaopt
```

(Inspect the allen.OPM file. an abridged version of it appears as Table 45. Note that there are several significantly negative margins, and that the buckling margin for ring sidesway (Margen no. 9 = -0.735) is the most negative. This very negative ring buckling margin occurs even though the amplitude of the general buckling modal imperfection has been set to a very small number: 0.1 inch.)

(Next we wish to re-optimize the shell with the following changes:

1. The factors of safety for buckling are reset to 0.999 .
2. There are three load sets:
   a. axial compression with a +0.5-inch general buckling mode shape
   b. axial compression with a -0.5-inch general buckling mode shape
   c. axial compression combined with internal pressure, perfect shell
3. At this time we don't want the alternative buckling solution. Later we will introduce it. By far most of the computer time is spent on the alternate buckling analyses. At first we want to obtain a reasonably good "global" optimum design in a short amount of computer time.)

```
mainsetup        (Table 46)
superopt         (total computer time is equal about one hour)
chooseplot
diplot
(Inspect the allen.OPP file and see Fig. 18)

superopt         (total computer time is equal about one hour)
chooseplot
diplot
(Inspect the allen.OPP file and see Fig. 19)

(Next, run a "fixed" design analysis [ITYPE = 2 in the allen.OPT file].
Turn on the alternate buckling solution for this "fixed" design
analysis.)

mainsetup        (Table 47)
pandaopt
(Inspect the allen.OPM file, an abridged version of which is
listed here as Table 48).

(Change ITYPE from 2 to 1 in allen.OPT file and execute SUPEROPT,
this time using the alternate buckling solution.)

superopt
(Inspect the allen.OPP file)
chooseplot
diplot
(The plot of objective v. design iterations is in Fig. 20).
(edit the allen.OPT file to get results for "fixed" design:
 NPRINT = 2; ITYPE = 2)
mainsetup
pandaopt
(Inspect the allen.OPM file, an abridged version of which is
listed here as Table 49).
change           (Table 50: save the optimum design)
change           (Table 51: get a "STAGSworthy" design)
setup
mainsetup
pandaopt
(Inspect the allen.OPM file, an abridged version of which is
listed here as Table 52). "STAGSworthy" design.

(Set the imperfection amplitude equal to zero and run only
the first load set (Load Set No. 1) "STAGSworthy" design.
mainsetup        (Table 53)
pandaopt
(Inspect the allen.OPM file, an abridged version of which is
listed here as Tables 54, 55, and 56). "STAGSworthy" design.
-------------------------------------------------------------------------

(Next, we wish to do linear buckling analyses with STAGS
for the "STAGSworthy" design. We do this for 3 STAGS models.)

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

STAGS model no. 1: 3 bay  x  3 bay model with all stiffeners and
substiffeners modeled as shell units:

stagsunit        (Table 57; 3 bay x 3 bay STAGS model)

(Possibly edit the allen.bin file, then tranfer both the
allen.bin and allen.inp files to a directory where we want to
run STAGS. Go to that directory an run STAGS.)

stags -b allen

(Inspect the allen.out2 file, an abridged version of which
is listed in Table 58).

stapl allen      (Table 59 lists the input data for STAPL).

acroread allen.pdf       (Fig. 21 shows the 1st buckling mode).

(Repeat the commands, "stapl allen" and "acroread allen.pdf"
for the 2nd, 3rd, and 4th buckling modes (Figs. 22 - 24)).
---------------------
```

STAGS Model no. 2: entire cylindrical shell with smeared sub and major stringers:

```
stagsunit        (Table 60 has input for stagsunit).
(edit the allen.bin file and transfer as before).
stags -b allen
stapl allen      (Table 61 has input for STAPL).
acroread allen.pdf      (Fig. 25; general buckling mode)
stapl allen      (Table 62 has input for STAPL).
acroread allen.pdf      (Fig. 26; general buckling mode)
---------------------
```

STAGS Model no. 3: The full length of the cylindrical shell over a circumferential sector that spans what is approximately one full circumferential wavelength of the critical general buckling mode shown in Figs. 25 and 26. The substringers are smeared and the major stringers and rings are flexible shell units. We use only a sector because modeling the full 360 degrees of circumference would generate too large a model and it would be too difficult to find the general buckling modal imperfection shape. First, we find linear bucking local and general modes and load factors. Then we compute collapse of the STAGS models for the sector "panel" first with a positive general buckling modal imperfection, then with a negative general buckling modal imperfection. This all takes quite a bit of effort, but it is worth it.

```
stagsunit        (Table 63 has input for stagsunit)
(Possibly edit the allen.bin file and transfer as before).
stags -b allen
stapl allen      (Table 64 has input for STAPL).
acroread allen.pdf      (Fig. 27; lowest buckling load factor and mode shape)
```

(Keep running linear buckling with different eigenvalue shifts, SHIFT, until you find the general buckling mode hidden in a "thicket" of local buckling modes. Start with eigenvalue shifts in the neighborhood of 2.4602 (Figs. 25 & 26) because that is the best estimate so far of the buckling load factor for general buckling. (See Item 1 in Table 67). It turns out that the general buckling mode corresponds to the 72nd eigenvalue for the STAGS model shown in Figs. 28 & 29.)

Collapse with a POSITIVE general buckling imperfection amplitude:

Next, run nonlinear equilibrium (INDIC=3) STAGS analysis for the same model as shown in Figs. 28 and 29. First, generate the allen.bin file appropriate for nonlinear (INDIC=3) analysis. An appropriate allen.bin file is listed in Table 65. Edit the allen.inp file to include the imperfection shape shown in Figs. 28 and 29. The changes to the allen.inp file are indicated in Table 66. Run a series of nonlinear STAGS runs to determine collapse of the shell or to determine if the shell can be loaded above a load factor PA = 1.0, which corresponds to the design load in this case because the factors of safety for buckling are essentially unity. See Table 67 for details. Collapse is found in the presence of two buckling modal imperfections:
1. the linear general buckling modal imperfection shown in Figs.28 & 29
2. the nonlinear "local" buckling modal imperfection shown in Fig. 30.
The overall deformation at the highest load step reached is shown in Fig. 31.
The post-collapsed state is shown in Figs. 32 - 35.
A load-normal-deflection curve is generated as exhibited in Tables 70 - 73 and Figs. 36 and 37.

Collapse with a NEGATIVE general buckling imperfection amplitude:

A similar series of STAGS runs leads to information about the behavior of the imperfect shell with a general buckling modal imperfection of the shape displayed in Figs. 28 and 29 and with NEGATIVE amplitude, Wimp = -0.5 inch.

Table 24 allen.BEG

```
     n          $ Do you want a tutorial session and tutorial output?
    124         $ Panel length normal to the plane of the screen, L1
  622.0353      $ Panel length in the plane of the screen, L2
     r          $ Identify type of stiffener along L1 (N,T,J,Z,R,A,C,G)
      8         $ stiffener spacing, b
 0.6670000      $ width of stringer base, b2 (must be > 0, see Help)
 6.0000000      $ height of stiffener (type H for sketch), h
     n          $ Are the stringers cocured with the skin?
   10000        $ What force/(axial length) will cause web peel-off?
     n          $ Is the next group of layers to be a "default group" (12 layers!)?
      1         $ number of layers in the next group in Segment no.( 1)
     n          $ Can winding (layup) angles ever be decision variables?
      1         $ layer index (1,2,...), for layer no.( 1)
     y          $ Is this a new layer type?
 0.6500000E-01  $ thickness for layer index no.( 1)
      0         $ winding angle (deg.) for layer index no.( 1)
      1         $ material index (1,2,...) for layer index no.( 1)
     y          $ Any more layers or groups of layers in Segment no.( 1)
     n          $ Is the next group of layers to be a "default group"?
     y          $ Does one of the additional layers consist of sub-stiffeners?
     n          $ Does this sub-stiffener "layer" form an isogrid?
      0         $ Index, NSURF = 0 or 1, for substiffener "layer"( 1)
      1         $ Index, NB2 = 0 or 1, for substiffener "layer"( 1)
 0.2000000      $ Thickness, TSUB, of substiffener set( 1)
 2.0000000      $ Height, HSUB, of substiffener set( 1)
      0         $ Angle, THSUB (degrees), of substiffener set( 1)
      2         $ Spacing, BSUB, of substiffener set( 1)
      1         $ Material type, MATSUB,  for substiffener set( 1)
     n          $ Are there any more substiffener sets in substiffener "layer"
     n          $ Is the next group of layers to be a "default group" (12 layers!)?
      1         $ number of layers in the next group in Segment no.( 2)
     n          $ Can winding (layup) angles ever be decision variables?
      1         $ layer index (1,2,...), for layer no.( 1)
     n          $ Is this a new layer type?
     n          $ Any more layers or groups of layers in Segment no.( 2)
     n          $ Is the next group of layers to be a "default group" (12 layers!)?
      1         $ number of layers in the next group in Segment no.( 3)
     n          $ Can winding (layup) angles ever be decision variables?
      2         $ layer index (1,2,...), for layer no.( 1)
     y          $ Is this a new layer type?
 0.6500000      $ thickness for layer index no.( 2)
      0         $ winding angle (deg.) for layer index no.( 2)
      1         $ material index (1,2,...) for layer index no.( 2)
     n          $ Any more layers or groups of layers in Segment no.( 3)
      1         $ choose external (0) or internal (1) stringers
     r          $ Identify type of stiffener along L2  (N, T, J, Z, R, A)
      8         $ stiffener spacing, b
      0         $ width of ring base, b2 (zero is allowed)
 4.0000000      $ height of stiffener (type H for sketch), h
     n          $ Are the rings cocured with the skin?
     n          $ Is the next group of layers to be a "default group" (12 layers!)?
      1         $ number of layers in the next group in Segment no.( 3)
     n          $ Can winding (layup) angles ever be decision variables?
      3         $ layer index (1,2,...), for layer no.( 1)
     y          $ Is this a new layer type?
 0.6500000      $ thickness for layer index no.( 3)
      0         $ winding angle (deg.) for layer index no.( 3)
      1         $ material index (1,2,...) for layer index no.( 3)
     n          $ Any more layers or groups of layers in Segment no.( 3)
      1         $ choose external (0) or internal (1) rings
     y          $ Is the panel curved in the plane of the screen (Y for cyls.)?
    198         $ Radius of curvature (cyl. rad.) in the plane of screen, R
     n          $ Is panel curved normal to plane of screen? (answer N)
     y          $ Is this material isotropic (Y or N)?
 0.1120000E+08  $ Young's modulus,                 E( 1)
 0.3000000      $ Poisson's ratio,                NU( 1)
 4307692.       $ transverse shear modulus,      G13( 1)
      0         $ Thermal expansion coeff.,    ALPHA( 1)
      0         $ residual stress temperature (positive),TEMPTUR( 1)
     n          $ Want to supply a stress-strain "curve" for this mat'l? (N)
     y          $ Want to specify  maximum effective stress ?
 66000.00       $ Maximum allowable effective stress in material type( 1)
     n          $ Do you want to take advantage of "bending overshoot"?
 0.9800000E-01  $ weight density (greater than 0!) of material type( 1)
     n          $ Is lamina cracking permitted along fibers (type H(elp))?
      0         $ Prebuckling: choose 0=bending included; 2=use membrane theory
      0         $ Buckling: choose 0=simple support or 1=clamping
```

Table 25 allen.CHG

```
    n          $ Do you want a tutorial session and tutorial output?
    y          $ Do you want to change any values in Parameter Set No. 1?
       1       $ Number of parameter to change (1, 2, 3, . .)
 26.66660      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       2       $ Number of parameter to change (1, 2, 3, . .)
 8.879600      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       3       $ Number of parameter to change (1, 2, 3, . .)
 3.462700      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       4       $ Number of parameter to change (1, 2, 3, . .)
0.2536800      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       5       $ Number of parameter to change (1, 2, 3, . .)
0.1104900      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       6       $ Number of parameter to change (1, 2, 3, . .)
 1.335000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       7       $ Number of parameter to change (1, 2, 3, . .)
 7.293800      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       8       $ Number of parameter to change (1, 2, 3, . .)
0.2718100      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
       9       $ Number of parameter to change (1, 2, 3, . .)
 9.364200      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      10       $ Number of parameter to change (1, 2, 3, . .)
 0.000000      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      11       $ Number of parameter to change (1, 2, 3, . .)
 7.304600      $ New value of the parameter
    y          $ Want to change any other parameters in this set?
      12       $ Number of parameter to change (1, 2, 3, . .)
0.6500000E-01  $ New value of the parameter
    n          $ Want to change any other parameters in this set?
    n          $ Do you want to change values of "fixed" parameters?
    n          $ Do you want to change values of allowables?
```

Same as Table 15(b) on p.39(b):
Optimum design determined with ICONSV=1
in the allen.OPT file (Table 14)

Table 26 allen.DEC

```
       n          $ Do you want a tutorial session and tutorial output?
       n          $ Want to use default for thickness decision variables (type H(elp)?
          4       $ Choose a decision variable (1,2,3,...)
 0.6500000E-01    $ Lower bound of variable no.( 4)
  2.000000        $ Upper bound of variable no.( 4)
       y          $ Any more decision variables (Y or N) ?
          1       $ Choose a decision variable (1,2,3,...)
          2       $ Lower bound of variable no.( 1)
         50       $ Upper bound of variable no.( 1)
       y          $ Any more decision variables (Y or N) ?
          9       $ Choose a decision variable (1,2,3,...)
          2       $ Lower bound of variable no.( 9)
         50       $ Upper bound of variable no.( 9)
       y          $ Any more decision variables (Y or N) ?
          8       $ Choose a decision variable (1,2,3,...)
 0.6500000E-01    $ Lower bound of variable no.( 8)
  3.000000        $ Upper bound of variable no.( 8)
       y          $ Any more decision variables (Y or N) ?
         12       $ Choose a decision variable (1,2,3,...)
 0.6500000E-01    $ Lower bound of variable no.(12)
  3.000000        $ Upper bound of variable no.(12)
       y          $ Any more decision variables (Y or N) ?
          3       $ Choose a decision variable (1,2,3,...)
 0.6500000E-01    $ Lower bound of variable no.( 3)
  10.50000        $ Upper bound of variable no.( 3)
       y          $ Any more decision variables (Y or N) ?
          6       $ Choose a decision variable (1,2,3,...)
          0       $ Lower bound of variable no.( 6)
  10.50000        $ Upper bound of variable no.( 6)
       y          $ Any more decision variables (Y or N) ?
          7       $ Choose a decision variable (1,2,3,...)
          0       $ Lower bound of variable no.( 7)
          9       $ Upper bound of variable no.( 7)
       y          $ Any more decision variables (Y or N) ?
          5       $ Choose a decision variable (1,2,3,...)
          0       $ Lower bound of variable no.( 5)
          5       $ Upper bound of variable no.( 5)
       y          $ Any more decision variables (Y or N) ?
         11       $ Choose a decision variable (1,2,3,...)
 0.6500000E-01    $ Lower bound of variable no.(11)
  10.50000        $ Upper bound of variable no.(11)
       n          $ Any more decision variables (Y or N) ?
       y          $ Any linked variables (Y or N) ?
          2       $ Choose a linked variable (1,2,3,...)
          1       $ To which variable is this variable linked?
 0.3330000        $ Assign a value to the linking coefficient, C(j)
       n          $ Any other decision variables in the linking expression?
       n          $ Any constant C0 in the linking expression (Y or N)?
       n          $ Any more linked variables (Y or N) ?
       y          $ Any inequality relations among variables? (type H)
       n          $ Want to see an example of how to calculate C0, C1, D1,..?
          1       $ Identify the type of inequality expression (1 or 2)
  1.000000        $ Give a value to the constant, C0
       n          $ Are there any cross product terms in the inequality expression?
          1       $ Choose a variable from the list above (1, 2, 3,...)
 -1.000000        $ Choose a value for the coefficient, C1
          1       $ Choose a value for the power, D1
       y          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
          9       $ Choose a variable from the list above (1, 2, 3,...)
  5.000000        $ Choose a value for the coefficient, Cn
          1       $ Choose a value for the power, Dn
       n          $ Any more terms in the expression: C0 +C1*v1**D1 +C2*v2**D2 +...
       n          $ Are there any more inequality expressions?
       y          $ Any escape variables (Y or N) ?
       y          $ Want to have escape variables chosen by default?
```

Purpose is to keep SUPEROPT from bombing. See Fig. 3 & pp. 32-36. See Items 580 & 758 in panda2.news.

note: stringer spacing < 5 x ring spacing

B(STR) < 5 x B(RNG)

V(1) < 5 x V(9)

1.0 < 1.0 - V(1) + 5*V(9)

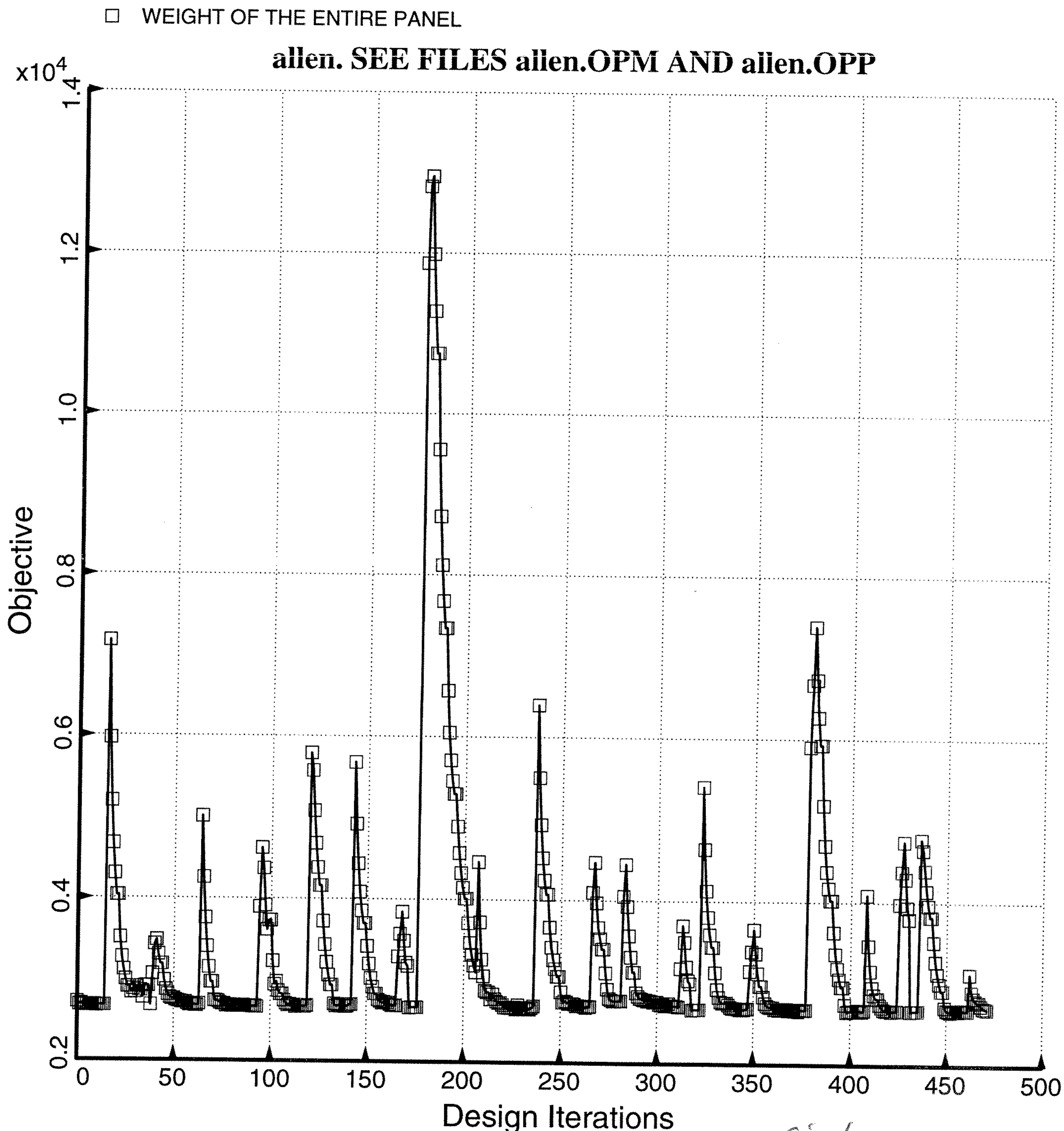
Table 27 alum. OPT

```
     n        $ Do you want a tutorial session and tutorial output?
  -8025       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
      0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
      0       $ In-plane shear in load set A,                       Nxy( 1)
     n        $ Does the axial load vary in the L2 direction?
      0       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
      0       $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
     y        $ Want to include effect of transverse shear deformation?
      0       $ IQUICK = quick analysis indicator (0 or 1)
     y        $ Do you want to vary M for minimum local buckling load?
     n        $ Do you want to choose a starting M for local buckling?
     y        $ Do you want to perform a "low-axial-wavenumber" search?
  2.153846    $ Factor of safety for general instability, FSGEN( 1)
  1.555556    $ Factor of safety for panel (between rings) instability, FSPAN( 1)
  1.555556    $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
  1.555556    $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
      1       $ Factor of safety for stress, FSSTR( 1)
     y        $ Do you want "flat skin" discretized module for local buckling?
     n        $ Do you want wide-column buckling to constrain the design?
      0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
      0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
      1       $ Axial load applied along the (0=neutral plane), (1=panel skin)
      0       $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
      0       $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
      0       $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
      0       $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
      0       $ Initial local imperfection amplitude (must be positive), Wloc( 1)
     n        $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
     y        $ Do you want PANDA2 to find the general imperfection shape?( 1)
      0       $ Maximum allowable average axial strain (type H for HELP)( 1)
     n        $ Is there any thermal "loading" in this load set (Y/N)?
     y        $ Do you want a "complete" analysis (type H for "Help")?
     y        $ Want to provide another load set ?
  -8025       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 2)
      0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 2)
      0       $ In-plane shear in load set A,                       Nxy( 2)
     n        $ Does the axial load vary in the L2 direction?
      0       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 2)
      0       $ Applied hoop moment resultant (e.g. in-lb/in), My( 2)
     y        $ Want to include effect of transverse shear deformation?
      0       $ IQUICK = quick analysis indicator (0 or 1)
     y        $ Do you want to vary M for minimum local buckling load?
     n        $ Do you want to choose a starting M for local buckling?
     y        $ Do you want to perform a "low-axial-wavenumber" search?
      1       $ Factor of safety for general instability, FSGEN( 2)
      1       $ Factor of safety for panel (between rings) instability, FSPAN( 2)
      1       $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 2)
      1       $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 2)
  1.265753    $ Factor of safety for stress, FSSTR( 2)
     y        $ Do you want "flat skin" discretized module for local buckling?
     n        $ Do you want wide-column buckling to constrain the design?
      0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 2)
  11266.20    $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 2)
      1       $ Axial load applied along the (0=neutral plane), (1=panel skin)
 -56.90000    $ Uniform applied pressure [positive upward. See H(elp)], p( 2)
     n        $ Is the pressure part of Load Set A?
     n        $ Is the pressure hydrostatic (Type H for "HELP")?
      0       $ Choose in-plane immovable (IFREE=0) or movable (IFREE=1) b.c.( 2)
     y        $ Are you feeling well today (type H)?
     n        $ Is there a maximum allowable deflection due to pressure?
      0       $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 2)
      0       $ Initial buckling modal general imperfection amplitude, Wimpg2( 2)
      0       $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 2)
      0       $ Initial local imperfection amplitude (must be positive), Wloc( 2)
     n        $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 2)
     y        $ Do you want PANDA2 to find the general imperfection shape?( 2)
      0       $ Maximum allowable average axial strain (type H for HELP)( 2)
     n        $ Is there any thermal "loading" in this load set (Y/N)?
     y        $ Do you want a "complete" analysis (type H for "Help")?
     n        $ Want to provide another load set ?
     n        $ Do you want to impose minimum TOTAL thickness of any segment?
     n        $ Do you want to impose maximum TOTAL thickness of any segment?
     n        $ Do you want to impose minimum TOTAL thickness of any segment?
     n        $ Do you want to impose maximum TOTAL thickness of any segment?
     n        $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
      0       $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
      0       $ Index for type of shell theory (0 or 1 or 2), ISAND
     n        $ Does the postbuckling axial wavelength of local buckles change?
```

Table 27b, continued

```
  n          $ Want to suppress general buckling mode with many axial waves?
  n          $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
      1      $ Choose (0=transverse inextensional; 1=transverse extensional)
      0      $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
      1      $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
  Y          $ Do you want to prevent secondary buckling (mode jumping)?
  Y          $ Do you want to use the "alternative" buckling solution?
1.000000     $ Factor of safety for "alternative" model of general buckling
      5      $ How many design iterations permitted in this run (5 to 25)?
1.000000     $ MAXMAR. Plot only those margins less than MAXMAR (Type H)
  N          $ Do you want to reset total iterations to zero (Type H)?
      1      $ Index for objective (1=min. weight, 2=min. distortion)
1.000000     $ FMARG (Skip load case with min. margin greater than FMARG)
```

note! The new section, CHAPTER 20c, is only executed if ICONSV < 1.


WEIGHT OF THE ENTIRE PANEL
allen. SEE FILES allen.OPM AND allen.OPP
x10^4
Objective
Design Iterations
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
50
100
150
200
250
300
350
400
450
500

65

Fig.6

Table 28 (6 pages) allen.OPM with NPRINT=2 in the allen.OPT file.

```
Abridged allen.OPM file for optimum design after
one SUPEROPT starting with the optimum design
obtained with ICONSV = 1

Here, ICONSV = 0 and IQUICK = 0

The version of PANDA2 used is that with all
ITEMS in the file, ...panda2/doc/panda2.news
up through ITEM 768 incorporated into PANDA2.


(lines skipped to save space)

 *************************************************************
 *************************************************************
 *************************************************************
 ************           CHAPTER 20c            ****************
 *************************************************************
 *************************************************************
 *************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 20c Compute buckling of a single discretized
             skin-substringer module. See panda2.news Item 764.
             The axial length of the module is equal to the
             spacing of the subrings, and the width of the
             module is equal to the spacing of the substringers.

 Find the skin-substringer module buckling from m=   1 to   17 axial halfwaves
 The spacing of the subrings,    BSUBX(2)=  1.0668E+01
 The height of the substringers, HSUBX(1)=  1.3451E+00
  LABEL NO. IN STRUCT= 9465
 Buckling load factor before t.s.d.=  2.6675E+00 After t.s.d.=  2.5010E+00
 Buckling load factor before t.s.d.=  2.4183E+00 After t.s.d.=  2.2807E+00
 Buckling load factor before t.s.d.=  2.0025E+00 After t.s.d.=  1.9072E+00
 Buckling load factor before t.s.d.=  1.6693E+00 After t.s.d.=  1.6026E+00
 Buckling load factor before t.s.d.=  1.6184E+00 After t.s.d.=  1.5556E+00
 Buckling load factor before t.s.d.=  1.7074E+00 After t.s.d.=  1.6376E+00
 Buckling load factor before t.s.d.=  1.8850E+00 After t.s.d.=  1.8003E+00
 Buckling load factor before t.s.d.=  2.1295E+00 After t.s.d.=  2.0221E+00
 Buckling load factor before t.s.d.=  2.4305E+00 After t.s.d.=  2.2915E+00
 Buckling load factor before t.s.d.=  2.7825E+00 After t.s.d.=  2.6019E+00
 Buckling load factor before t.s.d.=  3.1824E+00 After t.s.d.=  2.9483E+00
 Buckling load factor before t.s.d.=  3.6282E+00 After t.s.d.=  3.3270E+00
 Buckling load factor before t.s.d.=  4.1187E+00 After t.s.d.=  3.7348E+00
 Buckling load factor before t.s.d.=  4.6530E+00 After t.s.d.=  4.1690E+00
 Buckling load factor before t.s.d.=  5.2307E+00 After t.s.d.=  4.6268E+00
 Buckling load factor before t.s.d.=  6.5144E+00 After t.s.d.=  5.6035E+00

 Buckling of single module skin-substringer model. KOUNT=  16
 Axial halfwaves    Eigenvalue (buckling load factor)
         1  2.501015E+00
         2  2.280710E+00
         3  1.907238E+00
         4  1.602589E+00
         5  1.555556E+00  <- critical value
         6  1.637614E+00
         7  1.800314E+00
         8  2.022060E+00
         9  2.291540E+00
        10  2.601877E+00
        11  2.948275E+00
        12  3.326989E+00
        13  3.734848E+00
        14  4.169008E+00
        15  4.626827E+00
        17  5.603548E+00
  LABEL NO. IN STRUCT= 9466
 Buckling load factor before t.s.d.=  1.6183E+00 After t.s.d.=  1.5555E+00
        5         1.5555E+00

 ** BEGIN SUB. MODE (SKIN-SUBSTRINGER MODULE BUCKLNG MODE) **

 WIDTH-WISE WIDE COLUMN BUCKLING LOAD FACTOR =
 pi**2*EI/[abs(local hoop load)*WIDTH**2]=  1.5360E+01
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    1  4.3606E-05
```

New Chapter in PANDA2

Table 28 (p.2 of 6)

```
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    2  7.1975E-04
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    1  3.8802E-04
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    2  3.8801E-04
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    1  2.6469E-02
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    2  1.2669E-01
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    1  7.1969E-04
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    2  4.3501E-05
      Internal Stringer

     MODULE WITH RECTANGULAR STIFFENER...

                                      !   ^
          Segment No. 3 -----> !   !
                                      !   !
              Seg. No. 2-.      !   h
                                 .    !   !
     Segment No. 1-.        .   !   !         .-Seg. No. 4
                          .       .   !   V        .(same as Seg. 1)
       -------------=====================-------------
                     !<------ b2 ------->!
       !<--- Module width  =  stiffener spacing, b --->!


   EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                                   (3,11)
                                      !
            Layer No. 1 -----> ! <---------- Layer No. k
                                      !
         Layer No. 1-.               !
                            .          !
   Layer No. 1-.        .           !          .-Layer No. 1
                   .        .         !          .
                  .           .   (3,1)            .
   -------------     ====================     --------------
 (1,1)    .   (1,11)(2,1)    . (2,6)    (2,11)(4,1)    .    (4,11)
             .                    .                           .
              .                    .                           .
            Layer No. m       Layer No. n     Layer No. m


   NORMAL MODAL DISPLACEMENTS IN THE PANEL MODULE SHOWN ABOVE
         SKIN-STRINGER PANEL MODULE HAS 4 SEGMENTS
       NUMBER OF HALF-WAVES IN THE AXIAL DIRECTION, M=  5
```

axial halfwaves between rings

NEW

MODAL DISPLACEMENTS FOR SEGMENT NO. 1

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	1.11E-03	0.00E+00	9.10E-04	0.00E+00	-1.59E-05	1.62E-04
2	0.00E+00	1.15E-03	2.89E-04	9.60E-04	-9.92E-06	-1.86E-05	1.62E-04
3	0.00E+00	1.28E-03	5.89E-04	1.01E-03	-2.15E-05	-2.22E-05	1.62E-04
4	0.00E+00	1.51E-03	9.04E-04	1.06E-03	-3.64E-05	-2.88E-05	1.82E-04
5	0.00E+00	1.83E-03	1.23E-03	1.07E-03	-5.67E-05	-3.85E-05	2.52E-05
6	0.00E+00	2.26E-03	1.53E-03	9.24E-04	-8.51E-05	-5.16E-05	-4.86E-04
7	0.00E+00	2.77E-03	1.74E-03	4.13E-04	-1.25E-04	-6.78E-05	-1.68E-03
8	0.00E+00	3.32E-03	1.67E-03	-8.55E-04	-1.79E-04	-8.58E-05	-4.17E-03
9	0.00E+00	3.79E-03	9.89E-04	-3.61E-03	-2.51E-04	-1.02E-04	-9.06E-03
10	0.00E+00	3.92E-03	-9.62E-04	-9.21E-03	-3.46E-04	-1.07E-04	-1.84E-02
11	0.00E+00	3.20E-03	-5.12E-03	-1.48E-02	-4.55E-04	-8.47E-05	-1.84E-02

MODAL DISPLACEMENTS FOR SEGMENT NO. 2

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	3.20E-03	-5.12E-03	-1.94E-02	-4.55E-04	-8.47E-05	-5.74E-02
2	0.00E+00	2.81E-03	-6.52E-03	-2.33E-02	-4.84E-04	-7.49E-05	-5.74E-02
3	0.00E+00	2.32E-03	-8.23E-03	-2.72E-02	-5.13E-04	-6.19E-05	-5.74E-02
4	0.00E+00	1.70E-03	-1.02E-02	-3.17E-02	-5.43E-04	-4.53E-05	-6.59E-02
5	0.00E+00	9.33E-04	-1.25E-02	-3.68E-02	-5.73E-04	-2.44E-05	-7.55E-02
6	0.00E+00	5.66E-08	-1.38E-02	3.52E-07	-5.88E-04	-4.40E-09	5.44E-01
7	0.00E+00	-9.33E-04	-1.25E-02	3.68E-02	-5.73E-04	2.44E-05	5.44E-01
8	0.00E+00	-1.70E-03	-1.02E-02	3.17E-02	-5.43E-04	4.53E-05	-7.55E-02
9	0.00E+00	-2.32E-03	-8.23E-03	2.72E-02	-5.13E-04	6.19E-05	-6.59E-02
10	0.00E+00	-2.81E-03	-6.52E-03	2.33E-02	-4.84E-04	7.49E-05	-5.74E-02
11	0.00E+00	-3.20E-03	-5.12E-03	1.94E-02	-4.55E-04	8.47E-05	-5.74E-02

MODAL DISPLACEMENTS FOR SEGMENT NO. 3

NODE	Z	W	WD	WDD	U	V	WDDD
1	-1.33E-01	-2.43E-03	-1.38E-02	-2.56E+00	-5.66E-08	6.71E-09	4.41E+00
2	-2.68E-01	-2.89E-02	-3.29E-01	-1.96E+00	-5.22E-08	8.16E-09	4.41E+00
3	-4.02E-01	-9.09E-02	-5.53E-01	-1.37E+00	-4.83E-08	8.99E-09	4.41E+00
4	-5.37E-01	-1.78E-01	-7.06E-01	-9.03E-01	-4.50E-08	9.46E-09	3.47E+00
5	-6.71E-01	-2.81E-01	-8.03E-01	-5.41E-01	-4.22E-08	9.85E-09	2.69E+00

Table 28 (p.3 of 6)

```
  6 -8.06E-01 -3.94E-01 -8.58E-01 -2.74E-01 -3.98E-08  1.04E-08  1.99E+00
  7 -9.40E-01 -5.12E-01 -8.83E-01 -1.01E-01 -3.80E-08  1.13E-08  1.28E+00
  8 -1.07E+00 -6.31E-01 -8.92E-01 -3.09E-02 -3.64E-08  1.29E-08  5.20E-01
  9 -1.21E+00 -7.52E-01 -8.99E-01 -8.02E-02 -3.52E-08  1.54E-08 -3.66E-01
 10 -1.34E+00 -8.73E-01 -9.23E-01 -2.75E-01 -3.39E-08  1.92E-08 -1.45E+00
 11 -1.48E+00 -1.00E+00 -9.72E-01 -4.70E-01 -3.26E-08  2.41E-08 -1.45E+00

              MODAL DISPLACEMENTS FOR SEGMENT NO. 4
  1  0.00E+00 -3.20E-03 -5.12E-03  1.48E-02 -4.55E-04  8.47E-05 -1.84E-02
  2  0.00E+00 -3.92E-03 -9.62E-04  9.21E-03 -3.46E-04  1.07E-04 -1.84E-02
  3  0.00E+00 -3.79E-03  9.89E-04  3.61E-03 -2.51E-04  1.02E-04 -1.84E-02
  4  0.00E+00 -3.32E-03  1.67E-03  8.54E-04 -1.79E-04  8.58E-05 -9.06E-03
  5  0.00E+00 -2.77E-03  1.74E-03 -4.15E-04 -1.25E-04  6.78E-05 -4.17E-03
  6  0.00E+00 -2.26E-03  1.53E-03 -9.26E-04 -8.51E-05  5.16E-05 -1.68E-03
  7  0.00E+00 -1.84E-03  1.23E-03 -1.07E-03 -5.67E-05  3.85E-05 -4.80E-04
  8  0.00E+00 -1.51E-03  9.03E-04 -1.06E-03 -3.64E-05  2.88E-05  2.95E-05
  9  0.00E+00 -1.29E-03  5.88E-04 -1.01E-03 -2.15E-05  2.22E-05  1.85E-04
 10  0.00E+00 -1.15E-03  2.89E-04 -9.57E-04 -9.92E-06  1.86E-05  1.63E-04
 11  0.00E+00 -1.11E-03  0.00E+00 -9.08E-04  0.00E+00  1.59E-05  1.63E-04
 **** END SUB. MODE (SKIN-SUBSTRINGER MODULE BUCKLNG MODE) **

******* NOTE ********** NOTE ******** NOTE *********
Discretized skin-substringer module buckling mode
involves significant sidesway of the substringer web.
***** END NOTE ****** END NOTE ***** END NOTE *********
Margin= -3.1829E-05  skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

(lines skipped to save space)

*********** LOAD SET NO. 1  **************
ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
            (ICASE=2 MEANS AT RINGS

  APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
        Applied     axial        stress resultant, Nx= -8.0250E+03
        Applied circumferential stress resultant, Ny= -8.0250E-03
        Applied    in-plane      shear  resultant,Nxy=  4.0125E+01
        Applied     axial        moment resultant, Mx=  0.0000E+00
        Applied circumferential moment resultant, My=  0.0000E+00
        Applied pressure (positive for upward),   p =  4.0530E-05

  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
        Applied     axial        stress resultant,Nx0=  0.0000E+00
        Applied circumferential stress resultant,Ny0=  0.0000E+00
        Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00

NOTE: "F.S." means "Factor of Safety";
"DONL" means "Donnell shell theory used.";
"SAND" means "Sanders shell theory used." panda2.news ITEM 128
"Dseg" means "Segment numbering used in discretized model"
"Iseg" means "Segment numbering used for input data." ITEM 272
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
MAR. MARGIN
NO.  VALUE                DEFINITION
 1  3.91E-03 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55
 2  3.91E-03 Bending-torsion buckling; M=2  ;FS=1.5556
 3  3.62E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55
 4  1.56E+00 eff.stress:matl=1,STR,Dseg=3,node=11,layer=1,z=-0.1044; MID.;FS=1.
 5  4.63E+03 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  1.59E+00 matl=1 ; substiffener effective stressSTRTHK MID.;FS=1.
 7  1.65E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556
 8 -3.18E-05 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
 9  5.77E+00 Inter-ring bucklng, discrete model, n=41  circ.halfwaves;FS=1.5556
10  1.58E+00 matl=1 ; substiffener effective stressSTRCON MID.;FS=1.
11  1.57E+00 eff.stress:matl=1,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  1.51E-01 buck.(DONL);simp-support inter-ring;  (1.00*altsol);FS=1.5556
13 -2.61E-02 buck.(DONL);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538
14 -3.56E-03 buck.(DONL);rolling with smear rings; M=21;N=1;slope=0.;FS=1.5556
15  3.00E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
16  1.08E-03 buckling:simp-support altsoln4  intermajorpatch; FS=1.5556
17  4.39E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
18  1.15E+00 1.-V(1)^1+5.V(9)^-1-1
19  1.51E-01 buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=1.5556
20 -2.86E-02 buck.(SAND);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538
21 -3.42E-03 buck.(SAND);rolling with smear rings; M=21;N=1;slope=0.;FS=1.5556
```

NEW

compare with STAGS result in Fig. 8

Table 28 (p. 4 of 6)

```
(lines skipped to save space)

*********** LOAD SET NO. 1  **************
ICASE =  2  (ICASE=1 MEANS PANEL MIDLENGTH)
            (ICASE=2 MEANS AT RINGS                           )

  APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
       Applied     axial       stress resultant, Nx= -8.0250E+03
       Applied circumferential stress resultant, Ny= -8.0250E-03
       Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
       Applied     axial       moment resultant, Mx=  0.0000E+00
       Applied circumferential moment resultant, My=  0.0000E+00
       Applied pressure (positive for upward),    p =  4.0530E-05

  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
       Applied     axial       stress resultant,Nx0=  0.0000E+00
       Applied circumferential stress resultant,Ny0=  0.0000E+00
       Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00

NOTE: "F.S." means "Factor of Safety";
"DONL" means "Donnell shell theory used.";
"SAND" means "Sanders shell theory used." panda2.news ITEM 128
"Dseg" means "Segment numbering used in discretized model"
"Iseg" means "Segment numbering used for input data." ITEM 272
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
MAR. MARGIN
NO.  VALUE                  DEFINITION
 1  2.00E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55
 2  2.00E-02 Bending-torsion buckling; M=2  ;FS=1.5556
 3  5.17E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55
 4  1.59E+00 eff.stress:matl=1,STR,Dseg=3,node=1,layer=1,z=-0.1044; RNGS;FS=1.
 5  4.81E+03 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6  1.59E+00 matl=1 ; substiffener effective stressSTRTHK RNGS;FS=1.
 7  3.20E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556
 8 -1.67E-04 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
 9  5.77E+00 Inter-ring bucklng, discrete model, n=41  circ.halfwaves;FS=1.5556
10  1.59E+00 matl=1 ; substiffener effective stressSTRCON RNGS;FS=1.
11  1.59E+00 eff.stress:matl=1,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
12 -4.69E-03 buck.(DONL);rolling with smear rings; M=21;N=1;slope=0.;FS=1.5556
13  3.16E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
14  4.38E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
15 -4.55E-03 buck.(SAND);rolling with smear rings; M=21;N=1;slope=0.;FS=1.5556


(lines skipped to save space)

*********** LOAD SET NO. 2  **************
ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
            (ICASE=2 MEANS AT RINGS                           )

  APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
       Applied     axial       stress resultant, Nx= -8.0250E+03
       Applied circumferential stress resultant, Ny= -8.0250E-03
       Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
       Applied     axial       moment resultant, Mx=  0.0000E+00
       Applied circumferential moment resultant, My=  0.0000E+00

  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
       Applied     axial       stress resultant,Nx0=  0.0000E+00
       Applied circumferential stress resultant,Ny0=  1.1266E+04
       Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00
       Applied pressure (positive for upward),    p = -5.6900E+01

NOTE: "F.S." means "Factor of Safety";
"DONL" means "Donnell shell theory used.";
"SAND" means "Sanders shell theory used." panda2.news ITEM 128
"Dseg" means "Segment numbering used in discretized model"
"Iseg" means "Segment numbering used for input data." ITEM 272
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 1
MAR. MARGIN
NO.  VALUE                  DEFINITION
1  9.11E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.1
2  9.11E-02 Bending-torsion buckling; M=2  ;FS=1.1
3  1.18E-01 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.1
4 -1.23E-03 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.1334; MID.;FS=1.26
```

Table 28 (4.5 d6)

```
 5  9.75E+02 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.2658
 6  4.97E-01 matl=1 ; substiffener effective stressSTRTHK MID.;FS=1.2658
 7  1.05E-01 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
 8  1.08E-01 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.1
 9  8.69E+00 Inter-ring bucklng, discrete model, n=23  circ.halfwaves;FS=1.1
10  4.78E-01 matl=1 ; substiffener effective stressSTRCON MID.;FS=1.2658
11  1.40E-04 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=-0.1334;-MID.;FS=1.26
12  9.06E-01 buck.(DONL);simp-support inter-ring;  (1.00*altsol);FS=1.1
13  1.19E+00 buck.(DONL);simp-support general buck;M=3;N=7;slope=0.;FS=1.1
14  5.07E-01 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1
15  2.44E-02 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
16  2.46E-02 buck.(DONL);hiwave roll. of stringers;M=22;N=0;slope=0.;FS=1.4
17  7.75E-01 buckling:simp-support altsoln4  intermajorpatch; FS=1.1
18  3.21E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
19  9.06E-01 buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=1.1
20  1.18E+00 buck.(SAND);simp-support general buck;M=3;N=7;slope=0.;FS=1.1
21  5.12E-01 buck.(SAND);rolling with smear rings; M=23;N=1;slope=0.;FS=1.1


 (lines skipped to save space)

 *********** LOAD SET NO. 2  **************
 ICASE =  2  (ICASE=1 MEANS PANEL MIDLENGTH)
             (ICASE=2 MEANS AT RINGS                  )

   APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
         Applied     axial       stress resultant, Nx= -8.0250E+03
         Applied circumferential stress resultant, Ny= -8.0250E-03
         Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
         Applied     axial       moment resultant, Mx=  0.0000E+00
         Applied circumferential moment resultant, My=  0.0000E+00

   APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
         Applied     axial       stress resultant,Nx0=  0.0000E+00
         Applied circumferential stress resultant,Ny0=  1.1266E+04
         Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00
         Applied pressure (positive for upward),   p = -5.6900E+01

 NOTE: "F.S." means "Factor of Safety";
 "DONL" means "Donnell shell theory used.";
 "SAND" means "Sanders shell theory used." panda2.news ITEM 128
 "Dseg" means "Segment numbering used in discretized model"
 "Iseg" means "Segment numbering used for input data." ITEM 272
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
 1  1.80E-01 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.1
 2  2.98E-01 Bending-torsion buckling; M=2  ;FS=1.
 3  2.04E-01 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.1
 4 -3.93E-03 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=0.1334; RNGS;FS=1.265
 5  1.47E+03 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.2658
 6  4.82E-01 matl=1 ; substiffener effective stressSTRTHK RNGS;FS=1.2658
 7  1.89E-01 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
 8  1.07E-01 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.1
 9  8.69E+00 Inter-ring bucklng, discrete model, n=23  circ.halfwaves;FS=1.1
10  4.98E-01 matl=1 ; substiffener effective stressSTRCON RNGS;FS=1.2658
11 -1.01E-03 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=0.1334;-RNGS;FS=1.265
12  4.96E-01 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1
13  6.73E-02 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
14  6.75E-02 buck.(DONL);hiwave roll. of stringers;M=22;N=0;slope=0.;FS=1.4
15  3.19E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
16  5.01E-01 buck.(SAND);rolling with smear rings; M=23;N=1;slope=0.;FS=1.1
 ***********  ALL 2 LOAD SETS PROCESSED  ***********
 ****************************************************

       SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER    CURRENT    UPPER      DEFINITION
  NO. VAR.  VAR.  VAR.   TO    CONSTANT    BOUND     VALUE     BOUND
   1   Y     N     N     0    0.00E+00  2.00E+00 2.4866E+01  5.00E+01       B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y     1    3.33E-01  0.00E+00 8.2804E+00  0.00E+00     B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N     0    0.00E+00  6.50E-02 3.5472E+00  1.05E+01      H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N     0    0.00E+00  6.50E-02 2.6676E-01  2.00E+00   T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     N     N     0    0.00E+00  1.10E-03 7.6755E-02  5.00E+00   TSUB,substr:Thickness, »
```

Optimum design from PANDA2

Table 28 (p.6 of 6)

```
TSUB, of substiffener set(1 ): SK
   6   Y     N     N     0    0.00E+00  1.33E-02 1.3451E+00  1.05E+01    HSUB,substr:Height, HSU»
B, of substiffener set(1 ): SKN s
   7   Y     N     N     0    0.00E+00  7.29E-02 6.7658E+00  9.00E+00    BSUB,substr:Spacing, BS»
UB, of substiffener set(1 ): SKN
   8   Y     Y     N     0    0.00E+00  6.50E-02 2.0884E-01  3.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   9   Y     N     N     0    0.00E+00  2.00E+00 1.0668E+01  5.00E+01       B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
  10   N     N     N     0    0.00E+00  0.00E+00 0.0000E+00  0.00E+00     B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
  11   Y     N     N     0    0.00E+00  6.50E-02 6.7093E+00  1.05E+01       H(RNG):height of s»
tiffener (type H for sketch), h:
  12   Y     Y     N     0    0.00E+00  6.50E-02 6.5000E-02  3.00E+00    T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3

 ******************* DESIGN OBJECTIVE *******************
 *************                          ***********
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE          DEFINITION
            0     0    2.666E+03    WEIGHT OF THE ENTIRE PANEL
  TOTAL WEIGHT OF SKIN                                 =    2.0164E+03
  TOTAL WEIGHT OF SUBSTIFFENERS                        =    1.1535E+02
  TOTAL WEIGHT OF STRINGERS                            =    2.2520E+02
  TOTAL WEIGHT OF RINGS                                =    3.0900E+02
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=    3.4563E-02

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

Optimum design after one execution of SUPEROPT

Compare with the ICONSV = 1 optimum listed in Table 15(a) (bottom) (p.39(a))

Table 29 allen.CHG

```
     n          $ Do you want a tutorial session and tutorial output?
     y          $ Do you want to change any values in Parameter Set No. 1?
        1       $ Number of parameter to change (1, 2, 3, . .)
 24.86600       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        2       $ Number of parameter to change (1, 2, 3, . .)
 8.280400       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        3       $ Number of parameter to change (1, 2, 3, . .)
 3.547200       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        4       $ Number of parameter to change (1, 2, 3, . .)
 0.2667600      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        5       $ Number of parameter to change (1, 2, 3, . .)
 0.0767550      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        6       $ Number of parameter to change (1, 2, 3, . .)
 1.345100       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        7       $ Number of parameter to change (1, 2, 3, . .)
 6.765800       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        8       $ Number of parameter to change (1, 2, 3, . .)
 0.2088400      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        9       $ Number of parameter to change (1, 2, 3, . .)
 10.668000      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
       10       $ Number of parameter to change (1, 2, 3, . .)
 0.000000       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
       11       $ Number of parameter to change (1, 2, 3, . .)
 6.709300       $ New value of the parameter
     y          $ Want to change any other parameters in this set?
       12       $ Number of parameter to change (1, 2, 3, . .)
 0.6500000E-01  $ New value of the parameter
     n          $ Want to change any other parameters in this set?
     n          $ Do you want to change values of "fixed" parameters?
     n          $ Do you want to change values of allowables?
```

Optimum design with ICONSV = 0

Compare with the optimum design obtained with ICONSV = 1 in Table 15(b)

The 4 "highlighted" quantities have to be changed to make the optimum design "STAGS worthy".

Table 30 allow.CHG for "STAGSworthy" configuration

```
   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, . .)
 24.88140     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       2      $ Number of parameter to change (1, 2, 3, . .)
 8.285510     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       3      $ Number of parameter to change (1, 2, 3, . .)
 3.547200     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       4      $ Number of parameter to change (1, 2, 3, . .)
 0.2667600    $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       5      $ Number of parameter to change (1, 2, 3, . .)
 0.0767550    $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       6      $ Number of parameter to change (1, 2, 3, . .)
 1.345100     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       7      $ Number of parameter to change (1, 2, 3, . .)
 6.220350     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       8      $ Number of parameter to change (1, 2, 3, . .)
 0.2088400    $ New value of the parameter
   y          $ Want to change any other parameters in this set?
       9      $ Number of parameter to change (1, 2, 3, . .)
 10.333330    $ New value of the parameter
   y          $ Want to change any other parameters in this set?
      10      $ Number of parameter to change (1, 2, 3, . .)
 0.000000     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
      11      $ Number of parameter to change (1, 2, 3, . .)
 6.709300     $ New value of the parameter
   y          $ Want to change any other parameters in this set?
      12      $ Number of parameter to change (1, 2, 3, . .)
 0.6500000E-01 $ New value of the parameter
   n          $ Want to change any other parameters in this set?
   n          $ Do you want to change values of "fixed" parameters?
   n          $ Do you want to change values of allowables?
```

exactly 12 major ring spacings in the 124-inch length of the cylindrical shell.

exactly 4 substringers per major stringer spacing of 24.8814 inches.

8.28551 = 0.333 X 24.8814

exactly 50 major stringers in the 360-degree cylindrical shell

Compare the 4 "STAGSworthy" quantities here with the optimum values listed in Table 29.

Table 31 (4 pages) allen.OPM for the "STAGSworthy" configuration

```
Abridged allen.OPM file for optimum design after
one SUPEROPT starting with the optimum design
obtained with ICONSV = 1 and with the major
stringer spacing, B(STR), changed to 24.8814 inches
(50 major stringers over 360 degrees of circumference);
B2(STR) equal to 0.333 x B(STR); substringer
spacing, BSUB(substringer) = 6.22035 inches
(4 substringers per major stringer spacing); and
ring spacing, B(RNG) = 10.33333 inches (12 ring
spacings over the entire axial length of the shell).
This is the "STAGSworthy" configuration closest to
the optimum design determined by PANDA2.


(lines skipped to save space)

 *********** LOAD SET NO. 1   **************
 ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
             (ICASE=2 MEANS AT RINGS                        )

   APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
         Applied     axial       stress resultant, Nx= -8.0250E+03
         Applied circumferential stress resultant, Ny= -8.0250E-03
         Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
         Applied     axial       moment resultant, Mx=  0.0000E+00
         Applied circumferential moment resultant, My=  0.0000E+00
         Applied pressure (positive for upward),   p =  4.0530E-05

   APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
         Applied     axial       stress resultant,Nx0=  0.0000E+00
         Applied circumferential stress resultant,Ny0=  0.0000E+00
         Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00

 NOTE: "F.S." means "Factor of Safety";
 "DONL" means "Donnell shell theory used.";
 "SAND" means "Sanders shell theory used." panda2.news ITEM 128
 "Dseg" means "Segment numbering used in discretized model"
 "Iseg" means "Segment numbering used for input data." ITEM 272
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
 1   2.12E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55
 2   2.11E-02 Bending-torsion buckling; M=2  ;FS=1.5556
 3   5.44E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55
 4   1.58E+00 eff.stress:matl=1,STR,Dseg=3,node=11,layer=1,z=0.1044; MID.;FS=1.
 5   4.74E+03 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6   1.60E+00 matl=1 ; substiffener effective stressSTRTHK MID.;FS=1.
 7   3.41E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556
 8   8.52E-03 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
 9   6.09E+00 Inter-ring bucklng, discrete model, n=42  circ.halfwaves;FS=1.5556
10   1.60E+00 matl=1 ; substiffener effective stressSTRCON MID.;FS=1.
11   1.59E+00 eff.stress:matl=1,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12   2.93E-01 buck.(DONL);simp-support inter-ring;  (1.00*altsol);FS=1.5556
13  -1.96E-02 buck.(DONL);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538
14   1.41E-02 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556
15   3.06E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
16   1.24E-01 buckling:simp-support altsoln4  intermajorpatch; FS=1.5556
17   4.41E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
18   1.08E+00 1.-V(1)^1+5.V(9)^1-1
19   2.93E-01 buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=1.5556
20  -2.21E-02 buck.(SAND);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538
21   1.43E-02 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556

 (lines skipped to save space)

 *********** LOAD SET NO. 1   **************
 ICASE =  2  (ICASE=1 MEANS PANEL MIDLENGTH)
             (ICASE=2 MEANS AT RINGS                        )

   APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
         Applied     axial       stress resultant, Nx= -8.0250E+03
         Applied circumferential stress resultant, Ny= -8.0250E-03
         Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
         Applied     axial       moment resultant, Mx=  0.0000E+00
         Applied circumferential moment resultant, My=  0.0000E+00
         Applied pressure (positive for upward),   p =  4.0530E-05
```

Table 31 (p2 of 4)

```
  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
        Applied     axial       stress resultant,Nx0=  0.0000E+00
        Applied circumferential stress resultant,Ny0=  0.0000E+00
        Applied    in-plane     shear  resultant,Nxy0=  0.0000E+00

 NOTE: "F.S." means "Factor of Safety";
 "DONL" means "Donnell shell theory used.";
 "SAND" means "Sanders shell theory used." panda2.news ITEM 128
 "Dseg" means "Segment numbering used in discretized model"
 "Iseg" means "Segment numbering used for input data." ITEM 272
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
 1   3.69E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55
 2   3.69E-02 Bending-torsion buckling; M=2  ;FS=1.5556
 3   6.96E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55
 4   1.60E+00 eff.stress:matl=1,STR,Dseg=3,node=1,layer=1,z=0.1044; RNGS;FS=1.
 5   4.91E+03 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6   1.60E+00 matl=1 ; substiffener effective stressSTRTHK RNGS;FS=1.
 7   4.93E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556
 8   8.40E-03 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
 9   6.09E+00 Inter-ring bucklng, discrete model, n=42  circ.halfwaves;FS=1.5556
10   1.60E+00 matl=1 ; substiffener effective stressSTRCON RNGS;FS=1.
11   1.60E+00 eff.stress:matl=1,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
12   1.30E-02 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556
13   3.22E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
14   4.40E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
15   1.31E-02 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556

 (lines skipped to save space)

 *********** LOAD SET NO. 2  **************
 ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
             (ICASE=2 MEANS AT RINGS                          )

  APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
        Applied     axial       stress resultant, Nx= -8.0250E+03
        Applied circumferential stress resultant, Ny= -8.0250E-03
        Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
        Applied     axial       moment resultant, Mx=  0.0000E+00
        Applied circumferential moment resultant, My=  0.0000E+00

  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
        Applied     axial       stress resultant,Nx0=  0.0000E+00
        Applied circumferential stress resultant,Ny0=  1.1266E+04
        Applied    in-plane     shear  resultant,Nxy0=  0.0000E+00
        Applied pressure (positive for upward),    p = -5.6900E+01

 NOTE: "F.S." means "Factor of Safety";
 "DONL" means "Donnell shell theory used.";
 "SAND" means "Sanders shell theory used." panda2.news ITEM 128
 "Dseg" means "Segment numbering used in discretized model"
 "Iseg" means "Segment numbering used for input data." ITEM 272
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
 1   1.16E-01 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.1
 2   1.16E-01 Bending-torsion buckling; M=2  ;FS=1.1
 3   1.45E-01 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.1
 4   4.23E-03 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.1334; MID.;FS=1.26
 5   1.08E+03 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.2658
 6   5.05E-01 matl=1 ; substiffener effective stressSTRTHK MID.;FS=1.2658
 7   1.30E-01 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
 8   1.22E-01 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.1
 9   9.14E+00 Inter-ring bucklng, discrete model, n=24  circ.halfwaves;FS=1.1
10   9.17E+00 Lo-n Inter-ring buck.,discrete model,n=6   circ.halfwaves;FS=1.1
11   4.87E-01 matl=1 ; substiffener effective stressSTRCON MID.;FS=1.2658
12   5.46E-03 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=-0.1334;-MID.;FS=1.26
13   1.09E+00 buck.(DONL);simp-support inter-ring;  (1.00*altsol);FS=1.1
14   1.20E+00 buck.(DONL);simp-support general buck;M=3;N=7;slope=0.;FS=1.1
15   5.31E-01 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1
16   3.20E-02 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
17   3.22E-02 buck.(DONL);hiwave roll. of stringers;M=22;N=0;slope=0.;FS=1.4
18   8.38E-01 buckling:simp-support altsoln4  intermajorpatch; FS=1.1
19   3.22E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

```
 20  1.09E+00 buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=1.1
 21  1.19E+00 buck.(SAND);simp-support general buck;M=3;N=7;slope=0.;FS=1.1
 22  5.31E-01 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1

  (lines skipped to save space)

  *********** LOAD SET NO. 2  **************
  ICASE =  2  (ICASE=1 MEANS PANEL MIDLENGTH)
              (ICASE=2 MEANS AT RINGS                       )

    APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
          Applied    axial       stress resultant, Nx= -8.0250E+03
          Applied circumferential stress resultant, Ny= -8.0250E-03
          Applied    in-plane     shear  resultant,Nxy=  4.0125E+01
          Applied    axial       moment resultant, Mx=  0.0000E+00
          Applied circumferential moment resultant, My=  0.0000E+00

    APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
          Applied    axial       stress resultant,Nx0=  0.0000E+00
          Applied circumferential stress resultant,Ny0=  1.1266E+04
          Applied    in-plane     shear  resultant,Nxy0=  0.0000E+00
          Applied pressure (positive for upward),    p = -5.6900E+01

  NOTE: "F.S." means "Factor of Safety";
  "DONL" means "Donnell shell theory used.";
  "SAND" means "Sanders shell theory used." panda2.news ITEM 128
  "Dseg" means "Segment numbering used in discretized model"
  "Iseg" means "Segment numbering used for input data." ITEM 272
 0
  MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 2, SUBCASE NO. 2
  MAR. MARGIN
  NO.  VALUE                 DEFINITION
  1   2.02E-01 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.1
  2   3.22E-01 Bending-torsion buckling; M=2  ;FS=1.
  3   2.27E-01 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.1
  4   1.51E-03 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=0.1334; RNGS;FS=1.265
  5   1.55E+03 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.2658
  6   4.91E-01 matl=1 ; substiffener effective stressSTRTHK RNGS;FS=1.2658
  7   2.12E-01 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
  8   1.21E-01 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.1
  9   9.14E+00 Inter-ring bucklng, discrete model, n=24  circ.halfwaves;FS=1.1
 10   9.17E+00 Lo-n Inter-ring buck.,discrete model,n=8   circ.halfwaves;FS=1.1
 11   5.06E-01 matl=1 ; substiffener effective stressSTRCON RNGS;FS=1.2658
 12   4.33E-03 eff.stress:matl=1,SKN,Iseg=2,at:n=6,layer=1,z=0.1334;-RNGS;FS=1.265
 13   5.21E-01 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1
 14   7.33E-02 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
 15   7.35E-02 buck.(DONL);hiwave roll. of stringers;M=22;N=0;slope=0.;FS=1.4
 16   3.21E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 17   5.21E-01 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.1
 ***********  ALL 2 LOAD SETS PROCESSED  ***********
 ****************************************************
```

"STAGS worthy" design

```
         SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER     CURRENT     UPPER
  NO. VAR.  VAR.   VAR.   TO    CONSTANT   BOUND      VALUE      BOUND          DEFINITION
   1   Y     N      N     0    0.00E+00  2.00E+00  2.4881E+01  5.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N      Y     1    3.33E-01  0.00E+00  8.2855E+00  0.00E+00       B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N      N     0    0.00E+00  6.50E-02  3.5472E+00  1.05E+01        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y      N     0    0.00E+00  6.50E-02  2.6676E-01  2.00E+00   T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     N      N     0    0.00E+00  1.10E-03  7.6755E-02  5.00E+00  TSUB,substr:Thickness, »
TSUB, of substiffener set(1 ): SK
   6   Y     N      N     0    0.00E+00  1.33E-02  1.3451E+00  1.05E+01  HSUB,substr:Height, HSU»
B, of substiffener set(1 ): SKN s
   7   Y     N      N     0    0.00E+00  7.29E-02  6.2203E+00  9.00E+00  BSUB,substr:Spacing, BS»
UB, of substiffener set(1 ): SKN
   8   Y     Y      N     0    0.00E+00  6.50E-02  2.0884E-01  3.00E+00   T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   9   Y     N      N     0    0.00E+00  2.00E+00  1.0333E+01  5.00E+01        B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
  10   N     N      N     0    0.00E+00  0.00E+00  0.0000E+00  0.00E+00      B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
  11   Y     N      N     0    0.00E+00  6.50E-02  6.7093E+00  1.05E+01        H(RNG):height of s»
tiffener (type H for sketch), h:
  12   Y     Y      N     0    0.00E+00  6.50E-02  6.5000E-02  3.00E+00   T(3 )(RNG):thickness f»
```

Table 31 (p. 4 of 4)

```
or layer index no.(3 ): RNG seg=3

 ***************************************************
 ******************* DESIGN OBJECTIVE ******************
 *************                           ***********
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE          DEFINITION
            0     0    2.686E+03  WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                             =   2.0164E+03
  TOTAL WEIGHT OF SUBSTIFFENERS                    =   1.2546E+02
  TOTAL WEIGHT OF STRINGERS                        =   2.2505E+02
  TOTAL WEIGHT OF RINGS                            =   3.1902E+02
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=   3.4823E-02

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

Compare with Table 28

compare with 2.666 in Table 28 (p. 6 of 6)

Table 32 allen.OPT (1st load set only)

```
   n         $ Do you want a tutorial session and tutorial output?
 -8025       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
     0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
     0       $ In-plane shear in load set A,                  Nxy( 1)
   n         $ Does the axial load vary in the L2 direction?
     0       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
     0       $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
   y         $ Want to include effect of transverse shear deformation?
     0       $ IQUICK = quick analysis indicator (0 or 1)
   y         $ Do you want to vary M for minimum local buckling load?
   n         $ Do you want to choose a starting M for local buckling?
   y         $ Do you want to perform a "low-axial-wavenumber" search?
2.153846     $ Factor of safety for general instability, FSGEN( 1)
1.555556     $ Factor of safety for panel (between rings) instability, FSPAN( 1)
1.555556     $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
1.555556     $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
     1       $ Factor of safety for stress, FSSTR( 1)
   y         $ Do you want "flat skin" discretized module for local buckling?
   n         $ Do you want wide-column buckling to constrain the design?
     0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
     0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
     1       $ Axial load applied along the (0=neutral plane), (1=panel skin)
     0       $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
     0       $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
     0       $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
     0       $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
     0       $ Initial local imperfection amplitude (must be positive), Wloc( 1)
   n         $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
   y         $ Do you want PANDA2 to find the general imperfection shape?( 1)
     0       $ Maximum allowable average axial strain (type H for HELP)( 1)
   n         $ Is there any thermal "loading" in this load set (Y/N)?
   y         $ Do you want a "complete" analysis (type H for "Help")?
   n         $ Want to provide another load set ?
   n         $ Do you want to impose minimum TOTAL thickness of any segment?
   n         $ Do you want to impose maximum TOTAL thickness of any segment?
   n         $ Do you want to impose minimum TOTAL thickness of any segment?
   n         $ Do you want to impose maximum TOTAL thickness of any segment?
   n         $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
     2       $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
     0       $ Index for type of shell theory (0 or 1 or 2), ISAND
   n         $ Does the postbuckling axial wavelength of local buckles change?
   n         $ Want to suppress general buckling mode with many axial waves?
   n         $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
     1       $ Choose (0=transverse inextensional; 1=transverse extensional)
     0       $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
     2       $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
   Y         $ Do you want to prevent secondary buckling (mode jumping)?
   y         $ Do you want to use the "alternative" buckling solution?
1.000000     $ Factor of safety for "alternative" model of general buckling
```

One load set only because we want to find what STAGS predicts for the 1st load set only.

Table 33 allen.OPM for the 1st Load Set only. (because we want to run STAGS for the 1st load set only).

Abridged allen.OPM file for optimum design after one SUPEROPT starting with the optimum design obtained with ICONSV = 1 and with the major stringer spacing, B(STR), changed to 24.8814 inches (50 major stringers over 360 degrees of circumference); B2(STR) equal to 0.333 x B(STR); substringer spacing, BSUB(substringer) = 6.22035 inches (4 substringers per major stringer spacing); and ring spacing, B(RNG) = 10.33333 inches (12 ring spacings over the entire axial length of the shell). This is the "STAGSworthy" configuration closest to the optimum design determined by PANDA2.

Only the first load set is processed because we wish to use STAGS with only the first load set.

NPRINT=0

(lines skipped to save space)

```
 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -8.02E+03 -8.02E-03  4.01E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.05E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.6402E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.5884E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1   2.12E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55   1.58858
 2   2.11E-02 Bending-torsion buckling; M=2  ;FS=1.5556                         1.58872
 3   5.44E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55  1.64022
 4   1.58E+00 eff.stress:matl=1,STR,Dseg=3,node=11,layer=1,z=0.1044; MID.;FS=1.
 5   4.74E+03 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6   1.60E+00 matl=1 ; substiffener effective stressSTRTHK MID.;FS=1.
 7   3.41E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556   1.60865
 8   8.52E-03 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556   1.56885
 9   6.09E+00 Inter-ring bucklng, discrete model, n=42  circ.halfwaves;FS=1.5556
10   1.60E+00 matl=1 ; substiffener effective stressSTRCON MID.;FS=1.
11   1.59E+00 eff.stress:matl=1,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12   2.93E-01 buck.(DONL);simp-support inter-ring;  (1.00*altsol);FS=1.5556   2.01139
13  -1.96E-02 buck.(DONL);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538   2.11158
14   1.41E-02 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556   1.57753
15   3.06E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4   2.03161
16   1.24E-01 buckling:simp-support altsoln4  intermajorpatch; FS=1.5556   1.74849
17   4.41E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
18   1.08E+00 1.-V(1)^1+5.V(9)^1-1
19   2.93E-01 buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=1.5556
20  -2.21E-02 buck.(SAND);simp-support general buck;M=3;N=8;slope=0.;FS=2.1538
21   1.43E-02 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556
```

Compare with STAGS prediction, 1.5445 in Fig [illegible]

Compare with the STAGS (1.59[illegible]) in Fig. 8

Compare STAGS in Fig 12

(lines skipped to save space)

```
 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 2:
 LOADING: Nx, Ny, Nxy, Mx, My =  -8.02E+03 -8.02E-03  4.01E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.05E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.6638E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.6129E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 2
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1   3.69E-02 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.55
 2   3.69E-02 Bending-torsion buckling; M=2  ;FS=1.5556
 3   6.96E-02 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=1.55
 4   1.60E+00 eff.stress:matl=1,STR,Dseg=3,node=1,layer=1,z=0.1044; RNGS;FS=1.
 5   4.91E+03 stringer popoff margin:(allowable/actual)-1, web 1  RNGS;FS=1.
 6   1.60E+00 matl=1 ; substiffener effective stressSTRTHK RNGS;FS=1.
 7   4.93E-02 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=1.5556
 8   8.40E-03 skin-substringer discrete model-1.,M=5   axial halfwaves;FS=1.5556
 9   6.09E+00 Inter-ring bucklng, discrete model, n=42  circ.halfwaves;FS=1.5556
10   1.60E+00 matl=1 ; substiffener effective stressSTRCON RNGS;FS=1.
11   1.60E+00 eff.stress:matl=1,STR,Iseg=3,at:ROOT,layer=1,z=0.;-RNGS;FS=1.
12   1.30E-02 buck.(DONL);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556
13   3.22E-01 buck.(DONL);rolling only of stringers;M=20;N=0;slope=0.;FS=1.4
14   4.40E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

These are buckling load factors corresponding to the margins:

Load Factor = (margin+1.) x f.s.

"f.s." = factor of safety

Table 33 (p.2 of 2)

```
15  1.31E-02 buck.(SAND);rolling with smear rings; M=22;N=1;slope=0.;FS=1.5556
 ***********  ALL 1 LOAD SETS PROCESSED  ***********
 ******************************************************

          SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER    CURRENT     UPPER        DEFINITION
  NO. VAR.  VAR.   VAR.   TO    CONSTANT   BOUND     VALUE      BOUND
   1   Y     N      N     0    0.00E+00  2.00E+00 2.4881E+01  5.00E+01      B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N      Y     1    3.33E-01  0.00E+00 8.2855E+00  0.00E+00      B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N      N     0    0.00E+00  6.50E-02 3.5472E+00  1.05E+01      H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y      N     0    0.00E+00  6.50E-02 2.6676E-01  2.00E+00     T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     N      N     0    0.00E+00  1.10E-03 7.6755E-02  5.00E+00    TSUB,substr:Thickness, »
TSUB, of substiffener set(1 ): SK
   6   Y     N      N     0    0.00E+00  1.33E-02 1.3451E+00  1.05E+01    HSUB,substr:Height, HSU»
B, of substiffener set(1 ): SKN s
   7   Y     N      N     0    0.00E+00  7.29E-02 6.2203E+00  9.00E+00    BSUB,substr:Spacing, BS»
UB, of substiffener set(1 ): SKN
   8   Y     Y      N     0    0.00E+00  6.50E-02 2.0884E-01  3.00E+00     T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
   9   Y     N      N     0    0.00E+00  2.00E+00 1.0333E+01  5.00E+01      B(RNG):stiffener s»
pacing, b: RNG seg=NA, layer=NA
  10   N     N      N     0    0.00E+00  0.00E+00 0.0000E+00  0.00E+00     B2(RNG):width of ri»
ng base, b2 (zero is allowed): RN
  11   Y     N      N     0    0.00E+00  6.50E-02 6.7093E+00  1.05E+01      H(RNG):height of s»
tiffener (type H for sketch), h:
  12   Y     Y      N     0    0.00E+00  6.50E-02 6.5000E-02  3.00E+00     T(3 )(RNG):thickness f»
or layer index no.(3 ): RNG seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE            DEFINITION
            0     0    2.686E+03   WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                               =    2.0164E+03
  TOTAL WEIGHT OF SUBSTIFFENERS                      =    1.2546E+02
  TOTAL WEIGHT OF STRINGERS                          =    2.2505E+02
  TOTAL WEIGHT OF RINGS                              =    3.1902E+02
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=       3.4823E-02
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 allen.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF allen.OPM FILE ****************
```

"STAGSworthy" design

Table 34 Detail from Chapter 14 of the allen.OPM file

Some output from PANDA2 for buckling between major rings and between major stringers with substringers smeared out. The discretized single-module skin-plus-smeared-substringers/ major stringer model is used, that is, a BOSOR4-type of model.

```
 (lines skipped to save space)

 ***********************************************************************
 ***********************************************************************
 ***********************************************************************
 ************            CHAPTER 14            ****************
 ***********************************************************************
 ***********************************************************************
 ***********************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *********************************************************************
 CHAPTER 14 Compute local buckling from BOSOR4-type
            discretized skin-stringer single module model.
            See Section 12.2 (upper table on p. 511) and
            Figs. 46c and 98b in [1A], for examples.
```

the skin has smeared substringers

```
 (lines skipped to save space)

 BUCKLING LOAD FACTORS FROM BOSOR4-TYPE DISCRETIZED MODEL...
         (skin-stringer discretized module of local buckling)
  AXIAL     BUCKLING        KNOCKDOWN FOR    KNOCKDOWN FOR      BUCKLING
  HALF-    LOAD FACTOR    TRANSVERSE SHEAR  IN-PLANE SHEAR    LOAD FACTOR
  WAVES  BEFORE KNOCKDOWN   DEFORMATION    LOADING AND/OR  AFTER KNOCKDOWN
                                             ANISOTROPY
    M       EIGOLD              KSTAR           KNOCK      EIGOLD*KSTAR*KNOCK
    1     1.85198E+00       1.00000E+00      1.00000E+00     1.85198E+00
    2     1.69211E+00       1.00000E+00      1.00000E+00     1.69211E+00
    3     2.29654E+00       1.00000E+00      1.00000E+00     2.29654E+00
 Buckling load factor before t.s.d.=  1.6921E+00 After t.s.d.=  1.5784E+00
 Buckling load factor before t.s.d.=  1.6921E+00 After t.s.d.=  1.6721E+00
    2     1.69211E+00       9.88152E-01      1.00000E+00     1.67206E+00

 (lines skipped to save space)

 Value of dm used in SUBROUTINE ARRAYS=  0.0000E+00
 IMOD= 0; Eigenvalue passed to STRUCT=  1.6720E+00
 Knockdown for transverse shear deformation=  9.8815E-01
 Buckling load factor from SUB. LOCAL, EIGITR(1)=  1.6720E+00
 Number of axial halfwaves between rings, N=    2
 ****  END  SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****
  **** END OF LOCAL BUCKLING EIGENVALUE CALC.****

**** BEGIN SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ****

 WIDTH-WISE WIDE COLUMN BUCKLING LOAD FACTOR =
 pi**2*EI/[abs(local hoop load)*WIDTH**2]=  1.1093E+00
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    1  1.1616E-06
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    2  2.2562E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    1  4.3909E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    2  4.3909E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    1  3.4597E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    2  1.2320E-01
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    1  2.2562E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    2  1.1616E-06
       Internal Stringer

      MODULE WITH RECTANGULAR STIFFENER...

                                     !    ^
         Segment No. 3 -----> !    !
                                     !    !
            Seg. No. 2-.          !    h
                           .          !    !
      Segment No. 1-.        .    !    !         .-Seg. No. 4
                  .          .  !    V         .(same as Seg. 1)
        ------------==================------------
                      !<------ b2 ------->!
        !<--- Module width  =  stiffener spacing, b --->!

    EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS
```

Table 34, (p. 2 of 3)

```
                               (3,11)
                                 !
        Layer No. 1 -----> ! <---------- Layer No. k
                                 !
     Layer No. 1-.               !
                       .         !
 Layer No. 1-.          .        !            .-Layer No. 1
             .           .       !            .
            .             .    (3,1)           .
 --------------    =====================    --------------
(1,1)  .   (1,11)(2,1)   . (2,6)    (2,11)(4,1)   .    (4,11)
          .                 .                  .
          .                  .                .
         Layer No. m       Layer No. n    Layer No. m
```

NORMAL MODAL DISPLACEMENTS IN THE PANEL MODULE SHOWN ABOVE
SKIN-STRINGER PANEL MODULE HAS 4 SEGMENTS
NUMBER OF HALF-WAVES IN THE AXIAL DIRECTION, M= 2

MODAL DISPLACEMENTS FOR SEGMENT NO. 1

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	8.13E-07	0.00E+00	-1.13E-06	0.00E+00	-1.39E-07	-4.31E-06
2	0.00E+00	-3.49E-07	-3.35E-06	-4.70E-06	1.41E-07	-3.35E-07	-4.31E-06
3	0.00E+00	-4.75E-06	-8.74E-06	-8.28E-06	1.67E-07	-9.24E-07	-4.31E-06
4	0.00E+00	-1.48E-05	-1.71E-05	-1.19E-05	-1.36E-07	-2.38E-06	-4.42E-06
5	0.00E+00	-3.32E-05	-2.55E-05	-8.21E-06	-1.25E-06	-5.70E-06	4.51E-06
6	0.00E+00	-5.72E-05	-1.93E-05	2.31E-05	-4.24E-06	-1.29E-05	3.77E-05
7	0.00E+00	-6.53E-05	4.27E-05	1.26E-04	-1.13E-05	-2.78E-05	1.25E-04
8	0.00E+00	1.37E-05	2.55E-04	3.85E-04	-2.68E-05	-5.70E-05	3.11E-04
9	0.00E+00	3.58E-04	7.97E-04	9.22E-04	-5.87E-05	-1.11E-04	6.47E-04
10	0.00E+00	1.34E-03	1.95E-03	1.86E-03	-1.20E-04	-2.03E-04	1.12E-03
11	0.00E+00	3.59E-03	4.01E-03	2.79E-03	-2.17E-04	-3.16E-04	1.12E-03

MODAL DISPLACEMENTS FOR SEGMENT NO. 2

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	3.59E-03	4.01E-03	5.99E-03	-2.17E-04	-3.16E-04	-2.50E-03
2	0.00E+00	7.98E-03	6.92E-03	3.91E-03	-4.12E-04	-5.24E-04	-2.50E-03
3	0.00E+00	1.51E-02	9.31E-03	1.84E-03	-6.94E-04	-7.05E-04	-2.50E-03
4	0.00E+00	2.34E-02	6.33E-03	-9.02E-03	-1.08E-03	-7.81E-04	-1.31E-02
5	0.00E+00	2.56E-02	-1.41E-02	-4.04E-02	-1.54E-03	-5.61E-04	-3.78E-02
6	0.00E+00	1.05E-15	-3.08E-02	-3.07E-15	-1.78E-03	0.00E+00	4.87E-02
7	0.00E+00	-2.56E-02	-1.41E-02	4.04E-02	-1.54E-03	5.61E-04	4.87E-02
8	0.00E+00	-2.34E-02	6.33E-03	9.02E-03	-1.08E-03	7.81E-04	-3.78E-02
9	0.00E+00	-1.51E-02	9.31E-03	-1.84E-03	-6.94E-04	7.05E-04	-1.31E-02
10	0.00E+00	-7.98E-03	6.92E-03	-3.91E-03	-4.12E-04	5.24E-04	-2.50E-03
11	0.00E+00	-3.59E-03	4.01E-03	-5.99E-03	-2.17E-04	3.16E-04	-2.50E-03

MODAL DISPLACEMENTS FOR SEGMENT NO. 3

NODE	Z	W	WD	WDD	U	V	WDDD
1	-1.33E-01	-5.90E-03	-3.08E-02	-3.47E-01	-7.77E-16	-4.07E-17	2.40E-01
2	-4.88E-01	-4.05E-02	-1.44E-01	-2.62E-01	-7.19E-16	1.52E-17	2.40E-01
3	-8.43E-01	-1.08E-01	-2.22E-01	-1.77E-01	-6.65E-16	5.41E-17	2.40E-01
4	-1.20E+00	-1.98E-01	-2.73E-01	-1.11E-01	-6.16E-16	7.90E-17	1.85E-01
5	-1.55E+00	-3.02E-01	-3.04E-01	-6.19E-02	-5.75E-16	9.61E-17	1.39E-01
6	-1.91E+00	-4.13E-01	-3.19E-01	-2.67E-02	-5.40E-16	1.11E-16	9.90E-02
7	-2.26E+00	-5.28E-01	-3.25E-01	-5.70E-03	-5.12E-16	1.27E-16	5.93E-02
8	-2.62E+00	-6.44E-01	-3.26E-01	-3.17E-05	-4.90E-16	1.51E-16	1.60E-02
9	-2.97E+00	-7.60E-01	-3.28E-01	-1.24E-02	-4.71E-16	1.87E-16	-3.50E-02
10	-3.33E+00	-8.77E-01	-3.39E-01	-4.74E-02	-4.54E-16	2.41E-16	-9.85E-02
11	-3.68E+00	-1.00E+00	-3.61E-01	-8.23E-02	-4.35E-16	3.11E-16	-9.85E-02

Compare with STAGS in Fig. 7

MODAL DISPLACEMENTS FOR SEGMENT NO. 4

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	-3.59E-03	4.01E-03	-2.79E-03	-2.17E-04	3.16E-04	1.12E-03
2	0.00E+00	-1.34E-03	1.95E-03	-1.86E-03	-1.20E-04	2.03E-04	1.12E-03
3	0.00E+00	-3.58E-04	7.97E-04	-9.22E-04	-5.87E-05	1.11E-04	1.12E-03
4	0.00E+00	-1.37E-05	2.55E-04	-3.85E-04	-2.68E-05	5.70E-05	6.47E-04
5	0.00E+00	6.53E-05	4.27E-05	-1.26E-04	-1.13E-05	2.78E-05	3.11E-04
6	0.00E+00	5.72E-05	-1.93E-05	-2.31E-05	-4.24E-06	1.29E-05	1.25E-04
7	0.00E+00	3.32E-05	-2.55E-05	8.21E-06	-1.25E-06	5.70E-06	3.77E-05
8	0.00E+00	1.48E-05	-1.71E-05	1.19E-05	-1.36E-07	2.38E-06	4.51E-06
9	0.00E+00	4.75E-06	-8.74E-06	8.28E-06	1.67E-07	9.24E-07	-4.42E-06
10	0.00E+00	3.49E-07	-3.35E-06	4.70E-06	1.41E-07	3.35E-07	-4.31E-06
11	0.00E+00	-8.13E-07	0.00E+00	1.13E-06	0.00E+00	1.39E-07	-4.31E-06

```
**** END SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ******
EILOCL,EIGLCS(1),FKNOCS,EIGRAT=
 1.9526E+00  1.6720E+00  1.0000E+00  1.1678E+00
 **************************************
 **** LOCAL MODE HAS STRINGER SIDESWAY ****
 **************************************
```

Table 34 (p. 3 of 3)

```
 **** END OF LOCAL BUCKLING EIGENVECTOR CALC.****
 IPANDA= 0

 *** NOTE: Local buckling eigenvalue reduced by EIGMLT=  9.5000E-01
           because there are smeared substiffeners.*******

 Margin=  2.1152E-02  Local buckling from discrete model-1.,M=2   axial halfwaves;FS=1.5556

 *** NOTE: Bending-torsion buckling eigvalue reduced by EIGMLT=  9.5000E-01
     because there are smeared substiffeners.*******

 Margin=  2.1134E-02  Bending-torsion buckling; M=2  ;FS=1.5556
 ******** THE FOLLOWING BENDING-TORSION MARGIN JUST COMPUTED:
Bending-torsion buckling; M=2  ;FS=1.5556
 ******** CONSTRAINT NO.  2; LOAD SET NO. 1; SUBCASE NO. 1
```

eig. = 1.672 x 0.95

Table 35 allen.STG

```
n          $ Do you want a tutorial session and tutorial output?
   1       $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
   0       $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.700000   $ Local buckling load factor from PANDA2, EIGLOC
  y        $ Are the dimensions in this case in inches?
   0       $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
   0       $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
31.0       $ X-direction length of the STAGS model of the panel: XSTAGS
74.6442    $ Panel length in the plane of the screen, L2
  y        $ Is the nodal point spacing uniform along the stringer axis?
  101      $ Number of nodes in the X-direction: NODEX
 -8025     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
   0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
   0       $ In-plane shear in load set A,                      Nxy
   0       $ Normal pressure in STAGS model in Load Set A, p
   0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
   0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
   0       $ Normal pressure in STAGS model in Load Set B, p0
   1       $ Starting load factor for Load System A, STLD(1)
   0       $ Load factor increment for Load System A, STEP(1)
   1       $ Maximum load factor for Load System A, FACM(1)
   0       $ Starting load factor for Load System B, STLD(2)
   0       $ Load factor increment for Load System B, STEP(2)
   0       $ Maximum load factor for Load System B, FACM(2)
   5       $ How many eigenvalues do you want? NEIGS
  480      $ Choose element type (410 or 411 or 480) for panel skin
  n        $ Have you obtained buckling modes from STAGS for this case?
   50      $ Number of stringers in STAGS model of 360-deg. cylinder
   4       $ Number of rings in the STAGS model of the panel
  y        $ Are there rings at the ends of the panel?
   3       $ Sub-stringer model, ISTRSB = 1 or 2 or 3 (Type H(elp))
   7       $ Number of nodes over height of sub-stringer web, NPSUBS
note 4     $ Number of finite elements between adjacent sub-stringers
   11      $ Number of finite elements between adjacent rings
   3       $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
   3       $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
  -1       $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
  n        $ Do you want to use fasteners (they are like rigid links)?
  n        $ Are the stringers to be "smeared out"?
  n        $ Are the rings to be "smeared out"?
   7       $ Number of nodes over height of stiffener webs, NODWEB
   7       $ Number of nodes over width of stringer flange, NDFLGS
   7       $ Number of nodes over width of ring flange, NDFLGR
  n        $ Do you want stringer(s) with a high nodal point density?
  n        $ Do you want ring(s) with a high nodal point density?
  n        $ Is there plasticity in this STAGS model?
  n        $ Do you want to use the "least-squares" model for torque?
  n        $ Is stiffener sidesway permitted at the panel edges?
  y        $ Do you want symmetry conditions along the straight edges?
```

3 major stringer spacings = 3 x 24.8814 inches

3 major ring spacings = 3 x 10.33333 = 31.0 inches

3 bay x 3 bay STAGS "patch" model.
All stiffeners & substiffeners are flexible shell branches.

Table 36 (2 pages) allen.bin & allen.out2 from STAGS

allen.bin file produced automatically by STAGSUNIT

```
allen STAGS INPUT FOR STIFFENED CYL.(STAGSUNIT=SHELL UNITS)
1, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ ICHIST=index for crack archive option
0, $ IFLU  =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
1.000E+00, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
0.000E+00, $ STEP(1) = load factor increment, System A
1.000E+00, $ FACM(1) = maximum load factor, System A
0.000E+00, $ STLD(2) = starting load factor, System B
0.000E+00, $ STEP(2) = load factor increment, System B
0.000E+00, $ FACM(2) = maximum load factor, System B
0   $ ITEMP =0 means no thermal loads. END C-1 rec.
10000, $ NSEC= number of CPU seconds before run termination
0., $ DELEV is eigenvalue error tolerance (0=.00001)
0   $ IPRINT=0 means print modes, iteration data, END D-2 rec.
 5, $ NEIGS= number of eigenvalues sought.  BEGIN D-3 rec.
1.190E+00, $ SHIFT=initial eigenvalue shift
0.000E+00, $ EIGA =lower bound of eigenvalue range
0.000E+00  $ EIGB =upper bound of eigenvalue range.      END D-3 rec.
```

Abridged allen.out2 file from STAGS correponding
to the eigenvalue shift, SHIFT = 1.19

```
MAXIMUM NUMBER OF ITERATIONS
 CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES  1 THROUGH   2
 CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES   3 THROUGH   5
```

Note

NO.	EIGENVALUE	CRITICAL LOAD FACTOR COMBINATION LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	1.544511E+00	1.544511E+00	0.000000E+00	73075
2	1.544524E+00	1.544524E+00	0.000000E+00	72531
3	1.589948E+00	1.589948E+00	0.000000E+00	74947
4	1.591137E+00	1.591137E+00	0.000000E+00	43903
5	1.592227E+00	1.592227E+00	0.000000E+00	63231

allen.bin file edited to have a new eigenvalue SHIFT = 1.57
that is approximately in the middle of the cluster of 5
eigenvalues determined in the previous STAGS execution
(results just listed).

```
allen STAGS INPUT FOR STIFFENED CYL.(STAGSUNIT=SHELL UNITS)
1, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ ICHIST=index for crack archive option
0, $ IFLU  =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
1.000E+00, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
0.000E+00, $ STEP(1) = load factor increment, System A
1.000E+00, $ FACM(1) = maximum load factor, System A
0.000E+00, $ STLD(2) = starting load factor, System B
0.000E+00, $ STEP(2) = load factor increment, System B
0.000E+00, $ FACM(2) = maximum load factor, System B
0   $ ITEMP =0 means no thermal loads. END C-1 rec.
10000, $ NSEC= number of CPU seconds before run termination
0., $ DELEV is eigenvalue error tolerance (0=.00001)
0   $ IPRINT=0 means print modes, iteration data, END D-2 rec.
 5, $ NEIGS= number of eigenvalues sought.  BEGIN D-3 rec.
1.570E+00, $ SHIFT=initial eigenvalue shift
0.000E+00, $ EIGA =lower bound of eigenvalue range
0.000E+00  $ EIGB =upper bound of eigenvalue range.      END D-3 rec.
```

note new SHIFT

Table 36 (p. 2 of 2) output from STAGS (allen.out2)

Abridged output from STAGS, allen.out2, for the
3 bay x 3 bay STAGS "patch" model with use
of the eigenvalue SHIFT = ~~1.565~~ 1.57

(lines skipped to save space)

```
 ---------------------------------------------
 Compact-matrix VSS decomposition completed ....
 Number of renumbering schemes used ..       6
 Determinant ...  3.9955D+00 x 10**(    426319 )
 Number of negative roots ...........       64
 Estimated condition number .....   1.741591D-04
 ---------------------------------------------
```

(lines skipped to save space)

```
NO OF MODES          SHIFT                ALPHA                BETA
          5   0.15650000E+01    0.00000000E+00    0.00000000E+00

 ------------------------------------------
 COMPACT SYSTEM-MATRIX ASSEMBLY COMPLETED ...
 # of equations in the system matrix:   91618
 # of nonzero off-diagonal entries:   2993861
 ------------------------------------------

CP SEC =    55.480.  I/O REQSTS =    47838   WORDS USED =  14973443   WORDS TRANSFD =    1.75941»
E+08

 ---------------------------------------------
 Compact-matrix VSS decomposition completed ....
 Number of renumbering schemes used ..       1
 Determinant ...  1.8659D+00 x 10**(    426006 )
 Number of negative roots ...........       66
 Estimated condition number .....   1.241339D-03
 ---------------------------------------------
```

2 skipped roots for SHIFT = 1.565

(lines skipped to save space)

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 5

CRITICAL LOAD FACTOR COMBINATION

NO	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	1.544510E+00	1.544510E+00	0.000000E+00	73075
2	1.544523E+00	1.544523E+00	0.000000E+00	70659
3	1.587997E+00	1.587997E+00	0.000000E+00	74947
4	1.588004E+00	1.588004E+00	0.000000E+00	70659
5	1.591493E+00	1.591493E+00	0.000000E+00	43719

here are the 2 "skipped" roots. The STAGS run is therefore okay.

Fig. 8

Fig. 7

Table 37 allen.pin File → Fig. 7

```
linear buckling of perfect shell from STAGS
  1  0  1  0   $PL-2  NPLOT,IPREP,IPRS,KDEV
     1     0     4     0     1  $PL-3  KPLOT,NUNIT,ITEM,STEP,MODE
    0.0   3  $PL-5  DSCALE,NROTS
  1   -35.84    $PL-6  IROT,ROT
  2   180.14    $PL-6  IROT,ROT
  3    35.63    $PL-6  IROT,ROT
```

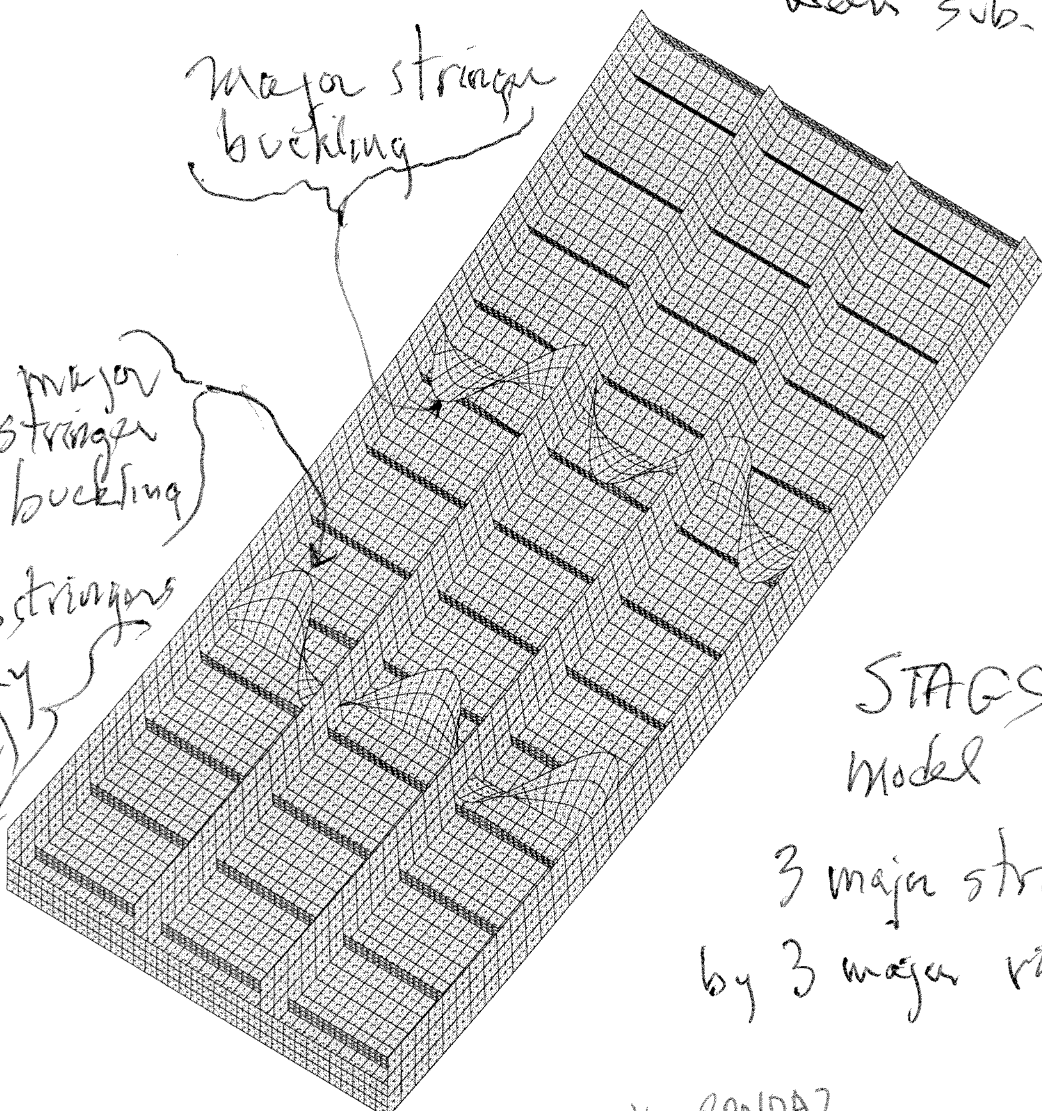
input for STAPL (Fig. 7)

Note: For a proper STAGS model you must have an even number of finite elements between sub-stiffeners

major stringer buckling

major stringer buckling

4 substringers per bay (typical)



STAGS model

3 major stringer bays by 3 major ring bays

solution scale = 0.4646E+01
mode 1, pcr = 0.15445E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

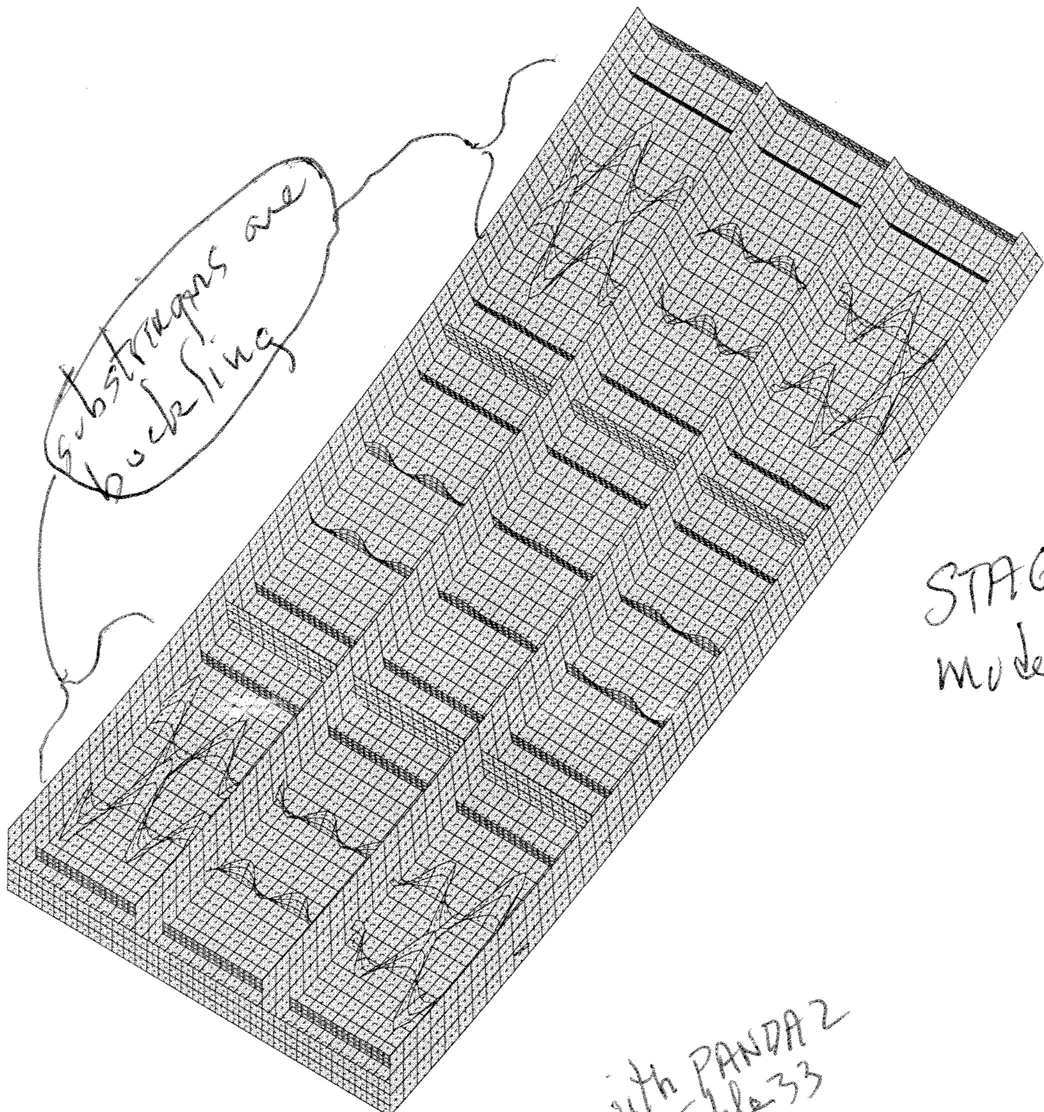
compare with PANDA2 prediction in Table 33

Θ x -35.84
Θ y -179.86
Θ z 35.63

x y z

1.213E+01

Fig. 7



STAGS model

compare with PANDA2 prediction in Table 33

solution scale = 0.4858E+01
mode 5, pcr = 0.15915E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

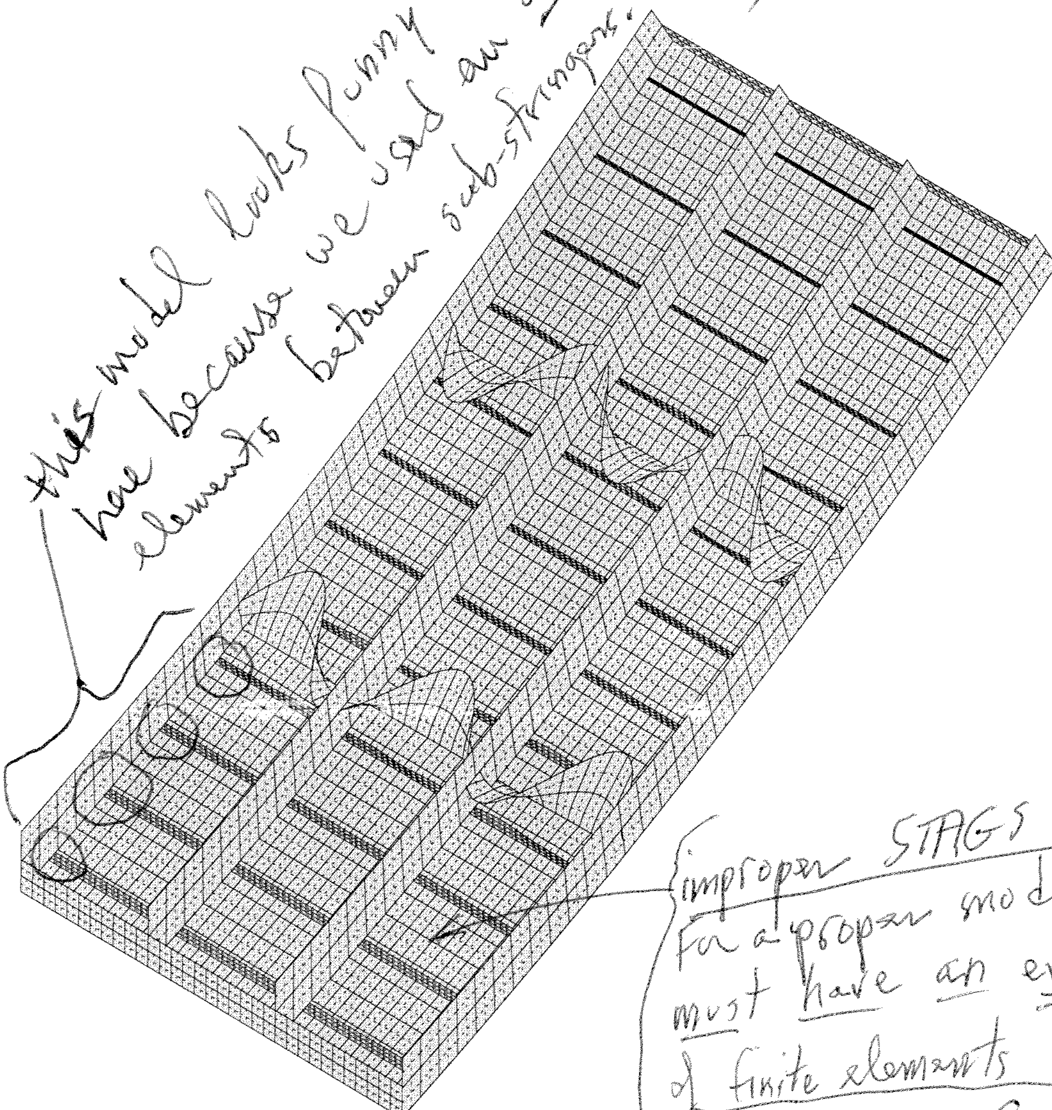
Θ x -35.84
Θ y -179.86
Θ z 35.63

1.213E+01

x y z

Fig. 8

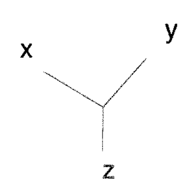
this model looks funny here because we used an odd no. of finite elements between sub-stringers. Must use even number.



improper STAGS model. For a proper model you must have an even number of finite elements between substiffeners. Compare Fig. 7.

solution scale = 0.4646E+01
mode 1, pcr = 0.15527E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63



1.213E+01

Fig. 9

Table 38 alkn.STG

```
n           $ Do you want a tutorial session and tutorial output?
   1        $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
   0        $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.700000    $ Local buckling load factor from PANDA2, EIGLOC
  y         $ Are the dimensions in this case in inches?
   0        $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
   0        $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
31.0        $ X-direction length of the STAGS model of the panel: XSTAGS
74.6442     $ Panel length in the plane of the screen, L2
  y         $ Is the nodal point spacing uniform along the stringer axis?
 101        $ Number of nodes in the X-direction: NODEX
-8025       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
   0        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
   0        $ In-plane shear in load set A,                       Nxy
   0        $ Normal pressure in STAGS model in Load Set A, p
   0        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
   0        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
   0        $ Normal pressure in STAGS model in Load Set B, p0
   1        $ Starting load factor for Load System A, STLD(1)
   0        $ Load factor increment for Load System A, STEP(1)
   1        $ Maximum load factor for Load System A, FACM(1)
   0        $ Starting load factor for Load System B, STLD(2)
   0        $ Load factor increment for Load System B, STEP(2)
   0        $ Maximum load factor for Load System B, FACM(2)
   5        $ How many eigenvalues do you want? NEIGS
 480        $ Choose element type (410 or 411 or 480) for panel skin
  n         $ Have you obtained buckling modes from STAGS for this case?
  50        $ Number of stringers in STAGS model of 360-deg. cylinder
   4        $ Number of rings in the STAGS model of the panel
  y         $ Are there rings at the ends of the panel?
   1        $ Sub-stringer model, ISTRSB = 1 or 2 or 3 (Type H(elp))
   7        $ Number of nodes over height of sub-stringer web, NPSUBS
   4        $ Number of finite elements between adjacent stringers
  11        $ Number of finite elements between adjacent rings
   3        $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
   3        $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
  -1        $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
  n         $ Do you want to use fasteners (they are like rigid links)?
  n         $ Are the stringers to be "smeared out"?
  n         $ Are the rings to be "smeared out"?
   7        $ Number of nodes over height of stiffener webs, NODWEB
   7        $ Number of nodes over width of stringer flange, NDFLGS
   7        $ Number of nodes over width of ring flange, NDFLGR
  n         $ Do you want stringer(s) with a high nodal point density?
  n         $ Do you want ring(s) with a high nodal point density?
  n         $ Is there plasticity in this STAGS model?
  n         $ Do you want to use the "least-squares" model for torque?
  n         $ Is stiffener sidesway permitted at the panel edges?
  y         $ Do you want symmetry conditions along the straight edges?
```

note: 1 means "smeared substringers"

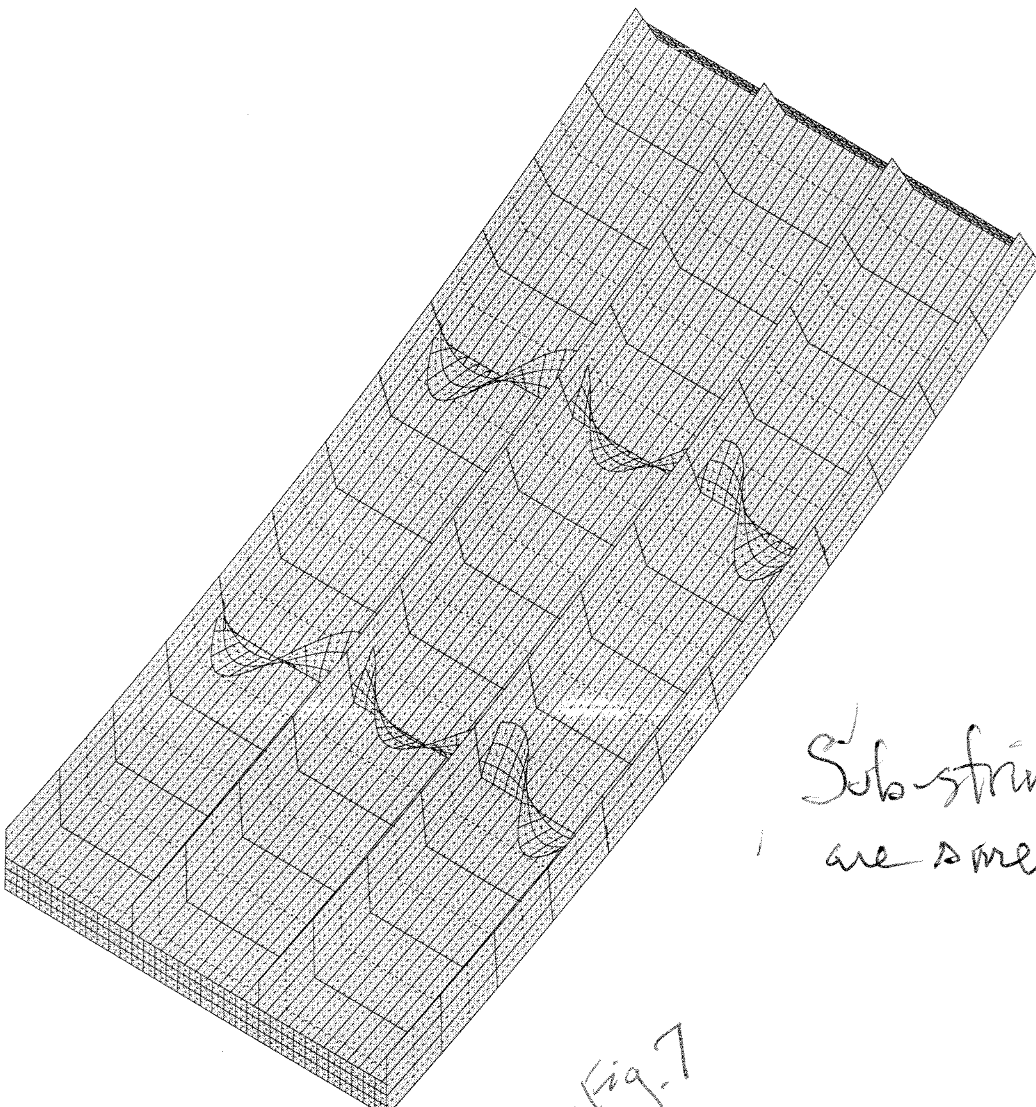
Same as Table 35 except sub-stringers are <u>smeared</u>.

3 bay x 3 bay model

Table 39 allen.out2 file

```
Abridged output from STAGS, allen.out2, for the
3 bay  x  3 bay STAGS "patch" model with use
of the eigenvalue SHIFT = 1.57. In this model
the substringers are smeared out.

 (lines skipped to save space)

          -----------------------------------------------
          Compact-matrix VSS decomposition completed ....
          Number of renumbering schemes used ..        6
          Determinant ...  1.1030D+00 x 10**(    114154 )
          Number of negative roots ...........        16
          Estimated condition number .....   6.222475D-04
          -----------------------------------------------

 (lines skipped to save space)

 NO OF MODES           SHIFT             ALPHA              BETA
           8     0.15700000E+01   0.00000000E+00    0.00000000E+00

          --------------------------------------------
          COMPACT SYSTEM-MATRIX ASSEMBLY COMPLETED ...
          # of equations in the system matrix:   23314
          # of nonzero off-diagonal entries:    708366
          --------------------------------------------

 CP SEC =     10.100.  I/O REQSTS =     6156   WORDS USED =    3874611   WORDS TRANSFD =     2.70826»
E+07

          -----------------------------------------------
          Compact-matrix VSS decomposition completed ....
          Number of renumbering schemes used ..        1
          Determinant ...  1.3199D+00 x 10**(    114145 )
          Number of negative roots ...........        16
          Estimated condition number .....   5.308598D-04
          -----------------------------------------------

 (lines skipped to save space)

 CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES  1 THROUGH    8

                         CRITICAL LOAD FACTOR COMBINATION
   NO.     EIGENVALUE    LOAD SYSTEM A  LOAD SYSTEM B    @DOF
     1   1.614901E+00    1.614901E+00    0.000000E+00   12723
     2   1.615966E+00    1.615966E+00    0.000000E+00   17047
     3   1.647897E+00    1.647897E+00    0.000000E+00   12723
     4   1.648410E+00    1.648410E+00    0.000000E+00   15139
     5   1.702798E+00    1.702798E+00    0.000000E+00   13875
     6   1.703349E+00    1.703349E+00    0.000000E+00   15859
     7   1.778828E+00    1.778828E+00    0.000000E+00   10271
     8   1.778830E+00    1.778830E+00    0.000000E+00   19463
```

Fig. 10



Sub-stringers are smeared out.

Compare Fig. 7

solution scale = 0.4647E+01
mode 1, pcr = 0.16149E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

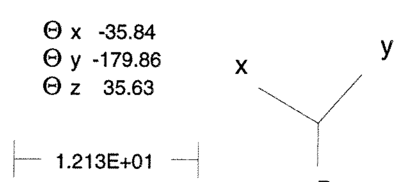


Fig. 10

Table 40 allen.STG

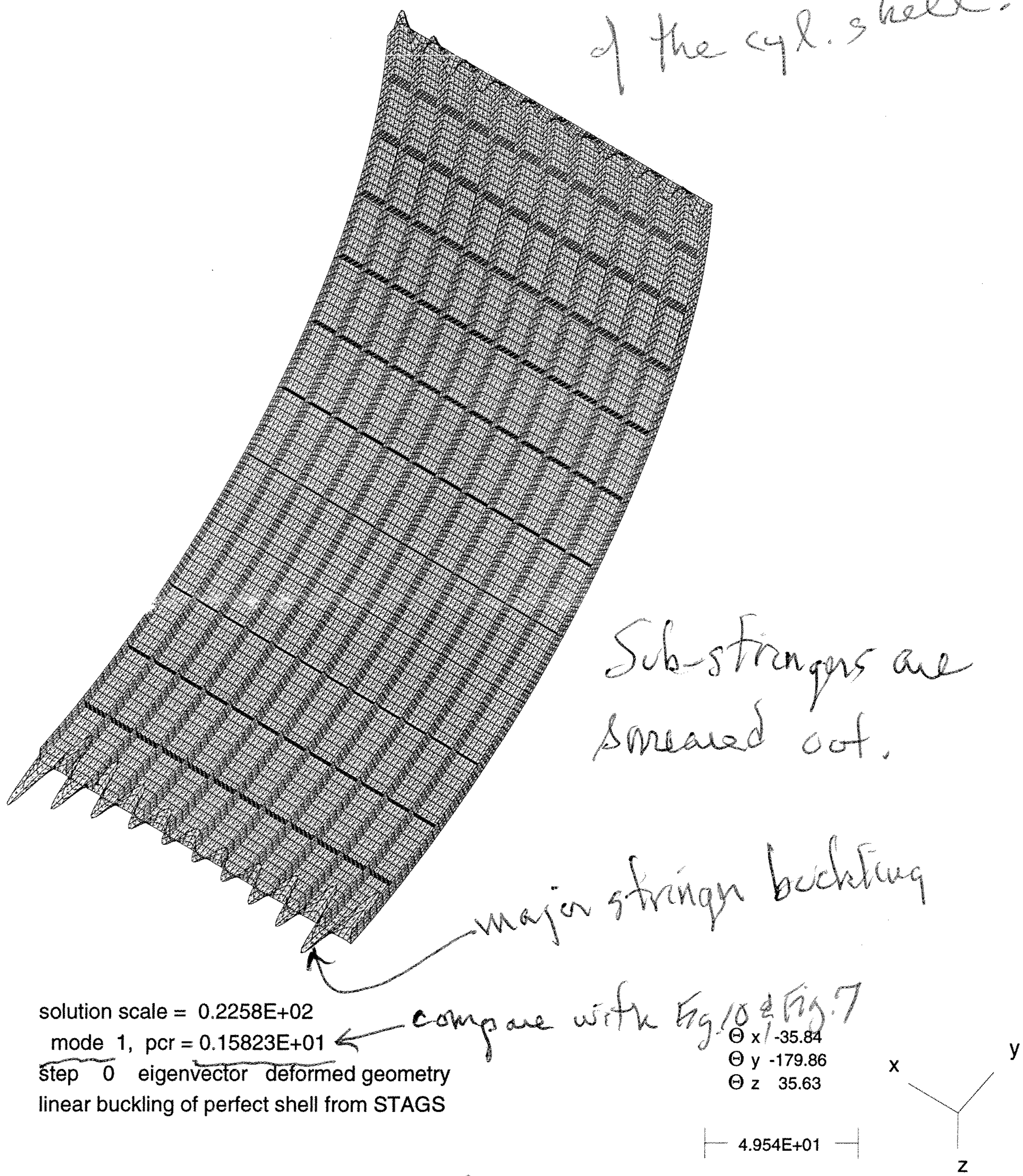
```
   n           $ Do you want a tutorial session and tutorial output?
     1         $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
     0         $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
1.700000       $ Local buckling load factor from PANDA2, EIGLOC
   y           $ Are the dimensions in this case in inches?
     0         $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
     0         $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
124.           $ X-direction length of the STAGS model of the panel: XSTAGS
298.5768       $ Panel length in the plane of the screen, L2
   y           $ Is the nodal point spacing uniform along the stringer axis?
   101         $ Number of nodes in the X-direction: NODEX
  -8025        $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
     0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
     0         $ In-plane shear in load set A,                       Nxy
     0         $ Normal pressure in STAGS model in Load Set A, p
     0         $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
     0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
     0         $ Normal pressure in STAGS model in Load Set B, p0
     1         $ Starting load factor for Load System A, STLD(1)
     0         $ Load factor increment for Load System A, STEP(1)
     1         $ Maximum load factor for Load System A, FACM(1)
     0         $ Starting load factor for Load System B, STLD(2)
     0         $ Load factor increment for Load System B, STEP(2)
     0         $ Maximum load factor for Load System B, FACM(2)
     2         $ How many eigenvalues do you want? NEIGS
   480         $ Choose element type (410 or 411 or 480) for panel skin
   n           $ Have you obtained buckling modes from STAGS for this case?
    50         $ Number of stringers in STAGS model of 360-deg. cylinder
    13         $ Number of rings in the STAGS model of the panel
   y           $ Are there rings at the ends of the panel?
     1         $ Sub-stringer model, ISTRSB = 1 or 2 or 3 (Type H(elp))
     5         $ Number of nodes over height of sub-stringer web, NPSUBS
     7         $ Number of finite elements between adjacent stringers
     6         $ Number of finite elements between adjacent rings
     3         $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
     3         $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
    -1         $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n           $ Do you want to use fasteners (they are like rigid links)?
   n           $ Are the stringers to be "smeared out"?
   n           $ Are the rings to be "smeared out"?
     7         $ Number of nodes over height of stiffener webs, NODWEB
     7         $ Number of nodes over width of stringer flange, NDFLGS
     7         $ Number of nodes over width of ring flange, NDFLGR
   n           $ Do you want stringer(s) with a high nodal point density?
   n           $ Do you want ring(s) with a high nodal point density?
   n           $ Is there plasticity in this STAGS model?
   n           $ Do you want to use the "least-squares" model for torque?
   n           $ Is stiffener sidesway permitted at the panel edges?
   n           $ Do you want symmetry conditions along the straight edges?
     0         $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

substringers are smeared.

12 major stringer bays (12 x 24.8814) inches

124" = entire length of the cyl. shell

12 major stringer bays;
entire axial length
of the cyl. shell.



Sub-stringers are
smeared out.

major stringer buckling

compare with Fig.10 & Fig.7

Fig. 11

Table 41 allen.STG

```
   n         $ Do you want a tutorial session and tutorial output?
      1      $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
      0      $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
 1.700000    $ Local buckling load factor from PANDA2, EIGLOC
   y         $ Are the dimensions in this case in inches?
      0      $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
      0      $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
 124.        $ X-direction length of the STAGS model of the panel: XSTAGS
 1244.0710   $ Panel length in the plane of the screen, L2
   y         $ Is the nodal point spacing uniform along the stringer axis?
    101      $ Number of nodes in the X-direction: NODEX
  -8025      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
      0      $ In-plane shear in load set A,                      Nxy
      0      $ Normal pressure in STAGS model in Load Set A, p
      0      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
      0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
      0      $ Normal pressure in STAGS model in Load Set B, p0
      1      $ Starting load factor for Load System A, STLD(1)
      0      $ Load factor increment for Load System A, STEP(1)
      1      $ Maximum load factor for Load System A, FACM(1)
      0      $ Starting load factor for Load System B, STLD(2)
      0      $ Load factor increment for Load System B, STEP(2)
      0      $ Maximum load factor for Load System B, FACM(2)
      2      $ How many eigenvalues do you want? NEIGS
    480      $ Choose element type (410 or 411 or 480) for panel skin
   n         $ Have you obtained buckling modes from STAGS for this case?
     50      $ Number of stringers in STAGS model of 360-deg. cylinder
     13      $ Number of rings in the STAGS model of the panel
   y         $ Are there rings at the ends of the panel?
      1      $ Sub-stringer model, ISTRSB = 1 or 2 or 3 (Type H(elp))
      7      $ Number of nodes over height of sub-stringer web, NPSUBS
      1      $ Number of finite elements between adjacent stringers
      1      $ Number of finite elements between adjacent rings
      3      $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
      3      $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
     -1      $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
   n         $ Do you want to use fasteners (they are like rigid links)?
   y         $ Are the stringers to be "smeared out"?
   n         $ Are the rings to be "smeared out"?
note  5      $ Number of nodes over height of stiffener webs, NODWEB
      5      $ Number of nodes over width of stringer flange, NDFLGS
      5      $ Number of nodes over width of ring flange, NDFLGR
   n         $ Do you want stringer(s) with a high nodal point density?
   n         $ Do you want ring(s) with a high nodal point density?
   n         $ Is there plasticity in this STAGS model?
   n         $ Do you want to use the "least-squares" model for torque?
   n         $ Is stiffener sidesway permitted at the panel edges?
   n         $ Do you want symmetry conditions along the straight edges?
      0      $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

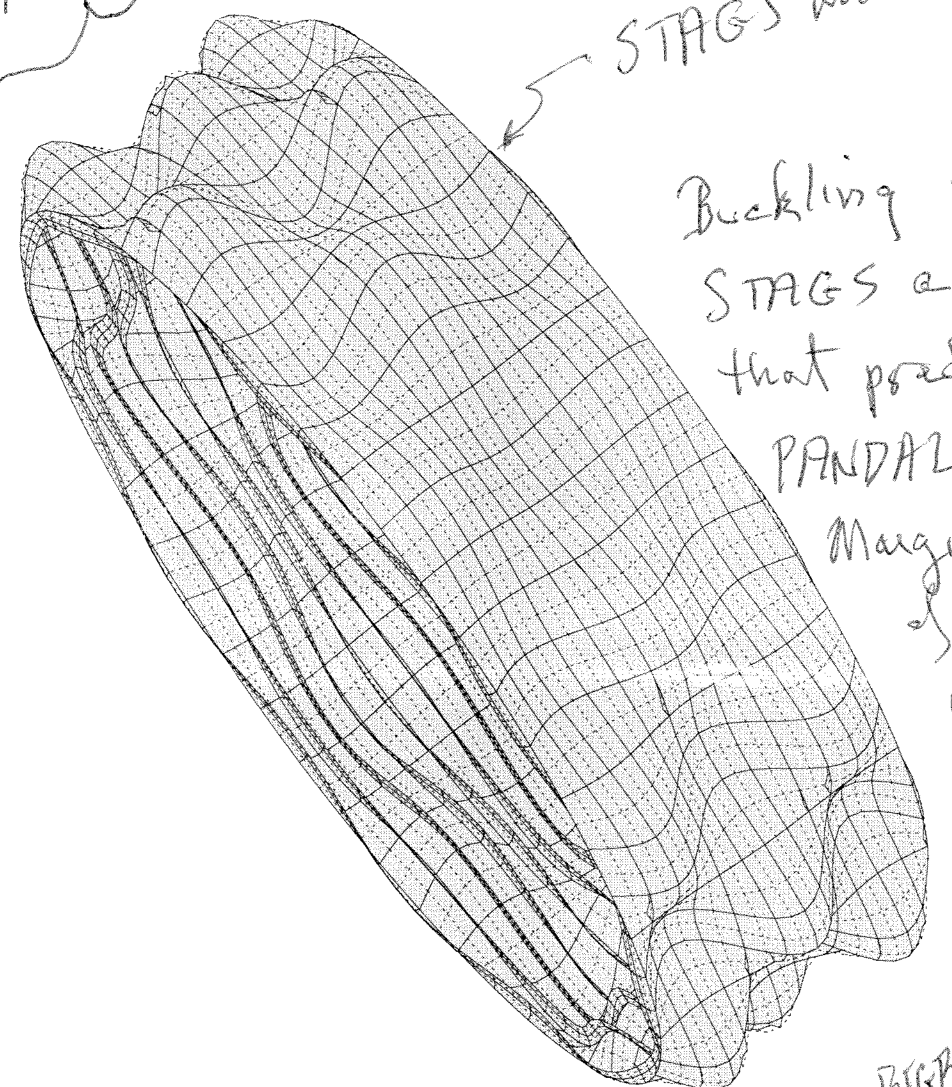
entire 360-degree cyl. shell

sub-stringers are smeared out

major stringers are smeared out.

M = 3 axial halfwaves in the general buckling pattern

STAGS model



Buckling mode from STAGS agrees with that predicted by PANDA2 & listed as Margin no. 13 on p. 1 of Table 33. (M=3, N=8)

BIGBOSOR4 gets 2.3239 (Fig. 17)

solution scale = 0.2052E+02
mode 1, pcr = 0.23180E+01 ← compare PANDA2 in Table 33. PANDA2 gets 2.11158
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

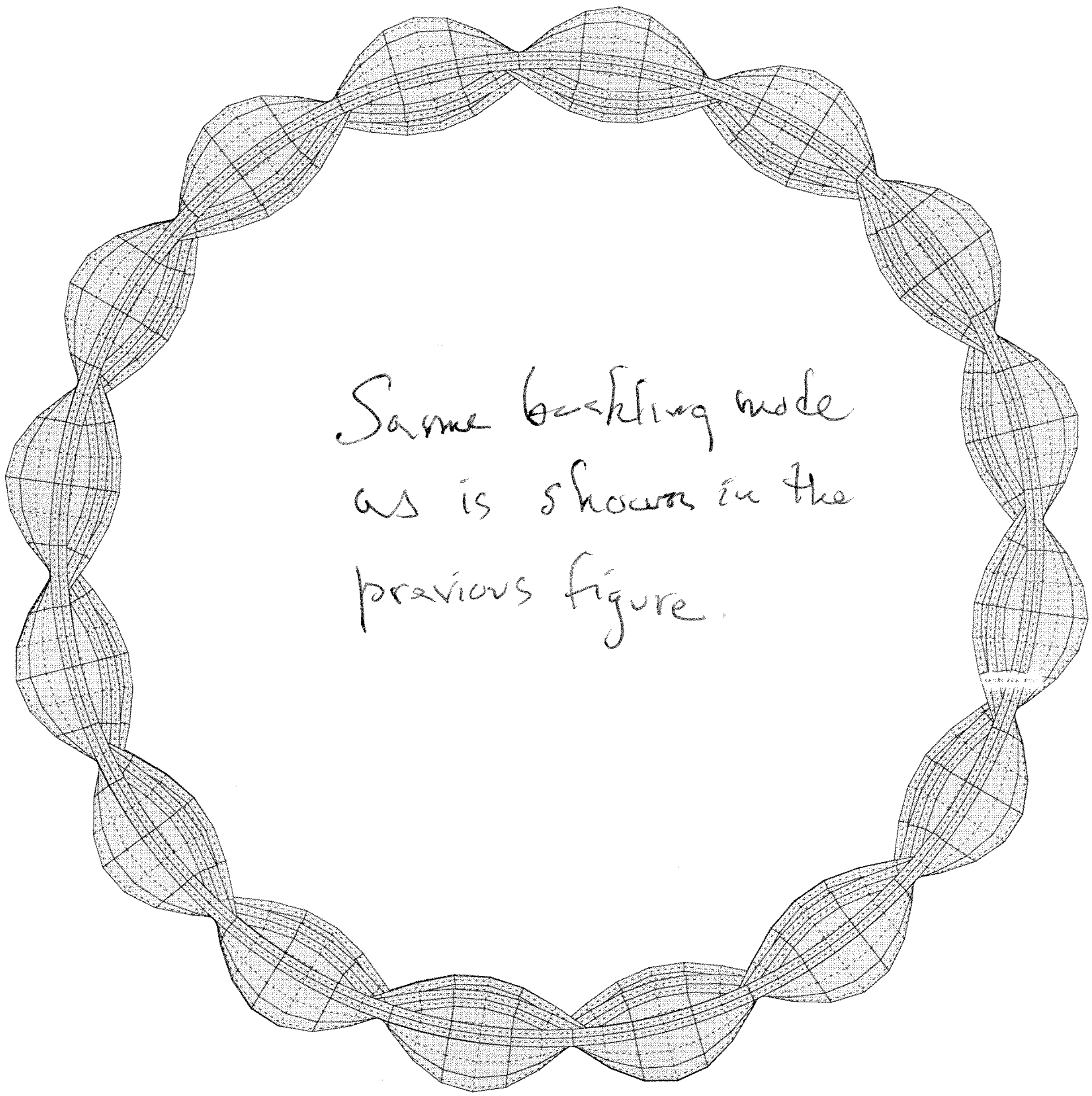
Θ x -35.84
Θ y -13.14
Θ z 35.63

y z x

6.869E+01

Fig 12

N = 8 full circumferential waves in the general buckling mode



Same buckling mode as is shown in the previous figure.

solution scale = 0.2002E+02
mode 1, pcr = 0.23180E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x 0.00
Θ y 90.00
Θ z 0.00

y
x z

6.596E+01

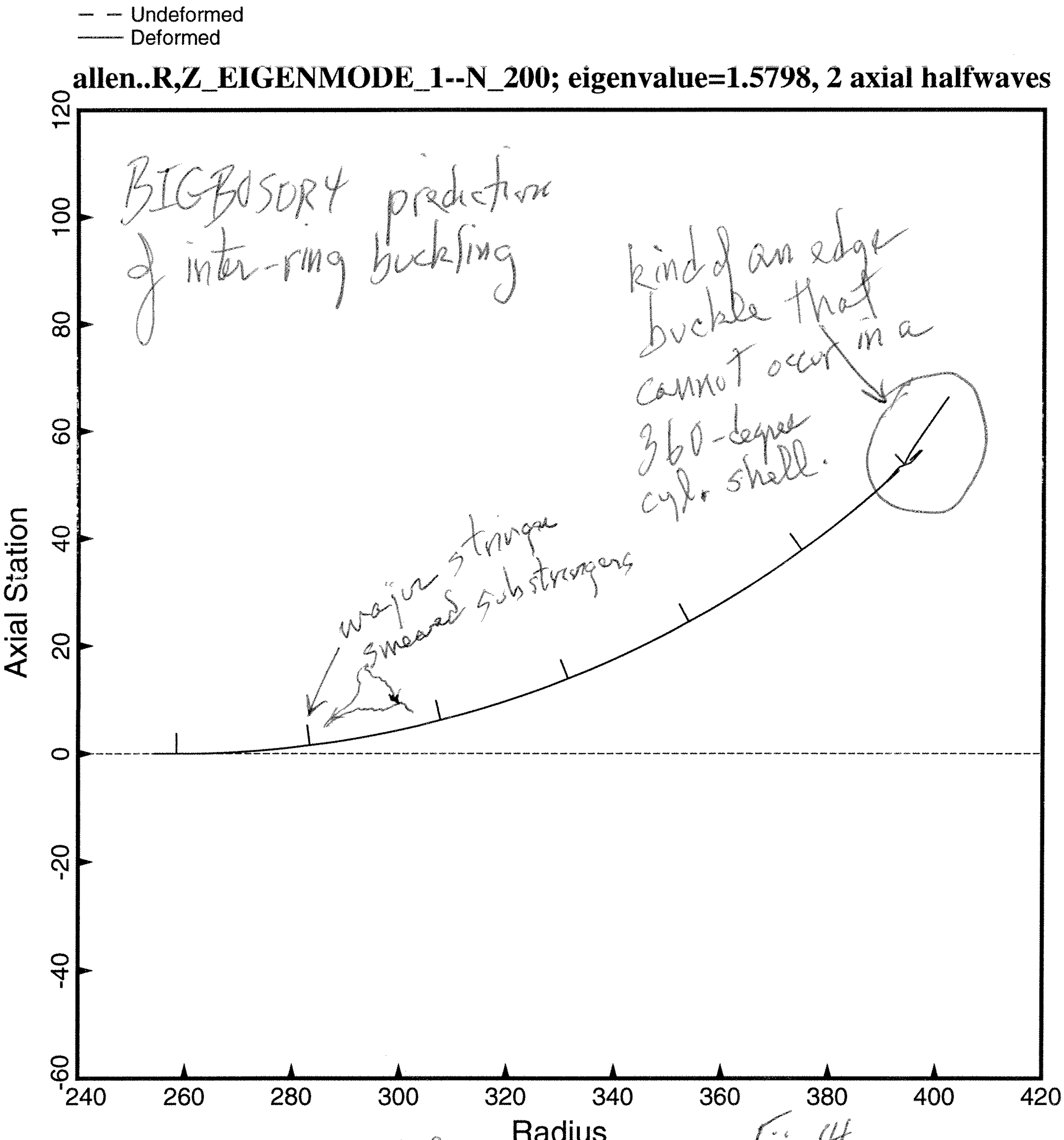
Fig 13

Table 42 allen.PAN

```
   n          $ Do you want a tutorial session and tutorial output?
149.2884      $ Panel length in the plane of the screen, L2
     1        $ Enter control (0 or 1) for stringers at panel edges
     1        $ Enter ILOCAL=0 for panel buckling; 1 for local buckling, ILOCAL
     2        $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
     3        $ How many eigenvalues (get at least 3) do you want?
```

6 major stringer bays.
sub stringers are smeared out.

Buckling is between major rings.



Undeformed
Deformed
allen..R,Z_EIGENMODE_1--N_200; eigenvalue=1.5798, 2 axial halfwaves
Axial Station
Radius
120
100
80
60
40
20
0
-20
-40
-60
240
260
280
300
320
340
360
380
400
420
BIGBOSOR4 prediction of inter-ring buckling
kind of an edge buckle that cannot occur in a 360-degree cyl. shell.
major stringer
smeared substringers

100

Fig. 14