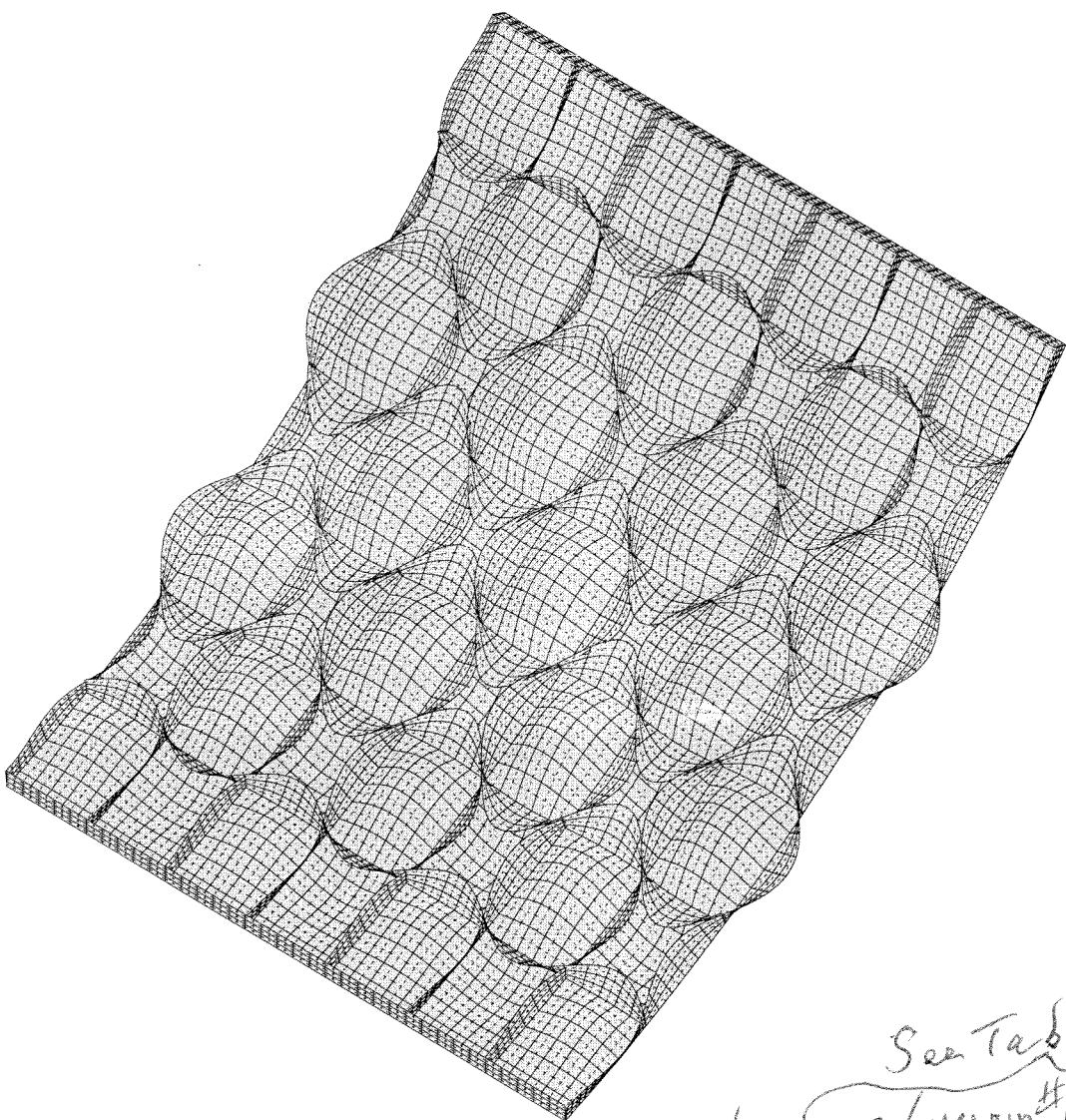


Table 64 allen.pin

linear buckling of perfect shell from STAGS

1	0	1	0	\$PL-2	NPLOT,IPREP,IPRS,KDEV
1		0	4	0	1 \$PL-3 KPOINT,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	

Smeared substringers



solution scale = 0.1058E+02
mode 1, pcr = 0.15626E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

152

PANDA2 gets: 1.33 (margin #1), 1.58 (margin #2),
1.54 (margin #11)
See Table 54

Θ_x -35.84
 Θ_y -179.86
 Θ_z 35.63

3.301E+01

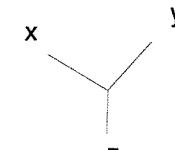
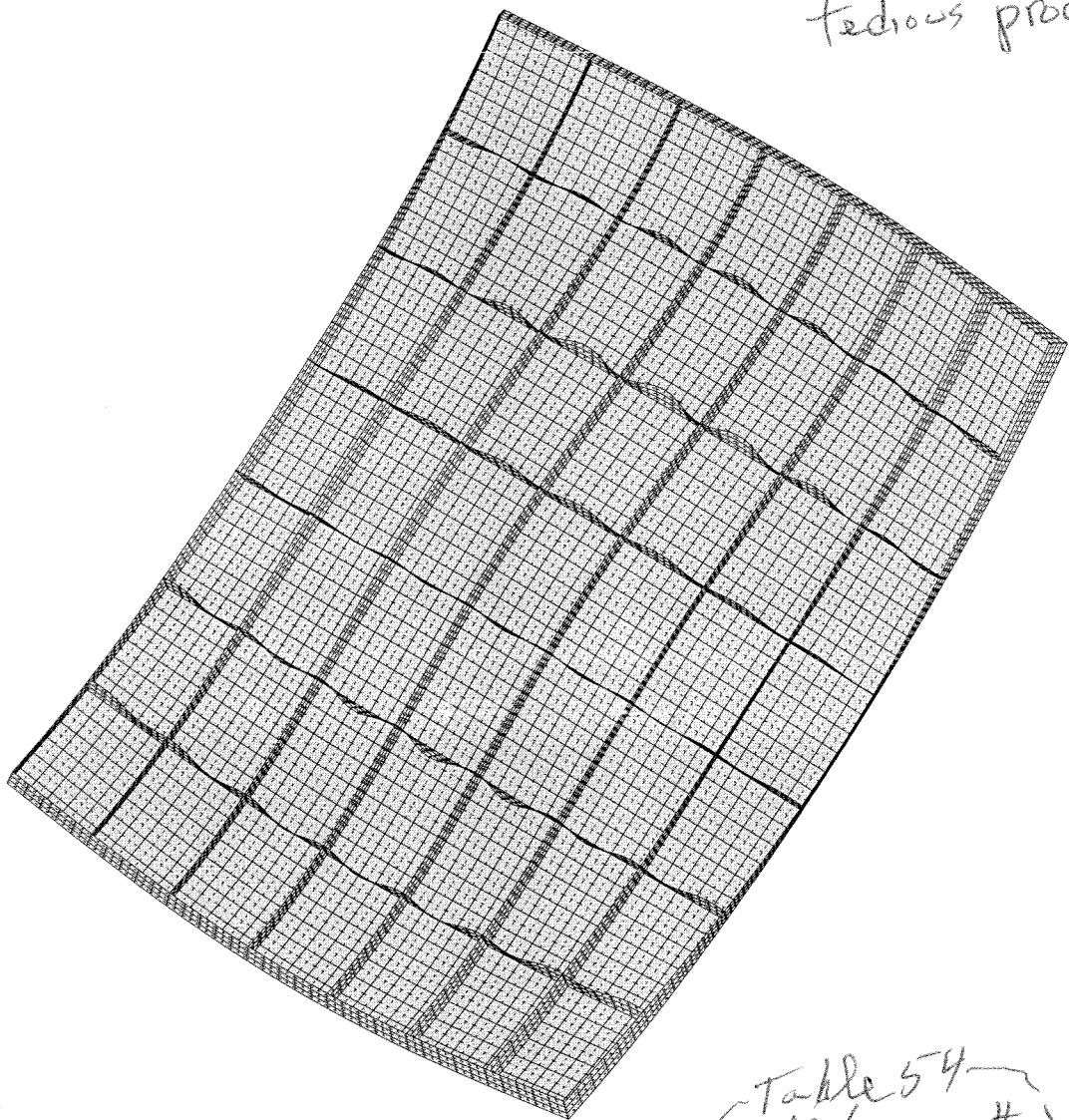


Fig. 27

This general buckling mode is extracted from a "thicket" of local buckling modes. It is a tedious procedure.



72

solution scale = 0.1049E+02
mode λ , pcr = 0.24685E+01

step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

153

PANDA2 gets 2.446 (wgeom #12) ^{Table 54}

Θ_x -35.84
 Θ_y -179.86
 Θ_z 35.63

3.301E+01

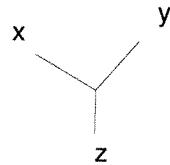
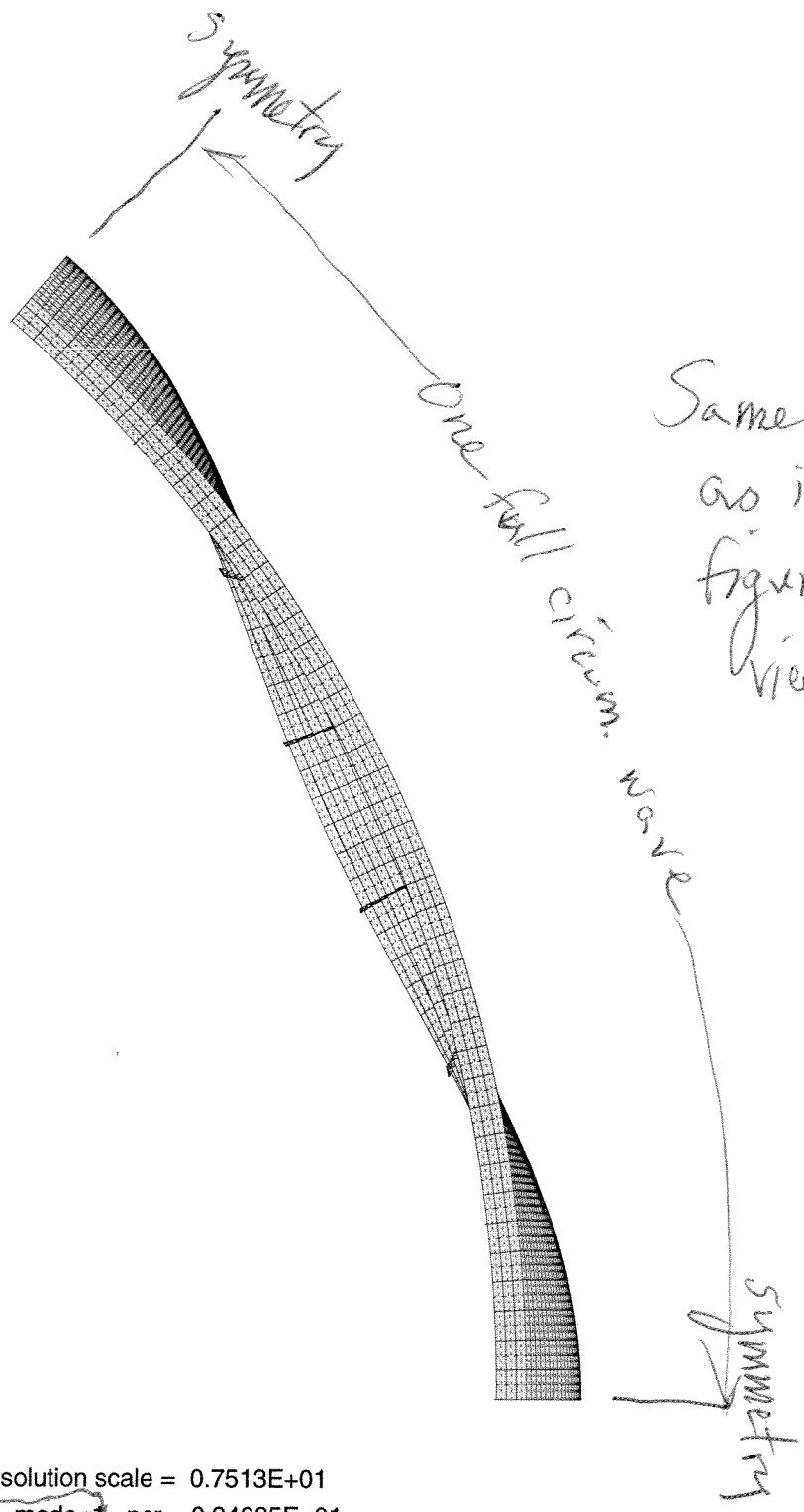


Fig. 28



Same buckling mode
as in the previous
figures, just a different
view of it.

(72)

solution scale = 0.7513E+01
mode 1, pcr = 0.24685E+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

2.504E+01

154

Fig 29

Table 65 allan.bm (INDIC=3)

optimized imperfect shell, nonlinear theory (INDIC=3)
3, \$ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, \$ IPOST=1 means save displacements every IPOSTth step
0, \$ ILIST =0 means normal batch-oriented output
0, \$ ICOR =0 means projection in; 1 means not in.
1, \$ IMPTHE=index for imperfection theory.
0, \$ IOPTIM=0 means bandwith optimization will be performed
0, \$ IFLU =0 means no fluid interaction.
-1 \$ ISOLVR= 0 means original solver; -1 new solver. END B-1 rec.
0.05, \$ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
5.000E-02, \$ 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.
0, \$ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
300, \$ NSEC= number of CPU seconds before run termination
10, \$ NCUT = number of times step size may be cut
-20, \$ NEWT = number of refactorings allowed
-1, \$ NSTRAT=-1 means path length used as independent parameter
0.0001, \$ DELX=convergence tolerance
0. \$ WUND = 0 means initial relaxation factor =1. END D-1 rec.
0, 4, 0 \$ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1

Nonlinear (INDIC=3) STAES analysis

Table 6.6 abridged allen.inp

Abridged allen.inp file for nonlinear analysis of imperfect shell.

```

C Begin B-2 input data...
17, $ NUNITS=number of shell units.           BEGIN B-2 rec.
0, $ NUNITE=number of fastener strips = finite element units
0, $ NSTFS = number of shell units with discrete stiffeners
0, $ NINTS means number of connections between shell units
21, $ NPATS=number of records for partial nodal compatibility
-32, $ NCONST= number of Lagrange constraint conditions
1, $ NIMPFS=number of buckling modal imperfections. ← new value for NIMPFS
0, $ INERT = 0 means no inertial load records
0 $ NINSR = 0 means no crack tip element sets. END B-2 rec.

C
C Begin B-3 input data...
7, $ NTAM = number of entries in material tabl.BEGIN B-3 rec.
5, $ NTAB = number of beam cross section entries
6, $ NTAW = number of entries in shell wall table.
0, $ NTAP = 0 means user parameters not included.
2, $ NTAMT = 2 means two fastener element tables.
1 $ NGCP = 1 means the GCP system will be used. END B-3 rec.

C
C Begin B-4, B-5 input data, if any...
0.500 0 1 1 $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (1st imperf.) ← New record.
C
C Begin F-1 input data (discretization)...
71 85, $ F-1 NROWS( 1), NCOLS( 1) unit 1 = cyl. shell
71 7, $ f-1 strng.web NROWS( 2),NCOLS( 2) Unit 2 stringer no. 1
71 7, $ f-1 strng.web NROWS( 3),NCOLS( 3) Unit 3 stringer no. 2
71 7, $ f-1 strng.web NROWS( 4),NCOLS( 4) Unit 4 stringer no. 3

```

note POSITIVE
imperfection
amplitude

Part of the allen.inp file,
showing the 2 changes that
must be made (from the allen.inp
file automatically produced by STAGSUNIT).

Table 67 (allen.out-14) (5 pages)

Series of STAGS runs to get nonlinear collapse

1. First get the general buckling mode because we wish to use that mode as an initial imperfection shape. We have to make several INDIC = 1 runs with eigenvalue SHIFTS in the neighborhood of 2.46 (Figs. 25 and 26) in order to extract the one general buckling mode among a "thicket" of local buckling modes. This is tedious but it must be done. When we get a general buckling mode, we erase all the STAGS "allen" files, then transfer again the allen.bin and allen.inp files from the directory where we ran STAGSUNIT and edit the allen.bin file to find only one root and to set the eigenvalue shift exactly to the eigenvalue that corresponds to general buckling, that is, SHIFT = 2.4685 (Figs. 28 & 29) in the allen.bin file:

```

1      allen STAGS INPUT FOR STIFFENED CYL. (STAGSUNIT=SHELL UNITS)
2      1, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0, $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ ICHIST=index for crack archive option
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
10     1.000E+00, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     0.000E+00, $ STEP(1) = load factor increment, System A
12     1.000E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment, System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMP =0 means no thermal loads. END C-1 rec.
17     10000, $ NSEC= number of CPU seconds before run termination
18     0., $ DELEV is eigenvalue error tolerance (0=.00001)
19     0 $ IPRT=0 means print modes, iteration data, END D-2 rec.
20     1, $ NEIGS= number of eigenvalues sought. BEGIN D-3 rec.
21     2.4685, $ SHIFT=initial eigenvalue shift
22     0.000E+00, $ EIGA =lower bound of eigenvalue range
23     0.000E+00 $ EIGB =upper bound of eigenvalue range.           END D-3 rec.

```

Abridged allen.out2.1 file:

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 1 CRITICAL LOAD FACTOR COMBINATION				
NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	<u>2.468452E+00</u>	<u>2.468452E+00</u>	<u>0.000000E+00</u>	37498

← general buckling

2. Next, we run a series of STAGS nonlinear equilibrium runs (INDIC=3) of the shell with the general buckling modal imperfection shape. The new allen.bin file is as follows:

```

1      optimized imperfect shell, nonlinear theory (INDIC=3)
2      3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0, $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ IOPTIM=0 means bandwith optimization will be performed
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
10     0.05, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     5.000E-02, $ STEP(1) = load factor increment, System A
12     1.000E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment, System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMP =0 means no thermal loads. END C-1 rec.
17     0, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
18     300, $ NSEC= number of CPU seconds before run termination
19     10, $ NCUT = number of times step size may be cut
20     -20, $ NEWT = number of refactorings allowed
21     -1, $ NSTRAT=-1 means path length used as independent parameter
22     0.0001, $ DELX=convergence tolerance
23     0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
24     0, 4, 0 $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1

```

Table 67 (p. 2 of 5)

The following changes have been made to the allen.inp file:

```

-32, $ NCONST= number of Lagrange constraint conditions
1, $ NIMPFS=number of buckling modal imperfections.           <--NOTE NIMPFS=1
0, $ INERT = 0 means no inertial load records
0 $ NINSR = 0 means no crack tip element sets. END B-2 rec.

C
C Begin B-3 input data...
7, $ NTAM = number of entries in material tabl.BEGIN B-3 rec.
5, $ NTAB = number of beam cross section entries
6, $ NTAW = number of entries in shell wall table.
0, $ NTAP = 0 means user parameters not included.
2, $ NTAMT = 2 means two fastener element tables.
1 $ NGCP = 1 means the GCP system will be used. END B-3 rec.

C
C Begin B-4, B-5 input data, if any...
0.500 0 1 1 $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (1st imperf.) <--NOTE new record

C
C Begin F-1 input data (discretization)...
71 85, $ F-1 NROWS( 1), NCOLS( 1) unit 1 = cyl. shell
-----
```

The abridged allen.out2.2 file is:

CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES				1 THROUGH	3
CRITICAL LOAD FACTOR COMBINATION					
NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF	
1	2.173425E+00	1.443605E+00	0.000000E+00	18105	
2	2.343410E+00	1.520932E+00	0.000000E+00	18177	
3	2.495270E+00	1.590014E+00	0.000000E+00	7911	

(lines skipped to save space)

LIST OF LOAD STEPS AND LOAD FACTORS			
STEP	PA	PB	PX
0	0.500000E-01	0.000000E+00	
1	0.500000E-01	0.000000E+00	
2	0.100000E+00	0.000000E+00	
3	0.137147E+00	0.000000E+00	
4	0.192253E+00	0.000000E+00	
5	0.300071E+00	0.000000E+00	
6	0.454905E+00	0.000000E+00	

← restart here for next run. →

We continue the nonlinear (INDIC=3) process via a STAGS restart.
The new allen.bin file is as follows:

```

1      optimized imperfect shell, nonlinear theory (INDIC=3)
2      3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0 $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ IOPTIM=0 means bandwidth optimization will be performed
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec.
10     0.454905, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     2.000E-01, $ STEP(1) = load factor increment, System A
12     1.000E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment, System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMP =0 means no thermal loads. END C-1 rec.
17     6, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
18     500, $ NSEC= number of CPU seconds before run termination
19     10, $ NCUT = number of times step size may be cut
20     -20, $ NEWT = number of refactorings allowed
21     -1, $ NSTRAT=-1 means path length used as independent parameter
22     0.0001, $ DELX=convergence tolerance
23     0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
24     0, 4, 0 $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1
-----
```

The allen.inp file remains unchanged.

The abridged allen.out2.3 file is:

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Table 67 (p.3 of 5)

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 4
 CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	3.803180E-01	1.380318E+00	0.000000E+00	18105
2	4.622793E-01	1.462279E+00	0.000000E+00	18171
3	5.325614E-01	1.532561E+00	0.000000E+00	18183
4	5.513110E-01	1.551311E+00	0.000000E+00	33405

(lines skipped to save space)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
6	0.454905E+00	0.000000E+00	
7	0.484661E+00	0.000000E+00	
8	0.528448E+00	0.000000E+00	
9	0.613015E+00	0.000000E+00	
10	0.769088E+00	0.000000E+00	
11	0.966649E+00	0.000000E+00	
12	0.100000E+01	0.000000E+00	

← restart here for next run,

We restart the nonlinear STAGS process again. The new `allen.bin` file is:

```

1      optimized imperfect shell, nonlinear theory (INDIC=3)
2      3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0, $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ IOPTIM=0 means bandwith optimization will be performed
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec.
10     1.0, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     1.000E-01, $ STEP(1) = load factor increment, System A
12     1.300E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment, System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMPL =0 means no thermal loads. END C-1 rec.
17     12, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
18     500, $ NSEC= number of CPU seconds before run termination
19     10, $ NCUT = number of times step size may be cut
20     -20, $ NEWT = number of refactorings allowed
21     -1, $ NSTRAT=-1 means path length used as independent parameter
22     0.0001, $ DELX=convergence tolerance
23     0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
24     0, 4, 0 $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1

```

and the abridged `allen.out2.4` file is:

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 4
 CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	2.066259E-02	1.299684E+00	0.000000E+00	13005
2	7.848526E-02	1.373314E+00	0.000000E+00	18165
3	1.367834E-01	1.447549E+00	0.000000E+00	13077
4	1.583768E-01	1.475046E+00	0.000000E+00	18027

← use as a "trigger"
imperfection shape.
Sketch 30.

CP SEC = 668.030. I/O REQSTS = 192828 WORDS USED = 16072818 WORDS TRANSFD = 1.05552»
 E+09

EIGENVECTOR: RUN 4, LOAD STEP 21, PA= 0.127337E+01, PB= 0.000000E+00
 MODE 1, EIG= 0.129968E+01 SAVED ON FILE: allen.evg

(lines skipped to save space)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
12	0.100000E+01	0.000000E+00	
13	0.100321E+01	0.000000E+00	
14	0.100800E+01	0.000000E+00	
15	0.101745E+01	0.000000E+00	
16	0.103586E+01	0.000000E+00	
17	0.107073E+01	0.000000E+00	
18	0.113293E+01	0.000000E+00	
19	0.120857E+01	0.000000E+00	

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Table 67 (p. 4 of 5)

20 0.125240E+01 0.000000E+00
 21 0.127337E+01 0.000000E+00

< Fig. 31 = deformed shape

Next, we want to introduce a second imperfection shape with a very small amplitude, $W_{imp}(2) = 0.01$ inch. The new imperfection shape is shown in Fig. 30. The deformed shell at STEP 21 is shown in Fig. 31.

We start over again at zero applied load factor PA because we now have a new imperfection shape. Therefore, we cannot just continue on from load step 21.

The new allen.inp file now has the following records:

```

2, $ NIMPFS=number of buckling modal imperfections.           <--NOTE: NIMPFS=2
0, $ INERT = 0 means no inertial load records
0 $ NINSR = 0 means no crack tip element sets. END B-2 rec.

C
C Begin B-3 input data...
7, $ NTAM = number of entries in material tabl.BEGIN B-3 rec.
5, $ NTAB = number of beam cross section entries
6, $ NTAW = number of entries in shell wall table.
0, $ NTAP = 0 means user parameters not included.
2, $ NTAMT = 2 means two fastener element tables.
1 $ NGCP = 1 means the GCP system will be used. END B-3 rec.

C
C Begin B-4, B-5 input data, if any...
0.500 0 1 1 $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (1st imperf.)
0.010 21 1 4 $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (2nd imperf.) <--a new record

```

use a small amplitude to serve as a "trigger";

The new allen.bin file is:

```

1      optimized imperfect shell, nonlinear theory (INDIC=3)
2      3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0, $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ IOPTIM=0 means bandwith optimization will be performed
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
10     → 0.05, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     5.000E-02, $ STEP(1) = load factor increment, System A
12     1.000E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment. System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMP =0 means no thermal loads. END C-1 rec.
17     → 0, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
18     1000, $ NSEC= number of CPU seconds before run termination
19     10, $ NCUT = number of times step size may be cut
20     -20, $ NEWT = number of refactorings allowed
21     -1, $ NSTRAT=-1 means path length used as independent parameter
22     0.0001, $ DELX=convergence tolerance
23     0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
24     0, 4, 0 $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1

```

The abridged allen.out2.5 file is:

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 4
 CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	3.833289E-01	1.383329E+00	0.000000E+00	18105
2	4.634797E-01	1.463480E+00	0.000000E+00	18039
3	5.340324E-01	1.534032E+00	0.000000E+00	18183
4	5.541275E-01	1.554127E+00	0.000000E+00	28305

(lines skipped to save space)

LIST OF LOAD STEPS AND LOAD FACTORS
 STEP PA PB PX
 0 0.500000E-01 0.000000E+00
 1 0.500000E-01 0.000000E+00
 2 0.100000E+00 0.000000E+00

Table 67 (p.5 of 5)

```

3 0.137149E+00 0.000000E+00
4 0.192260E+00 0.000000E+00
5 0.300097E+00 0.000000E+00
6 0.454981E+00 0.000000E+00
7 0.668360E+00 0.000000E+00
8 0.935174E+00 0.000000E+00
9 0.100000E+01 0.000000E+00

```

← restart here]

A nonlinear STAGS restart...

The new allen.bin file:

```

1      optimized imperfect shell, nonlinear theory (INDIC=3)
2      3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
3      1, $ IPOST=1 means save displacements every IPOSTth step
4      0, $ ILIST =0 means normal batch-oriented output
5      0, $ ICOR =0 means projection in; 1 means not in.
6      1, $ IMPTHE=index for imperfection theory.
7      0, $ IOPTIM=0 means bandwith optimization will be performed
8      0, $ IFLU =0 means no fluid interaction.
9      -1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
10     1.0, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
11     1.000E-01, $ STEP(1) = load factor increment, System A
12     1.500E+00, $ FACM(1) = maximum load factor, System A
13     0.000E+00, $ STLD(2) = starting load factor, System B
14     0.000E+00, $ STEP(2) = load factor increment, System B
15     0.000E+00, $ FACM(2) = maximum load factor, System B
16     0 $ ITEMP =0 means no thermal loads. END C-1 rec.
17     9, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
18     1000, $ NSEC= number of CPU seconds before run termination
19     10, $ NCUT = number of times step size may be cut
20     -20, $ NEWT = number of refactorings allowed
21     -1,$ NSTRAT=-1 means path length used as independent parameter
22     0.0001,$ DELX=convergence tolerance
23     0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
24     0, 4, 0 $ NPATH=0: Riks method, NEIGS=no.of eigs, NSOL=0: contin. ET-1

```

The abridged allen.out2.6 file...

STEP	PA	PB	PX
9	0.100000E+01	0.000000E+00	
10	0.100604E+01	0.000000E+00	
11	0.101498E+01	0.000000E+00	
12	0.103241E+01	0.000000E+00	
13	0.106548E+01	0.000000E+00	
14	0.112456E+01	0.000000E+00	
15	0.119552E+01	0.000000E+00	
16	0.125772E+01	0.000000E+00	
17	0.128112E+01	0.000000E+00	
18	0.128143E+01	0.000000E+00	<i>collapse load</i>
19	0.126790E+01	0.000000E+00	
20	0.123818E+01	0.000000E+00	
21	0.123237E+01	0.000000E+00	<i>Figs.32 & 33 & 34 & 35</i>

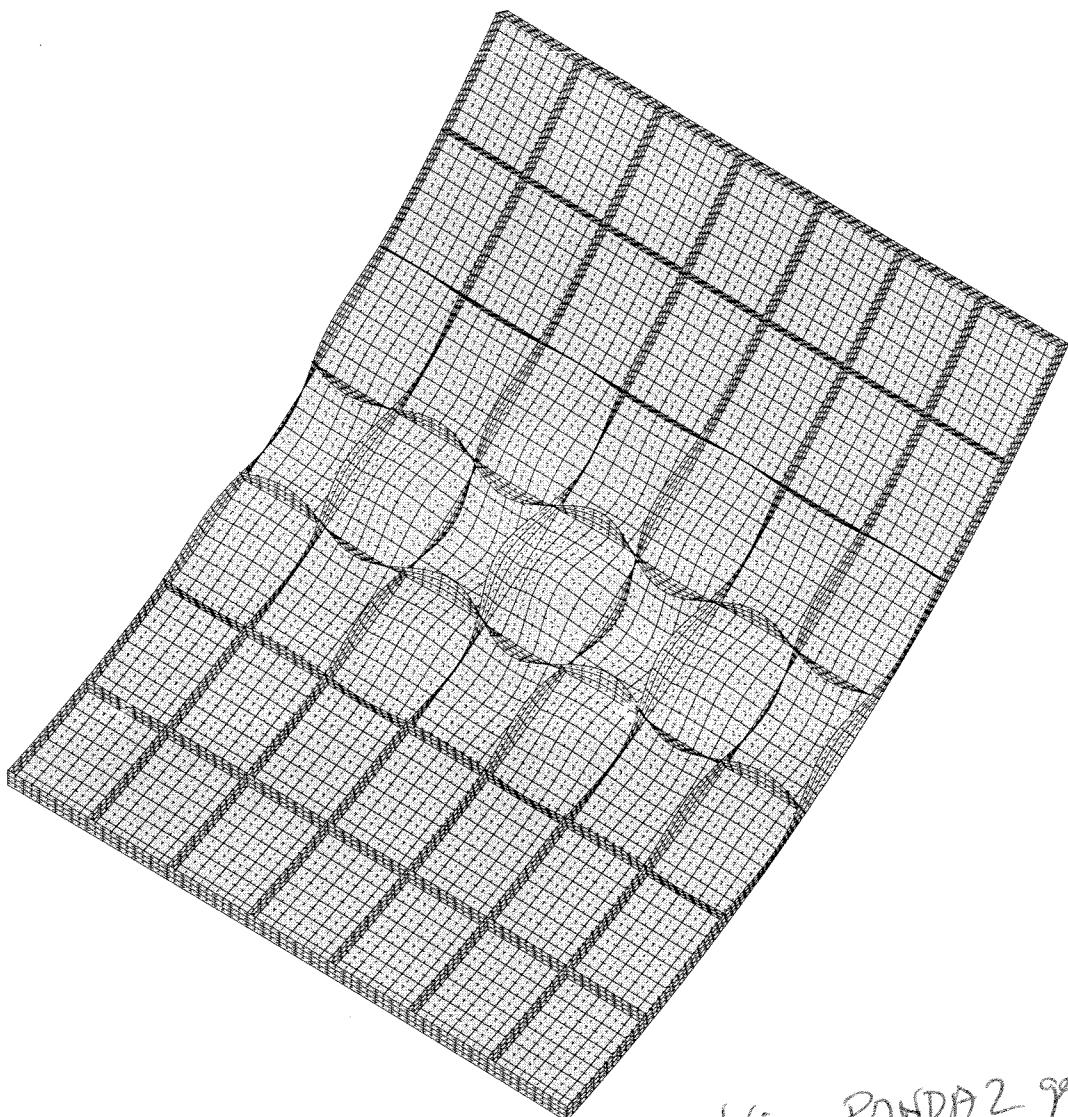
post-collapse state

Table 68 allen.pin

nonlinear buckling of imperfect shell from STAGS

1	0	1	0	\$PL-2	NPLOT,IPREP,IPRS,KDEV
1		0	4	21	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	

Nonlinear "local" buckling



solution scale = 0.1054E+02

mode 1, pcr = 0.12997E+01

step 21 eigenvector deformed geometry

nonlinear buckling of imperfect shell from STAGS

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nonlinear buckling: PANDA2 gets 1.312
(see margin #1 in
Table 5.2)

$\Theta_x -35.84$
 $\Theta_y -179.86$
 $\Theta_z 35.63$

3.301E+01

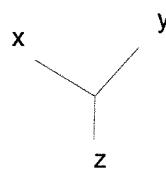


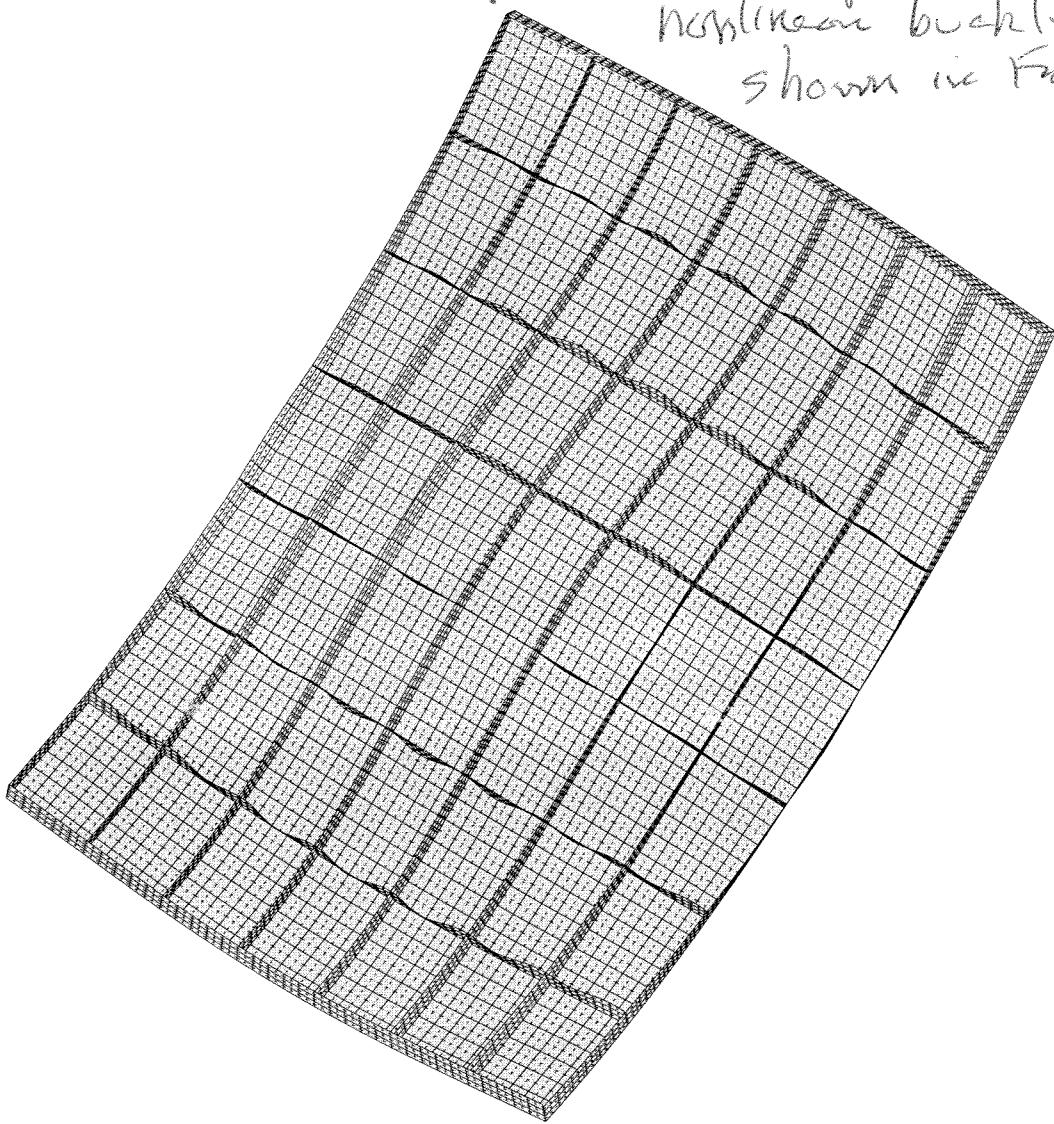
Fig. 30

Table 69 allen.pin

STAGS model: nonlinear deformation, same view as linear buckling modes

```
1 0 1 0 $PL-2 NPLOT,IPREP,IPRS,KDEV
1 0 1 21 0 0 0 3 $PL-3 KPLOT,VIEW,ITEM,STEP,MODE,IFRNG,COLOR,ICOMP
0.0 3 0.0 0.0 0.0 $PL-5 DSCALE,NROTS,LWSCALE,RNGMIN,RGMAX
1 -35.84 $PL-6 IROT,ROT
2 180.14 $PL-6 IROT,ROT
3 35.63 $PL-6 IROT,ROT
```

Nonlinear deformation at the load step that corresponds to the nonlinear buckling mode shown in Fig. 30,



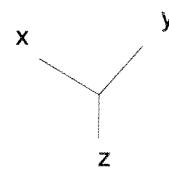
solution scale = 0.1473E+02

PA= 1.27337E+00 PB= 0.00000E+00 PX= 0.00000E+00

step 21 displacement deformed geometry

STAGS model: nonlinear deformation, same view as linear buckling modes

$\Theta_x -35.84$
 $\Theta_y -179.86$
 $\Theta_z 35.63$



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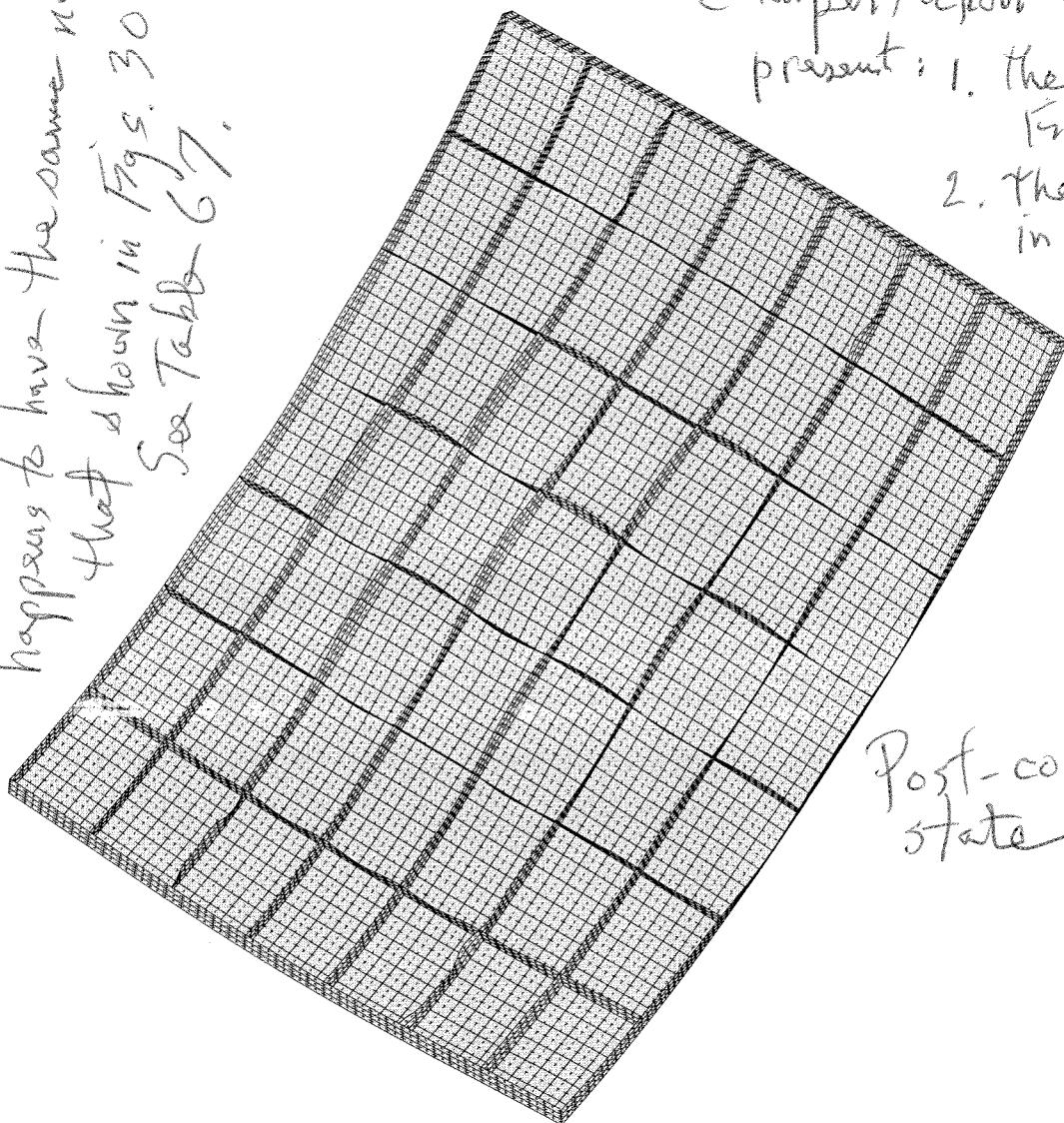
3.301E+01

Fig. 31

It's just a coincidence that this load step happens to have the same number as that shown in Figs. 30 & 31.
See Table 67.

Nonlinear deformations when

- 2 imperfection modes are present:
1. the mode shown in Fig. 28, $w_{imp} = 0.5$
 2. the mode shown in Fig. 30, ~~$w_{imp} = 0.01$~~



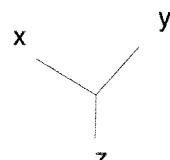
solution scale = 0.4579E+01

PA= 1.23237E+00 PB= 0.00000E+00 PX= 0.00000E+00

step 21 displacement deformed geometry

STAGS model: nonlinear deformation, same view as linear buckling modes

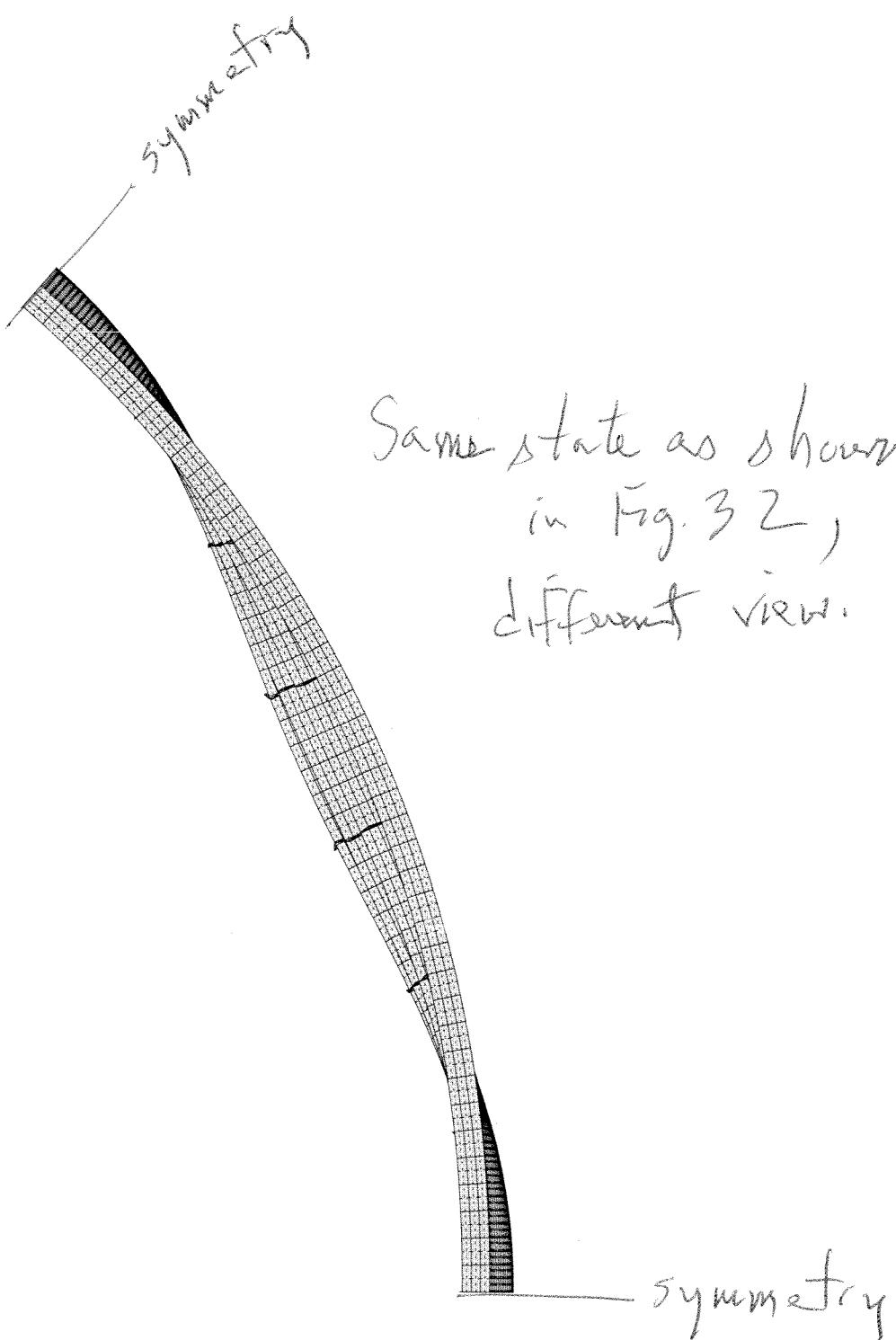
$\Theta_x -35.84$
 $\Theta_y -179.86$
 $\Theta_z 35.63$



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3.301E+01

Fig. 32



solution scale = 0.3512E+01

PA= 1.23237E+00 PB= 0.00000E+00 PX= 0.00000E+00

step 21 displacement deformed geometry

STAGS model: nonlinear deformation, same view as linear buckling modes

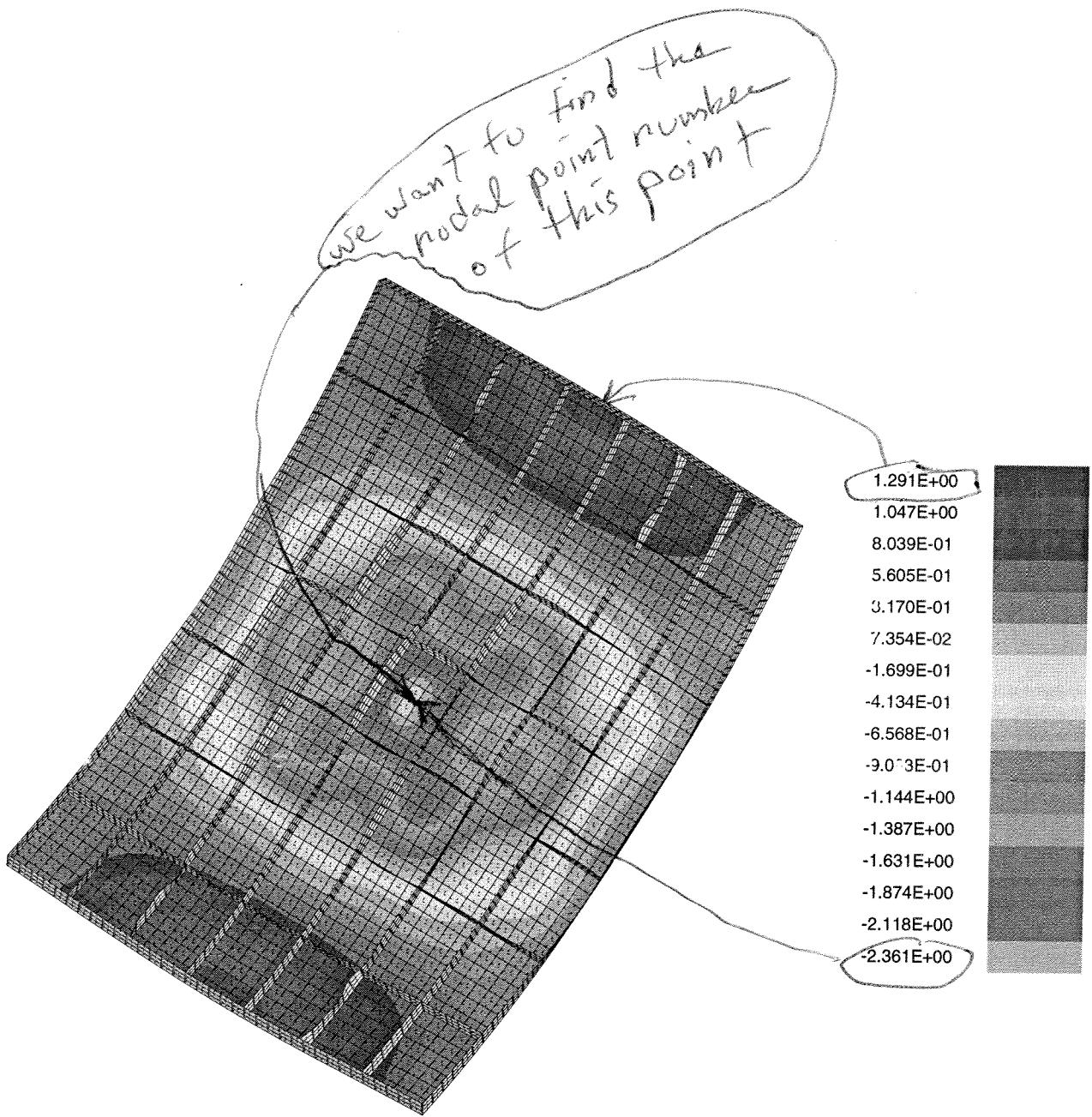
Θ_x 0.00
 Θ_y 90.00
 Θ_z 0.00

y
x z

2.511E+01

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Fig. 33



solution scale = 0.4579E+01

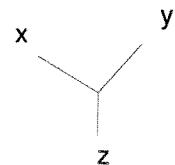
PA= 1.23237E+00 PB= 0.00000E+00 PX= 0.00000E+00

step 21 displacement w contours

nonlinear w same view as linear buckling mode

Minimum value = -2.36107E+00, Maximum value = 1.29085E+00

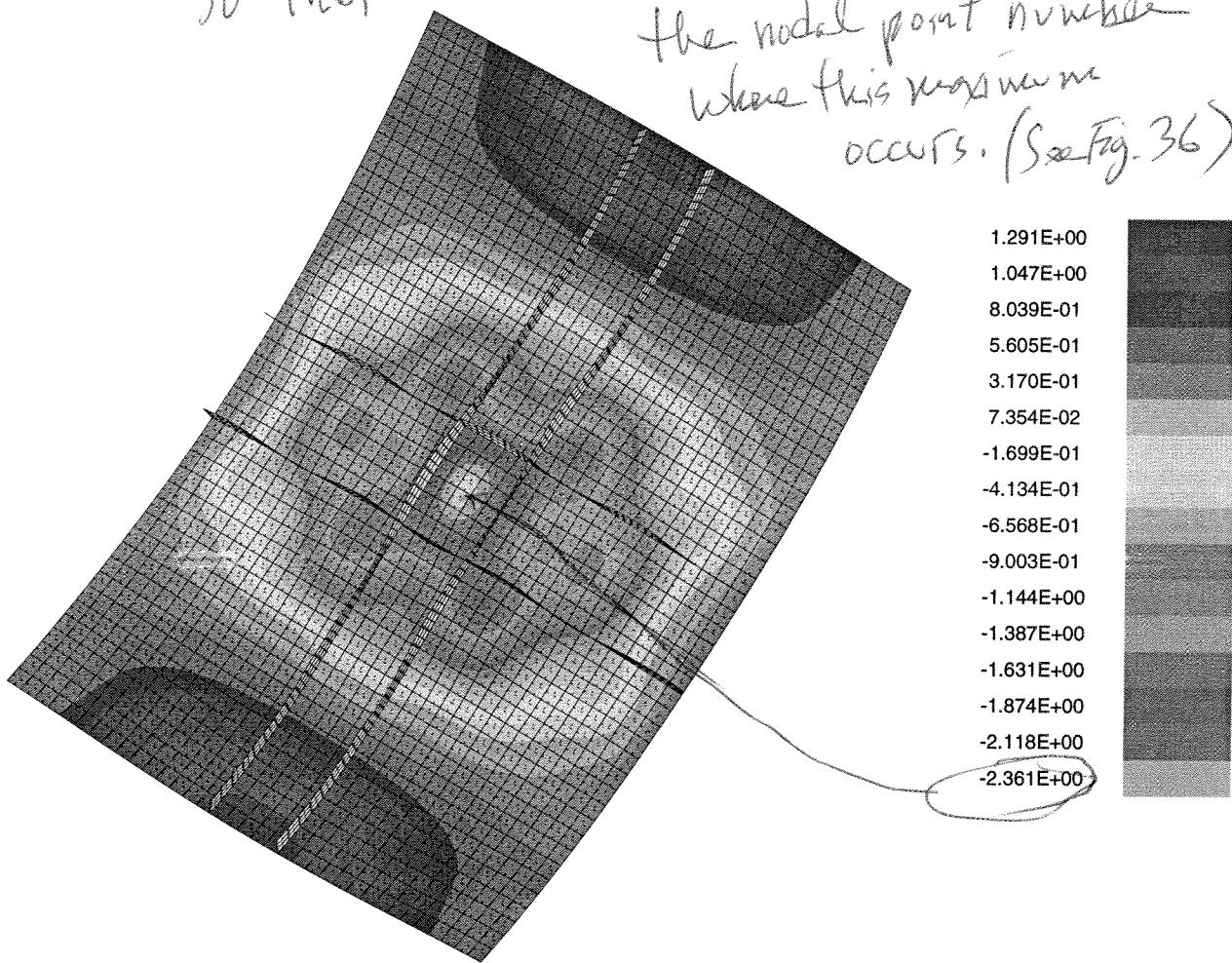
Θ_x -35.84
 Θ_y -179.86
 Θ_z 35.63



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Fig. 34

We plot only two stringers and
 two rings nearest the point of
 maximum (negative) normal deflection
 so that we can easily determine
 the nodal point number
 where this maximum
 occurs. (See Fig. 36)



solution scale = 0.4579E+01

PA= 1.23237E+00 PB= 0.00000E+00 PX= 0.00000E+00

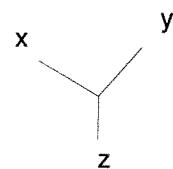
step 21 displacement w contours

nonlinear w same view as linear buckling mode

Minimum value = -2.36107E+00, Maximum value = 1.29085E+00

Θ_x -35.84
 Θ_y -179.86
 Θ_z 35.63

3.770E+01

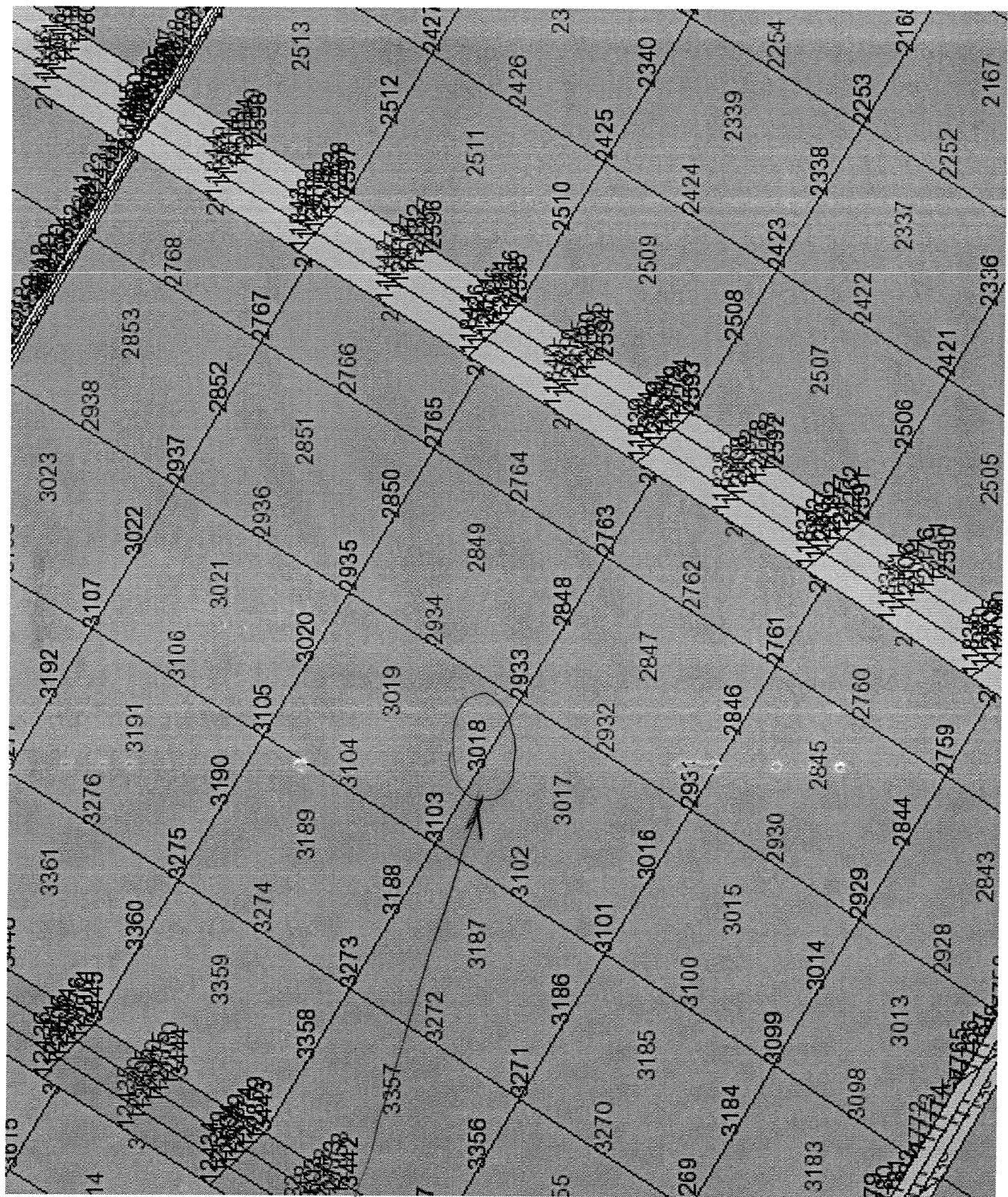


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Fig. 35

Table 70 allen.pin

nodal pts									
1	0	0	0	\$PL-2	NPLOT,IPREP,IPRS,KDEV				
	0		5	6	\$PL-3	KPLOT,VIEW,ITEM			
1	5	6	13	14					
0.0	3	0.0	0.0	0.0	\$PL-5	DSCALE,NROTS,LWSCALE,RNGMIN,RGMAX			
1	-35.84		\$PL-6	IROT,ROT					
2	180.14		\$PL-6	IROT,ROT					
3	35.63		\$PL-6	IROT,ROT					



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Max. (negative) normal deflection occurs here.

Fig. 36

Table 71 allen.pxy

P \$ (P) lotps or (S)pread_Sheet output
allen \$ STAGS solution 'Case Name'
F \$ (F)ull or (C)ondensed Model
Y \$ (Y)es-(N)o: setup data for another plot
5 \$ x-axis variable = choice (1 to 15)
3 \$ node no. (0 = ask for Unit,Row,Col)
S \$ comp no., dis,vel,acc (1-6) = u,v,w,ru,rv,rw
N \$ (G)lobal or (S)hell ref surface
N \$ (Y)es-(N)o: specify x-variable scale factor
2 \$ y-axis variable = choice (1 to 15)
N \$ (Y)es-(N)o: specify y-variable scale factor
N \$ (Y)es-(N)o: specify subrange of loadsteps
Y \$ (Y)es-(N)o: plotted points start at origin
N \$ (Y)es-(N)o: setup data for another plot

3018

Input to xytrans

See Fig. 36

(xytrans is one of the
STAGS postprocessors.)

Table 72 allen.plt

"Disp(3018,w,L) vs. load_PA	
0.000000E+00	0.000000E+00
-6.062267E-03	5.000000E-02
-1.267012E-02	1.000000E-01
-1.795808E-02	1.371490E-01
-2.644285E-02	1.922598E-01
-4.551424E-02	3.000967E-01
-7.981193E-02	4.549815E-01
-1.454831E-01	6.683604E-01
-2.799166E-01	9.351743E-01
-3.285631E-01	1.000000E+00
-3.336133E-01	1.006040E+00
-3.412620E-01	1.014979E+00
-3.568573E-01	1.032408E+00
-3.893023E-01	1.065477E+00
-4.599832E-01	1.124563E+00
-5.866479E-01	1.195516E+00
-8.418592E-01	1.257721E+00
-1.168232E+00	1.281121E+00
-1.505615E+00	1.281428E+00
-1.878039E+00	1.267902E+00
-2.299847E+00	1.238176E+00
-2.361071E+00	1.232369E+00

} output from xytrans

} we next incorporate these
data or into the file, allen.input,
listed in Table 73.

Table 73 allen.input

```
# Global directives, load-deflection curve for imperfect shell
=title(Load-deflection curve for shell with +0.5-inch imperfection)
=xlabel(normal displacement w (inches))
=ylabel(Load factor PA for axial compression)
# data set 1 Load-normal-deflection curve for shell with +0.5-inch imperfection.
+legend(STAGS Load-normal-deflection curve for shell with +0.5-inch imperfection. Node 3018)
+setmarker(0)
 0.000000E+00 0.000000E+00
-6.062267E-03 5.000000E-02
-1.267012E-02 1.000000E-01
-1.795808E-02 1.371490E-01
-2.644285E-02 1.922598E-01
-4.551424E-02 3.000967E-01
-7.981193E-02 4.549815E-01
-1.454831E-01 6.683604E-01
-2.799166E-01 9.351743E-01
-3.285631E-01 1.000000E+00
-3.336133E-01 1.006040E+00
-3.412620E-01 1.014979E+00
-3.568573E-01 1.032408E+00
-3.893023E-01 1.065477E+00
-4.599832E-01 1.124563E+00
-5.866479E-01 1.195516E+00
-8.418592E-01 1.257721E+00
-1.168232E+00 1.281121E+00
-1.505615E+00 1.281428E+00
-1.878039E+00 1.267902E+00
-2.299847E+00 1.238176E+00
-2.361071E+00 1.232369E+00
```

give the command:

/home/progs/bin/plotps.linux < allen.input > allen.ps

to get the plot in Fig. 37.

`allen.ps` = output from the long command given on the previous page.

- STAGS Load-normal-deflection curve for shell with +0.5-inch imperfection. Node 3018

Load-deflection curve for shell with +0.5-inch imperfection

