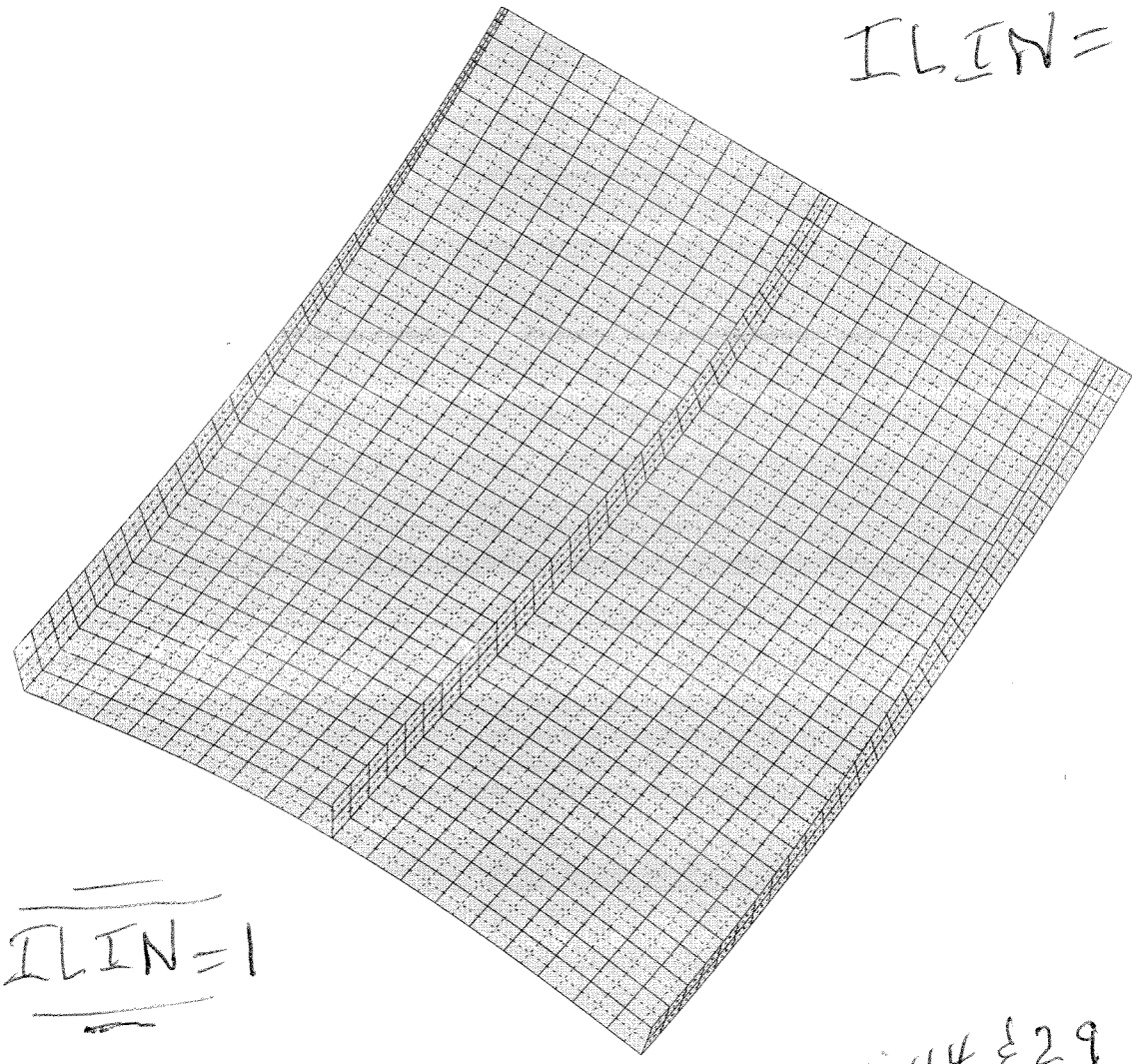
GENERAL BUCKLING

Compare with Fig. 29

ILIN=1



ILIN=1

compare with Figs 44 & 29

solution scale = 0.1737E+01

mode 2, pcr = 0.26044E+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

5.514E+00

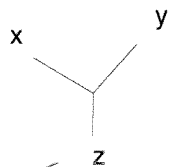
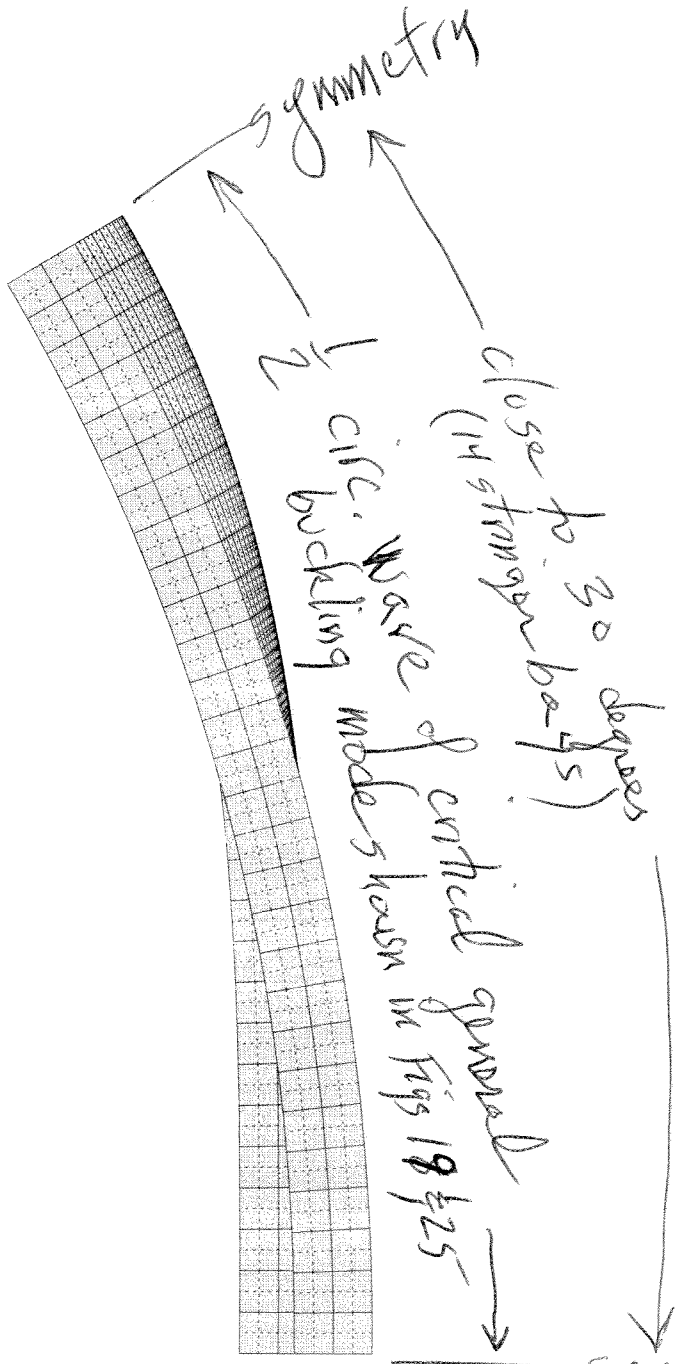


Fig 37



Compare with Figs. 19 & 25

solution scale = 0.1239E+01
mode 2, pcr = 0.26044E+01 ← Compare with Figs. 45, 19, 25
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

4.131E+00

Fig. 38

Table 47 nasaortho.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
1.000000    $ Local buckling load factor from PANDA2, EIGLOC
y           $ Are the dimensions in this case in inches?
1           $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
0           $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
22.916667   $ X-direction length of the STAGS model of the panel: XSTAGS
26.063582   $ 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
-2219       $ 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
1.000000    $ Starting load factor for Load System A, STLD(1)
0.000000    $ Load factor increment for Load System A, STEP(1)
1.000000    $ 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)
1           $ 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?
162         $ Number of stringers in STAGS model of 360-deg. cylinder
3           $ Number of rings in the STAGS model of the panel
y           $ Are there rings at the ends of the panel?
2           $ Number of finite elements between adjacent stringers
9           $ 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"?
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?
y           $ Do you want to use the "least-squares" model for torque?
y           $ Is stiffener sidesway permitted at the panel edges?
y           $ Do you want symmetry conditions along the straight edges?
0           $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

note → n

note

Input for STAGSUNIT

2 ring bays x 14 stringer bays

All stiffeners are shell units.

Linear buckling

Table 48 (4 pages) Search for general buckling with the 2 bay x 14 bay STAGS model with all stiffeners as branches (shell units)

nasaortholin1.small.out2.all

OUTPUT FROM STAGS FOR LINEAR BUCKLING RUNS
IN SEARCH OF THE GENERAL BUCKLING MODE AND
LOAD FACTOR: ILIN = 1. STAGS 30-DEGREE x 2-RING-BAY MODEL
==========

1 nasaortho.out2 (small model)

22	1	0.24427382E+01	0.13316948E-11	0.24427382E+01
22	2	0.24175858E+01	0.20549451E-08	0.24175858E+01
22	3	0.24475467E+01	0.14475322E-07	0.24475467E+01
22	4	0.24498362E+01	0.70551030E-09	0.24498362E+01
22	5	0.24120617E+01	0.84000775E-06	0.24120617E+01
22	6	0.24117373E+01	0.15269065E-06	0.24117373E+01
22	7	0.24105387E+01	0.28112078E-05	0.24105386E+01
22	8	0.24090183E+01	0.20324197E-03	0.24090138E+01
22	9	0.24547783E+01	0.12381262E-04	0.24547786E+01

STAGS run #

shift = 2.4314, 89 negative roots
MAXIMUM NUMBER OF ITERATIONS
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 7
CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES 8 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root	
1	2.409018E+00	2.409018E+00	0.000000E+00	16137	<--not converged
2	2.410539E+00	2.410539E+00	0.000000E+00	14361 86	
3	2.411737E+00	2.411737E+00	0.000000E+00	14361 87	
4	2.412062E+00	2.412062E+00	0.000000E+00	17433 88	
5	2.417586E+00	2.417586E+00	0.000000E+00	21369 89	
6	2.442738E+00	2.442738E+00	0.000000E+00	3189 90	
7	2.447547E+00	2.447547E+00	0.000000E+00	3333 91	
8	2.449836E+00	2.449836E+00	0.000000E+00	19593 92	

Note: In STAGS output the string "CONVERGENCE HAS BEEN OBTAINED..." refers to the eigenvalue list above and not following.

---

2 nasaortho.out2 (abridged, small model)
shift = 2.39, 80 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.398368E+00	2.398368E+00	0.000000E+00	25017 81
2	2.398650E+00	2.398650E+00	0.000000E+00	15849 82
3	2.402000E+00	2.402000E+00	0.000000E+00	14169 83
4	2.402574E+00	2.402574E+00	0.000000E+00	9711 84
5	2.409019E+00	2.409019E+00	0.000000E+00	25017 85
6	2.410539E+00	2.410539E+00	0.000000E+00	25017 86
7	2.411737E+00	2.411737E+00	0.000000E+00	18033 87
8	2.412062E+00	2.412062E+00	0.000000E+00	24537 88

---

3 nasaortho.out2 (abridged, small model)

22	1	0.23639292E+01	0.11557963E-10	0.23639292E+01
22	2	0.23585949E+01	0.10816903E-07	0.23585949E+01
22	3	0.23512055E+01	0.24574852E+01	0.23050182E+01
22	4	0.23479184E+01	0.21060781E-07	0.23479184E+01
22	5	0.23471349E+01	0.23290586E-05	0.23471349E+01
22	6	0.23459589E+01	0.42208933E-06	0.23459590E+01
22	7	0.23947179E+01	0.16626608E+01	0.24358155E+01
22	8	0.23983684E+01	0.53768590E-05	0.23983682E+01
22	9	0.23986545E+01	0.35982442E-03	0.23986442E+01
22	10	0.24020066E+01	0.31509198E-02	0.24021074E+01
22	18	0.23120875E+01	0.19009423E+01	0.24221758E+01

shift = 2.37, 80 negative roots
MAXIMUM NUMBER OF ITERATIONS
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 2
CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES 3 THROUGH 8

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root	
1	2.345959E+00	2.345959E+00	0.000000E+00	21321 76	
2	2.347135E+00	2.347135E+00	0.000000E+00	9663 77	
3	2.347918E+00	2.347918E+00	0.000000E+00	9147 78	
4	2.351205E+00	2.351205E+00	0.000000E+00	19017	<--not converged
5	2.358595E+00	2.358595E+00	0.000000E+00	18369 79	
6	2.363929E+00	2.363929E+00	0.000000E+00	22905 80	
7	2.394718E+00	2.394718E+00	0.000000E+00	20481	<--not converged
8	2.398368E+00	2.398368E+00	0.000000E+00	13593 81	

---

4 nasaortho.out2 (abridged, small model)

All are linear buckling STAGS runs

Table 48 (p2 of 4)

	22	1	0.23135221E+01	0.68554723E-13	0.23135221E+01
	22	2	0.23116394E+01	0.27620699E-11	0.23116394E+01
	22	3	0.23295307E+01	0.14444588E-11	0.23295307E+01
	22	4	0.23332318E+01	0.37572877E-09	0.23332318E+01
	22	5	0.23345160E+01	0.12522988E-08	0.23345160E+01
	22	6	0.23036932E+01	0.28434377E-09	0.23036932E+01
	22	7	0.22996633E+01	0.13179013E-05	0.22996633E+01
	22	8	0.23412290E+01	0.16975002E+01	0.23772653E+01
root 68	22	9	0.22980984E+01	0.46613581E-04	0.22980994E+01
root 76	22	10	0.23459586E+01	0.51892833E-04	0.23459599E+01

shift = 2.32, 72 negative roots
MAXIMUM NUMBER OF ITERATIONS
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 7

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.299663E+00	2.299663E+00	0.000000E+00	9879 69
2	2.303693E+00	2.303693E+00	0.000000E+00	24441 70
3	2.311639E+00	2.311639E+00	0.000000E+00	24969 71
4	2.313522E+00	2.313522E+00	0.000000E+00	19353 72
5	2.329531E+00	2.329531E+00	0.000000E+00	4359 73
6	2.333232E+00	2.333232E+00	0.000000E+00	19449 74
7	2.334516E+00	2.334516E+00	0.000000E+00	24777 75

---

5 nasaortho.out2 (abridged, small model)
shift = 2.500, 101 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.472246E+00	2.472246E+00	0.000000E+00	24393 97
2	2.488872E+00	2.488872E+00	0.000000E+00	1647 98
3	2.490547E+00	2.490547E+00	0.000000E+00	14025 99
4	2.490646E+00	2.490646E+00	0.000000E+00	3285 100
5	2.491972E+00	2.491972E+00	0.000000E+00	1431 101
6	2.506464E+00	2.506464E+00	0.000000E+00	4899 102
7	2.517371E+00	2.517371E+00	0.000000E+00	10395 103
8	2.523152E+00	2.523152E+00	0.000000E+00	3627 104

---

6 nasaortho.out2 (abridged, small model)

22	1	0.24279899E+01	0.10688771E+02	0.25029192E+01
22	2	0.24427382E+01	0.15322904E-10	0.24427382E+01
22	3	0.24475467E+01	0.10470278E-07	0.24475467E+01
22	4	0.24498362E+01	0.39781097E-06	0.24498362E+01
22	5	0.24175858E+01	0.84245941E-07	0.24175858E+01
22	6	0.24547756E+01	0.14322814E-03	0.24547784E+01
22	7	0.24562682E+01	0.18745618E-05	0.24562682E+01
22	8	0.24576316E+01	0.37315150E+00	0.24491866E+01
22	9	0.24120617E+01	0.19045637E-04	0.24120613E+01
22	10	0.24117425E+01	0.93352906E-03	0.24117208E+01
22	11	0.24105346E+01	0.31465079E-04	0.24105338E+01

shift = 2.435, 89 negative roots
MAXIMUM NUMBER OF ITERATIONS
CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES 1 THROUGH 7

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF	
1	2.417586E+00	2.417586E+00	0.000000E+00	24033 89	
2	2.427990E+00	2.427990E+00	0.000000E+00	24345	<--not convergec
3	2.442738E+00	2.442738E+00	0.000000E+00	9345 90	
4	2.447547E+00	2.447547E+00	0.000000E+00	3333 91	
5	2.449836E+00	2.449836E+00	0.000000E+00	19017 92	
6	2.454776E+00	2.454776E+00	0.000000E+00	14121	<--questionable convergence
7	2.456268E+00	2.456268E+00	0.000000E+00	4383 93	

---

7 nasaortho.out2 (abridged, small model) search for roots 94,95,96
shift = 2.46, 94 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.442738E+00	2.442738E+00	0.000000E+00	9345 90
2	2.447546E+00	2.447546E+00	0.000000E+00	9321 91
3	2.449836E+00	2.449836E+00	0.000000E+00	19593 92
4	2.454778E+00	2.454778E+00	0.000000E+00	18561 93
5	2.456268E+00	2.456268E+00	0.000000E+00	4383 94
6	2.465565E+00	2.465565E+00	0.000000E+00	3531 95
7	2.465628E+00	2.465628E+00	0.000000E+00	24801 96
8	2.472246E+00	2.472246E+00	0.000000E+00	24393 97

Table 48 (p. 3 of 4)

8 nasaortho.out2 (abridged, small model)

22	1	0.25443492E+01	0.00000000E+00	0.25443492E+01
22	2	0.25308864E+01	0.11694743E-10	0.25308864E+01
22	3	0.25279172E+01	0.22075094E-08	0.25279172E+01
22	4	0.25268352E+01	0.46054325E+01	0.24662056E+01
22	5	0.25231521E+01	0.71667965E-08	0.25231521E+01
22	6	0.25173715E+01	0.20905184E-06	0.25173715E+01
22	7	0.25690387E+01	0.12033789E-04	0.25690391E+01
22	8	0.25712657E+01	0.65702874E-05	0.25712659E+01
22	9	0.25064639E+01	0.36435485E-07	0.25064639E+01

shift = 2.54, 106 negative roots
MAXIMUM NUMBER OF ITERATIONS
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 3
CONVERGENCE CRITERION HAS NOT BEEN SATISFIED FOR EIGENVALUES 4 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root	
1	2.517371E+00	2.517371E+00	0.000000E+00	2187 103	
2	2.523152E+00	2.523152E+00	0.000000E+00	3627 104	
3	2.526835E+00	2.526835E+00	0.000000E+00	24297	<--not converged
4	2.527917E+00	2.527917E+00	0.000000E+00	18297 105	
5	2.530886E+00	2.530886E+00	0.000000E+00	19689 106	
6	2.544349E+00	2.544349E+00	0.000000E+00	19593 107	
7	2.569039E+00	2.569039E+00	0.000000E+00	14577 108	
8	2.571266E+00	2.571266E+00	0.000000E+00	10323 109	

---

9 nasaortho.out2 (abridged, small model)
shift = 2.60, 116 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.579470E+00	2.579470E+00	0.000000E+00	11079 111
2	2.581129E+00	2.581129E+00	0.000000E+00	19593 112
3	2.583110E+00	2.583110E+00	0.000000E+00	9147 113
4	2.584421E+00	2.584421E+00	0.000000E+00	3507 114
5	2.589644E+00	2.589644E+00	0.000000E+00	19545 115
6	2.593433E+00	2.593433E+00	0.000000E+00	19545 116
7	2.620100E+00	2.620100E+00	0.000000E+00	19545 117
8	2.623368E+00	2.623368E+00	0.000000E+00	24801 118

---

10 nasaortho.out2 (abridged, small model) (go back and capture root 110)
shift = 2.57, 108 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.569037E+00	2.569037E+00	0.000000E+00	21369 108
2	2.571266E+00	2.571266E+00	0.000000E+00	10371 109
3	2.576342E+00	2.576342E+00	0.000000E+00	1575 110
4	2.579470E+00	2.579470E+00	0.000000E+00	11079 111
5	2.581129E+00	2.581129E+00	0.000000E+00	19017 112
6	2.583111E+00	2.583111E+00	0.000000E+00	9147 113
7	2.584421E+00	2.584421E+00	0.000000E+00	8979 114
8	2.589644E+00	2.589644E+00	0.000000E+00	19065 115

---

11 nasaortho.out2 (abridged, small model)
shift = 2.670, 128 negative roots
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root
1	2.651922E+00	2.651922E+00	0.000000E+00	20457 125
2	2.666444E+00	2.666444E+00	0.000000E+00	11199 126
3	2.666855E+00	2.666855E+00	0.000000E+00	19185 127
4	2.669063E+00	2.669063E+00	0.000000E+00	1623 129
5	2.671929E+00	2.671929E+00	0.000000E+00	18225 129
6	2.690160E+00	2.690160E+00	0.000000E+00	2895 130
7	2.690990E+00	2.690990E+00	0.000000E+00	3603 131
8	2.693458E+00	2.693458E+00	0.000000E+00	3579 132

---

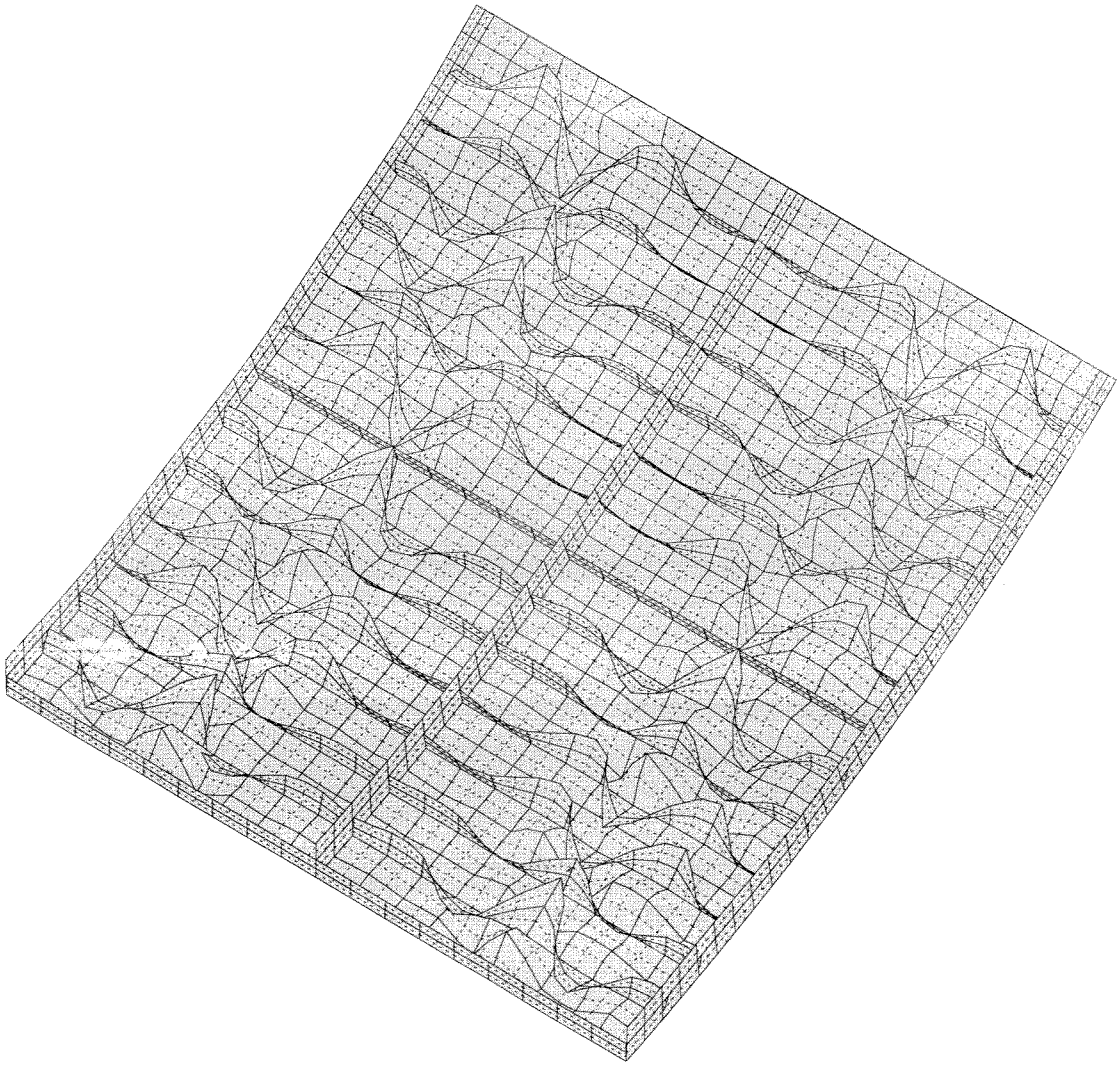
12 nasaortho.out2 (abridged, small model) (go back, capture roots 117-124)
shift = 2.620, 116 negative roots still missing 116
CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 8

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF root	
1	2.620100E+00	2.620100E+00	0.000000E+00	19065 117	
2	2.623368E+00	2.623368E+00	0.000000E+00	17697 118	
3	2.627425E+00	2.627425E+00	0.000000E+00	28705 119	<--general buckling!
4	2.629897E+00	2.629897E+00	0.000000E+00	20697 120	(finally!)
5	2.634832E+00	2.634832E+00	0.000000E+00	19257 121	

Table 48 (P. 4 of 4)

6	2.637229E+00	2.637229E+00	0.000000E+00	17145	122
7	2.641779E+00	2.641779E+00	0.000000E+00	9123	123
8	2.642601E+00	2.642601E+00	0.000000E+00	3531	124



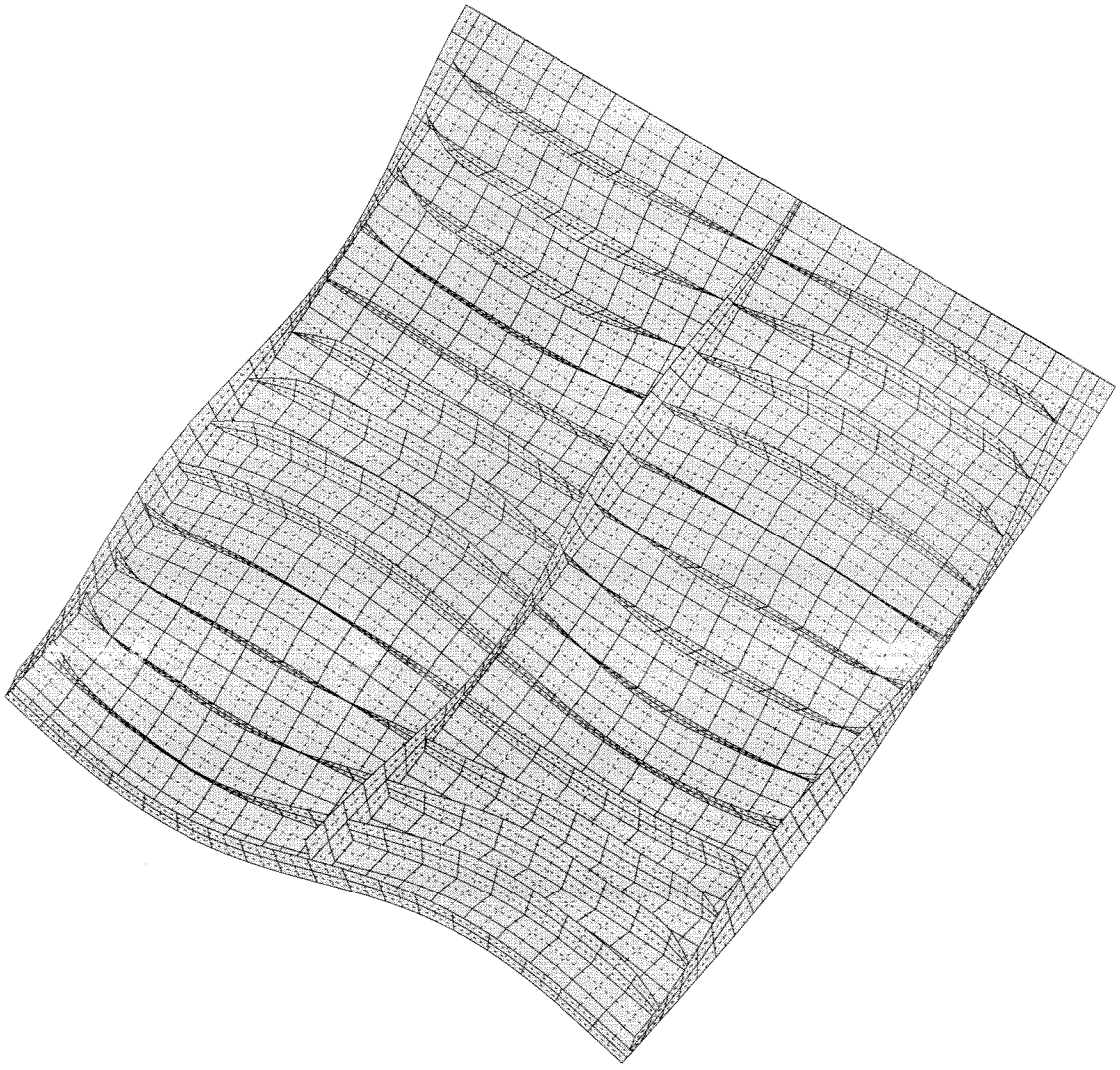
solution scale = 0.1900E+01
mode 1, pcr = 0.24722E+01
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63

5.514E+00

x
y
z

Fig. 39



solution scale = 0.1755E+01
mode 6, pcr = 0.24427E+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

5.514E+00

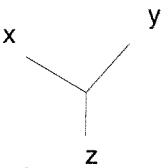
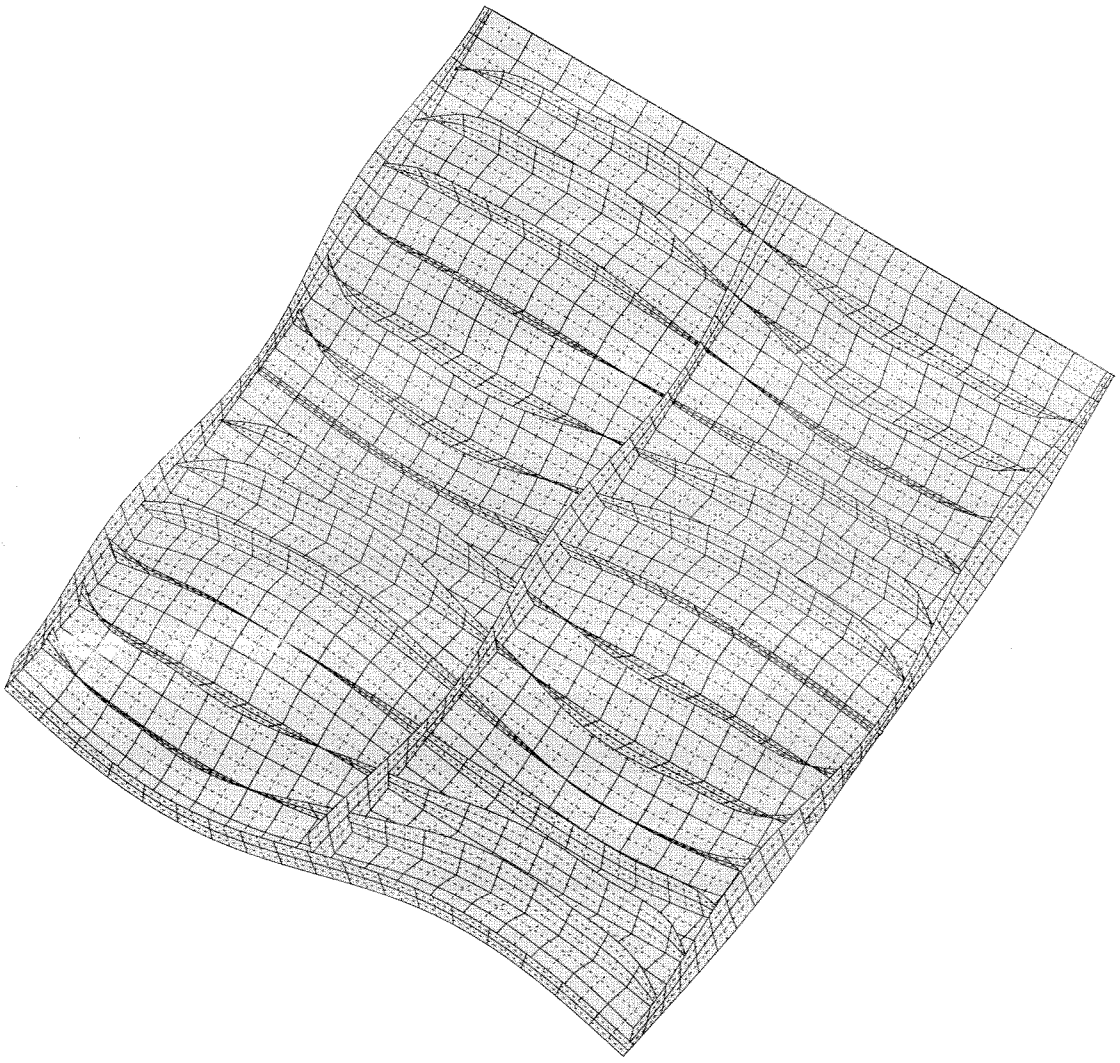


Fig. 40



solution scale = 0.1748E+01
mode 7, pcr = 0.24475E+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

5.514E+00

x
y
z

Fig. 41

solution scale = 0.1776E+01
mode 4, pcr = 0.24906E+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

5.514E+00

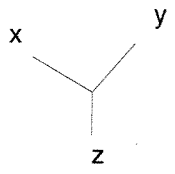
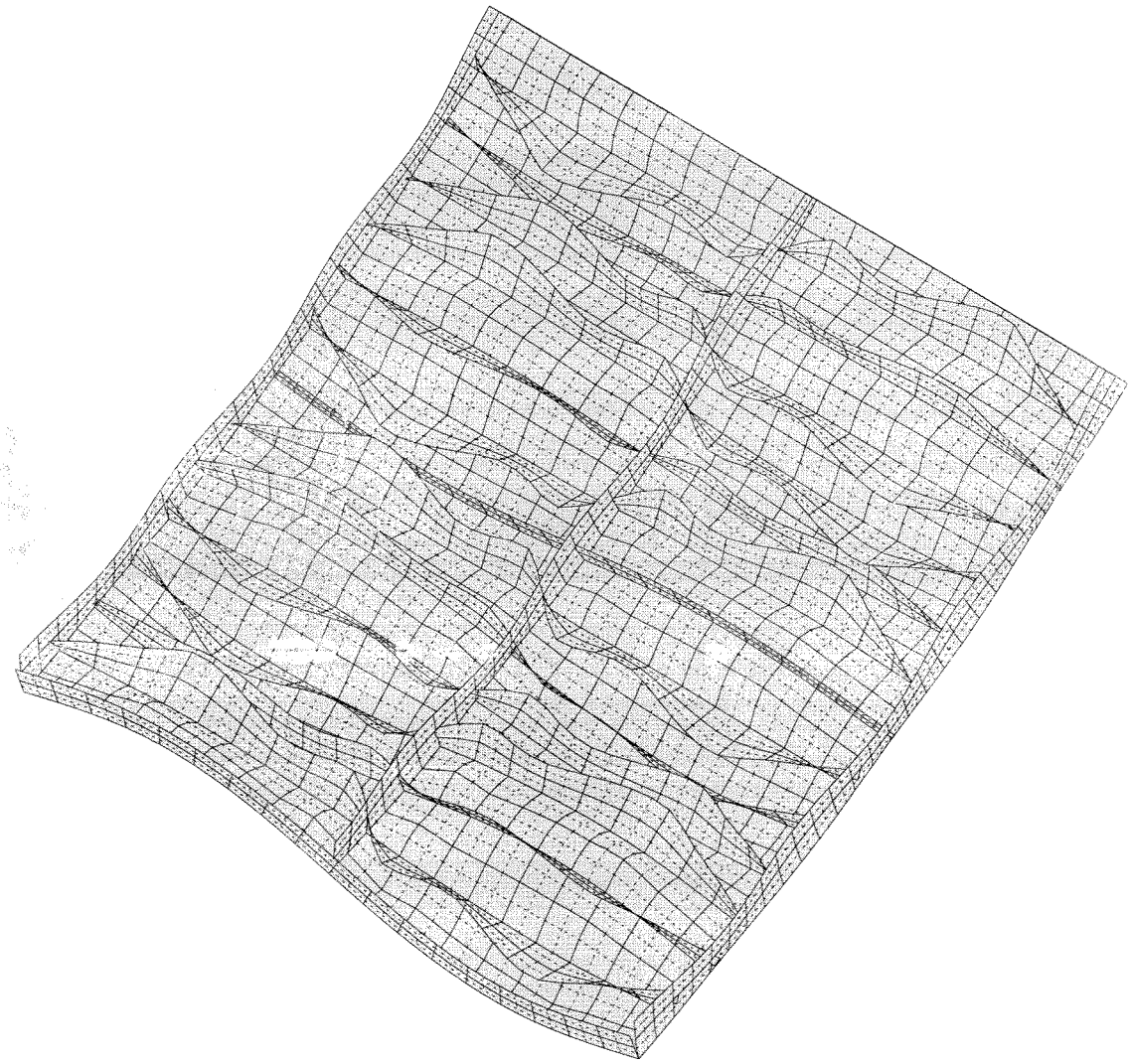


Fig. 42



solution scale = 0.1747E+01
mode 8, pcr = 0.25713E+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

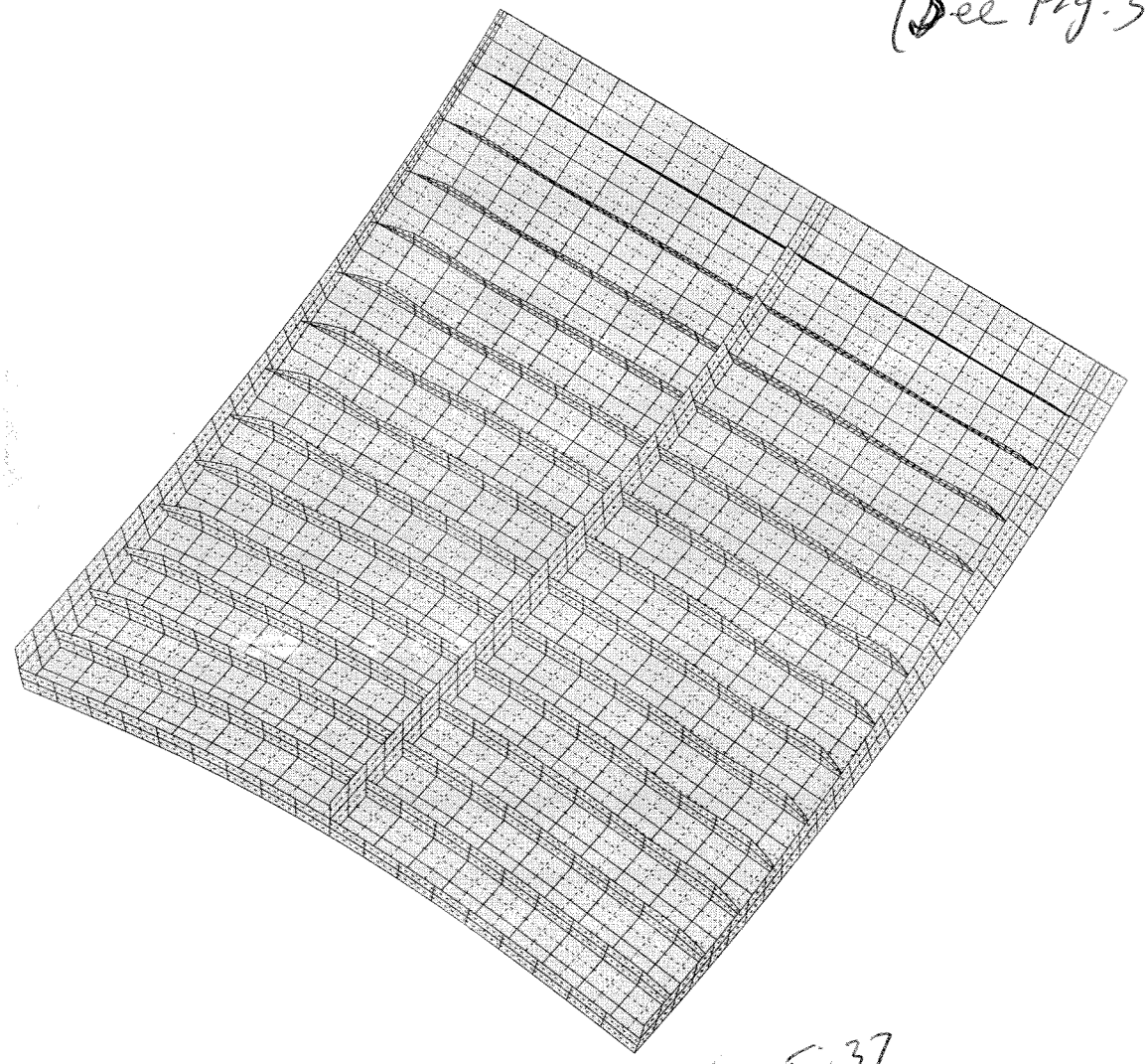
5.514E+00

x
y
z

Fig. 43

This general buckling mode was found after the 12th STAGS run (Table 48, bottom) with the "small" STAGS model.

It is surprising that the eigenvalue for this model is higher than that for the model in which the stringers are smeared out. (See Fig. 37)



compare with Fig. 37

solution scale = 0.1736E+01
mode 3, pcr = 0.26274E+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

5.514E+00

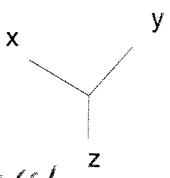
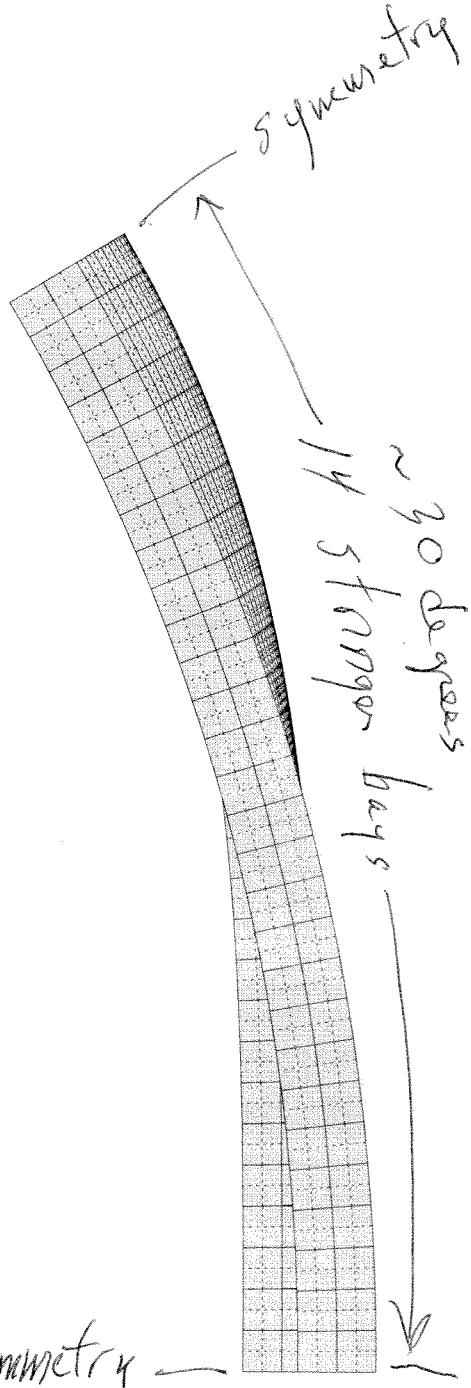


Fig. 44



This general buckling mode is the same as that displayed in the previous figure.

Compressive Fig. 38

solution scale = 0.1239E+01
mode 3, pcr = 0.26274E+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

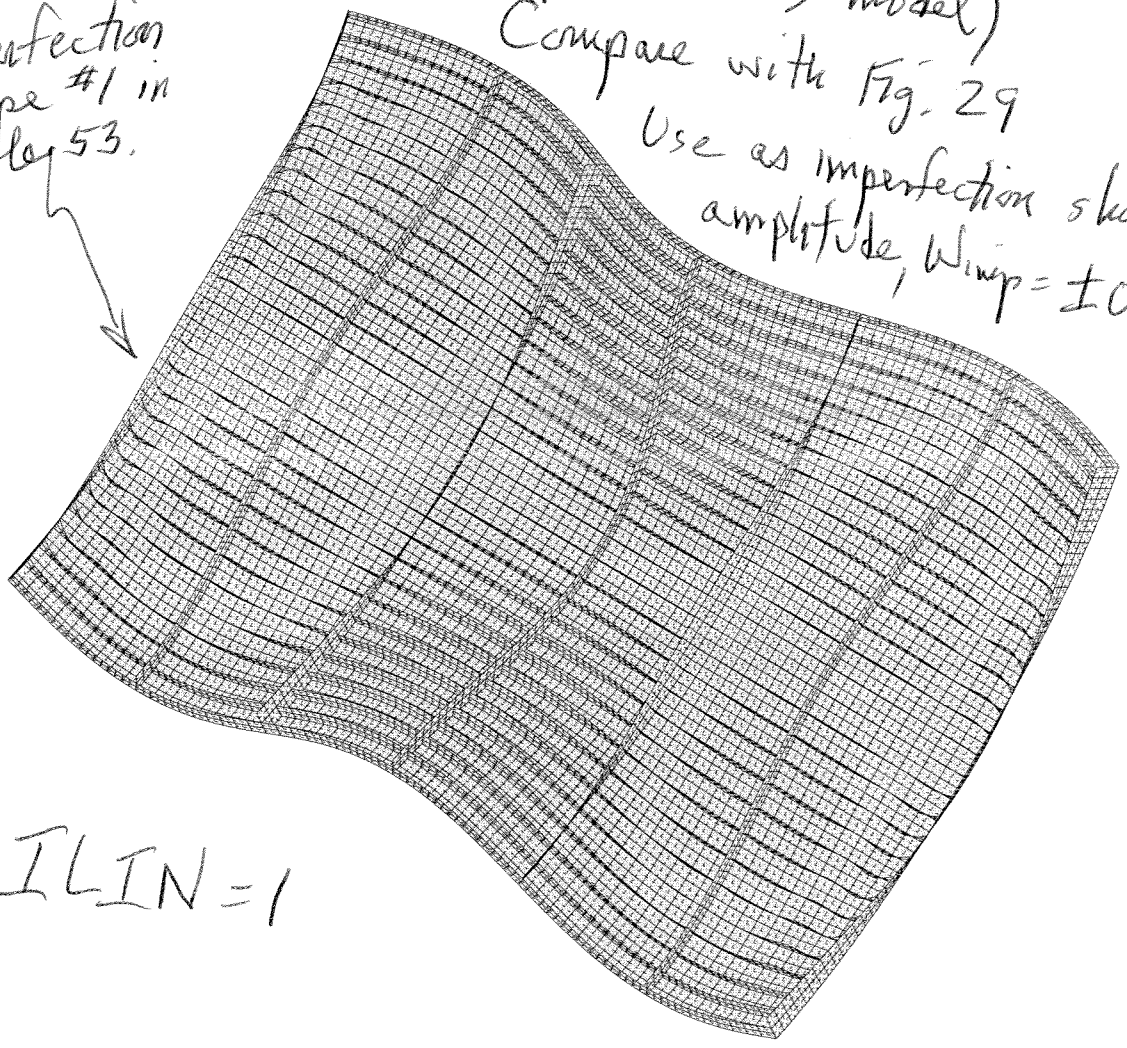
y
x z

4.131E+00

Fig. 45

STAGS general buckling mode shape
ILIN = 1
(60-degree STAGS model)
Compare with Fig. 29
Use as imperfection shape with amplitude, $W_{imp} = \pm 0.125$"

imperfection shape #1 in Table 53.



ILIN = 1

solution scale = 0.4205E+01
mode 1, pcr = 0.26090E+01 ← Compare with Fig. 29
step 0 eigenvector deformed geometry
linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63

1.336E+01

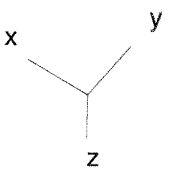


Fig. 46(a)

Table 49 nasaortho.bin (Linear buckling STAGS run)

```
nasaortho 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.
 1, $ NEIGS= number of eigenvalues sought.  BEGIN D-3 rec.
2.608979, $ 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.
```

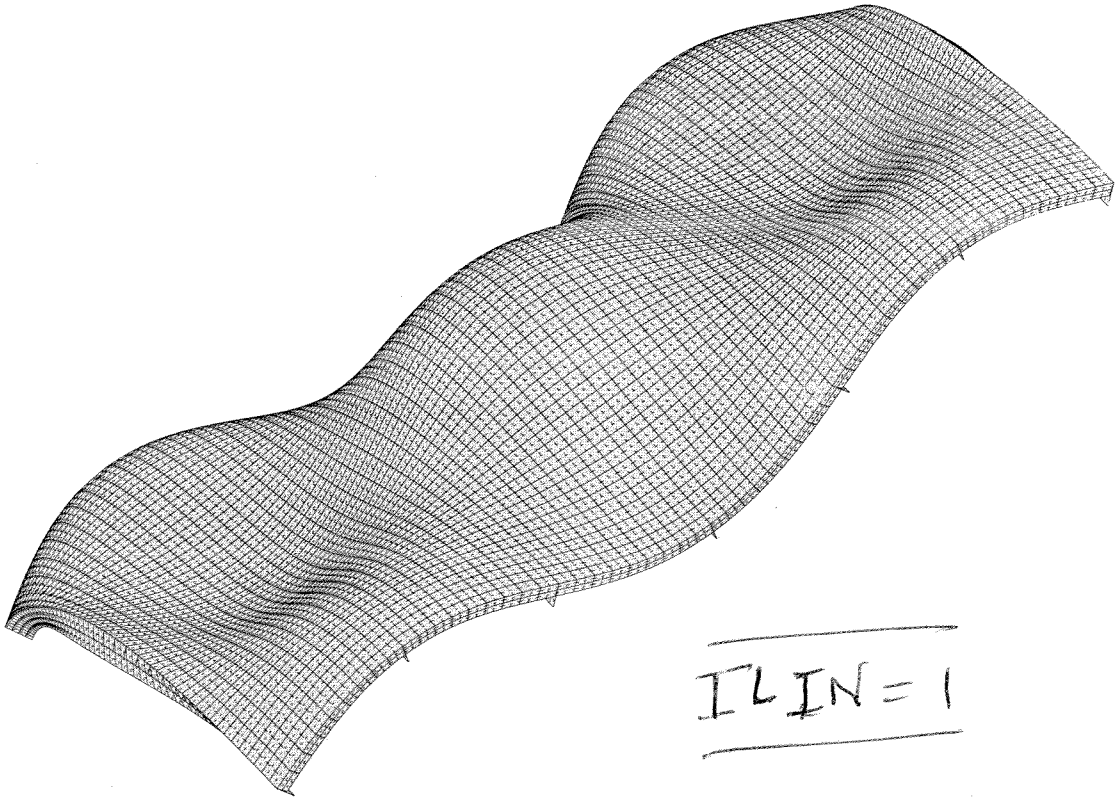
note: See bottom of Table 44, General buckling, Fig. 46

Clear all STAGS "nasaortho" files & start over with SHIFT = 2.608979, the eigenvalue that was found to correspond to general buckling.

This is Run #1

STAGS general buckling

Same mode as shown in Fig. 46a



ILIN = 1

solution scale = 0.4520E+01
mode 1, pcr = 0.26090E+01
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

1.216E+01

Fig. 46(b)

Table 50 nasaortho.bin (linear buckling STAGS run)

```
nasaortho 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.
 1, $ NEIGS= number of eigenvalues sought.  BEGIN D-3 rec.
2.431432, $ 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.
```

inter-ring buckling. See STAGS run #26 in Table 44 ⇕ see Fig. 35

Get inter-ring imperfection shape (See Fig. 35)

This is Run #3

Table-5) nasaortho.bin (linear buckling STAGS run)

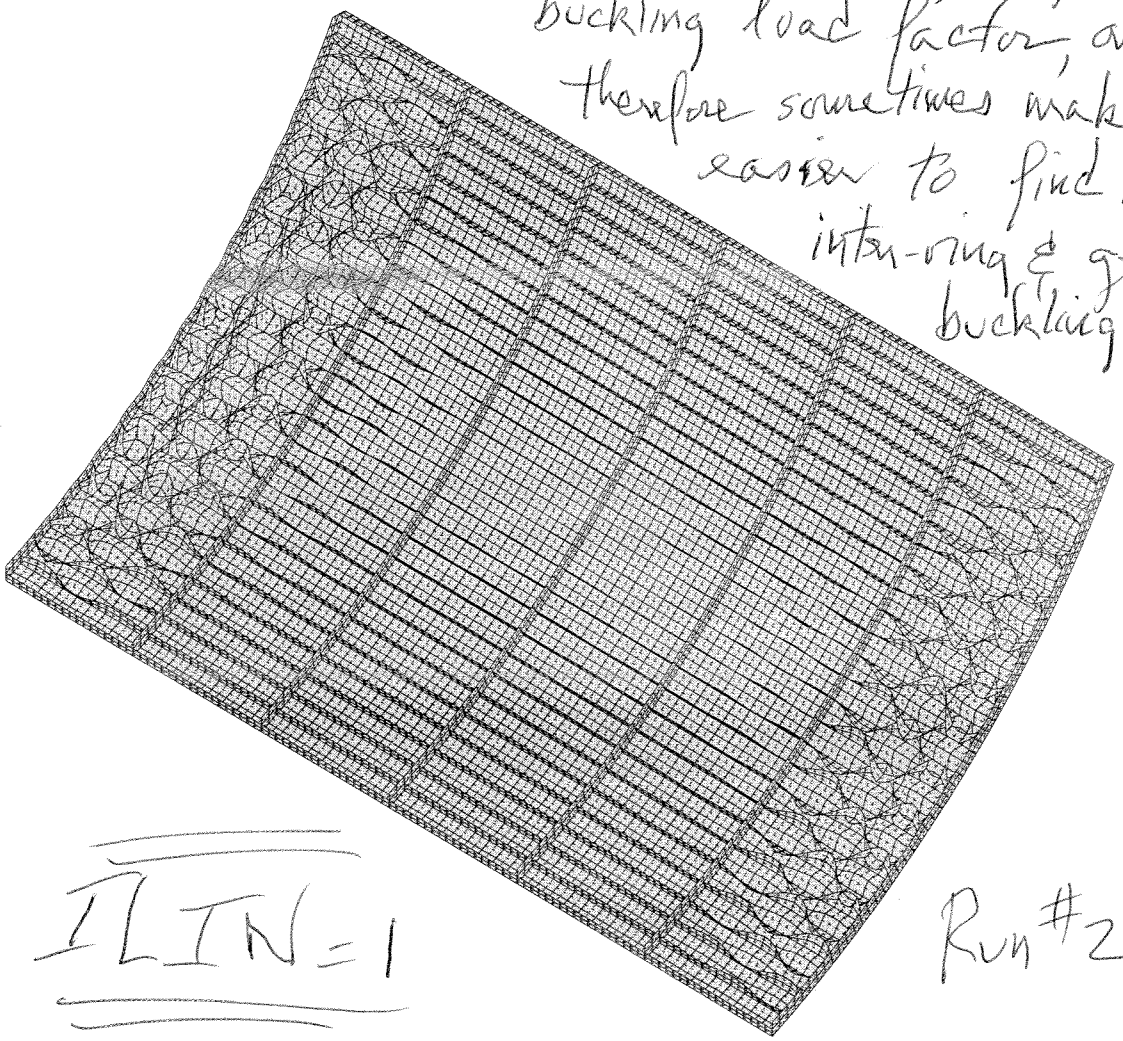
```
nasaortho STAGS INPUT FOR STIFFENED CYL.(STAGSUNIT=SHELL UNITS)
1, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index 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.
 1, $ NEIGS= number of eigenvalues sought.  BEGIN D-3 rec.
1.30, $ 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.
```

local buckling.

Get local buckling imperfection shape

Lowest buckling mode with ILIN=1

(ILIN=1 forces local buckling to have a significantly higher buckling load factor, and therefore sometimes makes it easier to find higher inter-ring & general buckling modes.)



ILIN=1

Run #2

solution scale = 0.4628E+01

mode 1, pcr = 0.17661E+01 ← Compare with Fig 48

step 0 eigenvector deformed geometry

linear buckling of perfect shell from STAGS

Θ x -35.84
Θ y -179.86
Θ z 35.63

1.336E+01

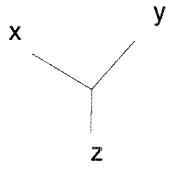
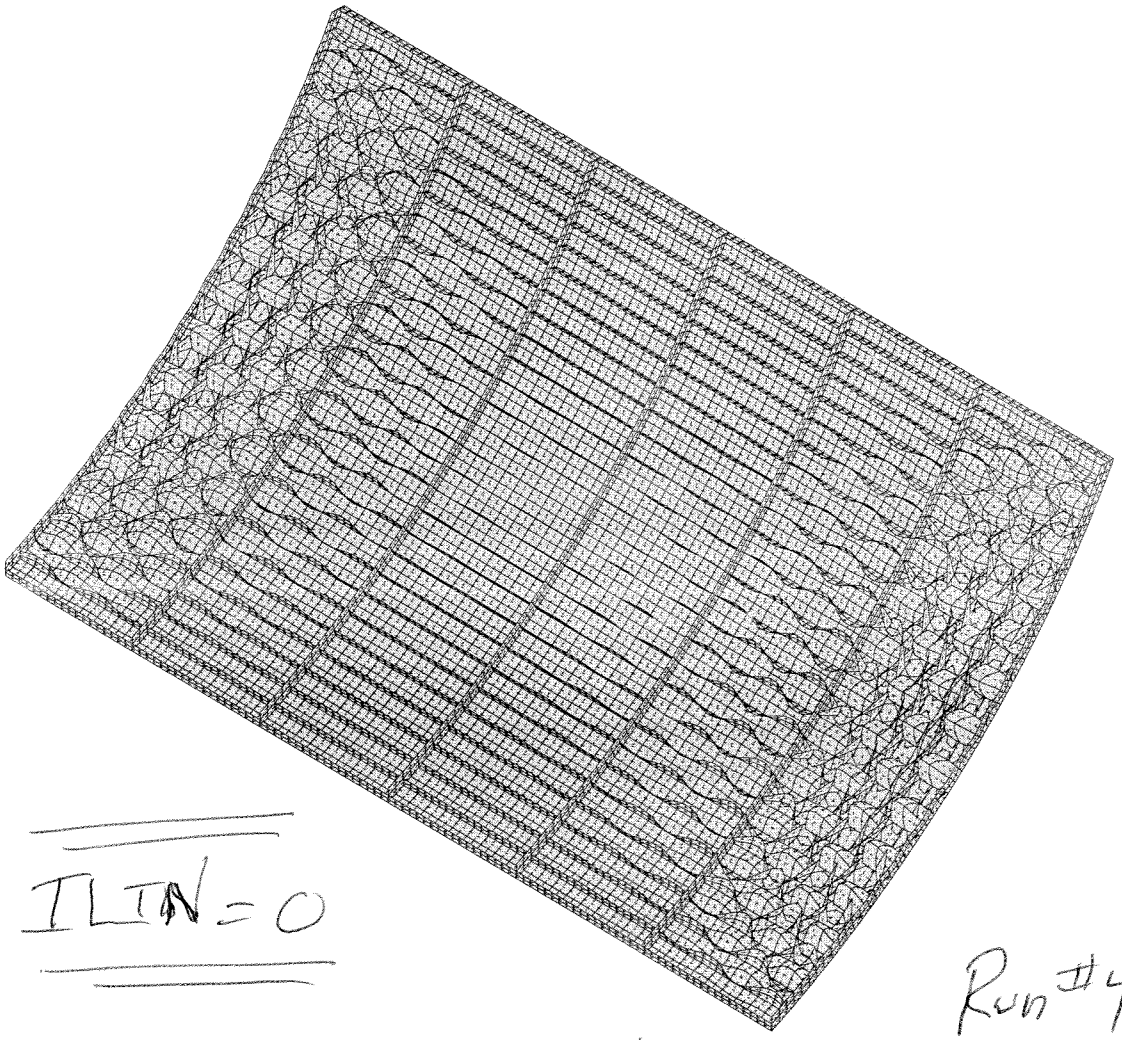


Fig. 47

NOTE: ILIN=0 must be used for local buckling & for nonlinear analysis.

Local buckling with ILIN=0



ILIN=0

Run #4

Compare with Fig. 47

solution scale = 0.4628E+01
mode 1, pcr = 0.13654E+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

1.336E+01

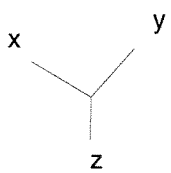
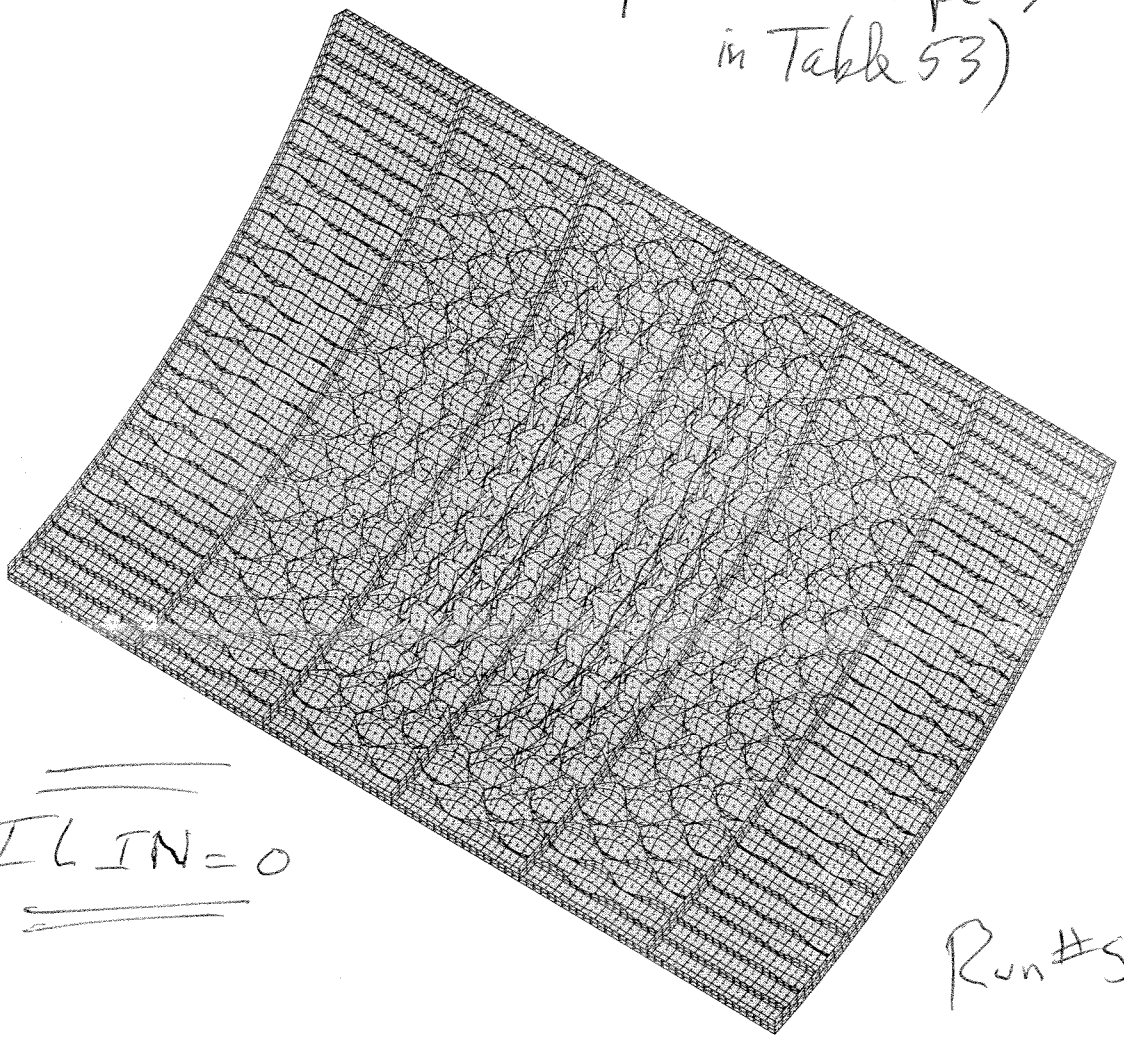


Fig. 48

Linear buckling, ILIN=0
This mode is used as an
imperfection "trigger"
(Imperfection Shape #3
in Table 53)

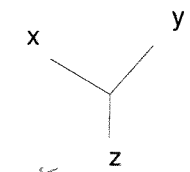


ILIN=0

Run #5

solution scale = 0.4627E+01
mode 5, pcr = 0.13765E+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



1.336E+01

Fig. 49

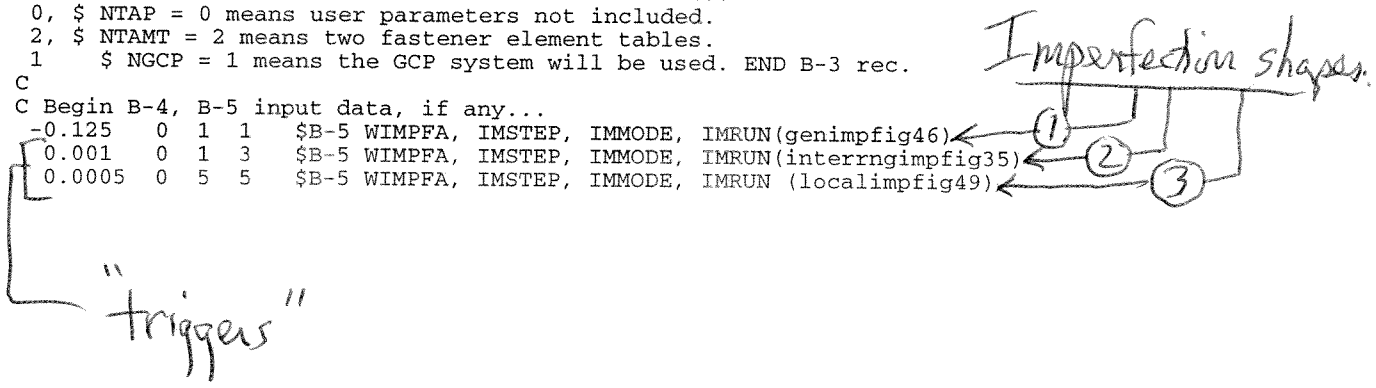
Table 52 nasaortho.bin (nonlinear STAGS run)

```
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.
10000,$ 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
```

Table 53 nasaortho.inp (fragment)

nasaortho.nonlinear.inp (abridged):

```
 3, $ NIMPFS=number of bucklng modal imperfections.          <--NOTE 3 imper. shapes
 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...
10, $ NTAM = number of entries in material tabl.BEGIN B-3 rec.
 4, $ NTAB = number of beam cross section entries
 5, $ 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...
 -0.125   0  1  1   $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN(genimpfig46)
  0.001   0  1  3   $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN(interrngimpfig35)
  0.0005  0  5  5   $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (localimpfig49)
```



$W_{imp} = -0.125"$

Table 54 nasaortho.out2 (edited) nonlinear run

Output from STAGS for nonlinear runs with NEGATIVE general buckling modal imperfection, Wimp = 0.125 inch Wimp = -0.125"

```
Imperfections used in the nonlinear run:
C Begin B-4, B-5 input data, if any...
 -0.125    0  1  1    $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN(genimpfig46)
  0.001    0  1  3    $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN(interrngimpfig35)
  0.0005   0  5  5    $B-5 WIMPFA, IMSTEP, IMMODE, IMRUN (localimpfig49)
```

(lines skipped to save space) See Table 33a, page 1, Load Set 1, Subcase 1

CONVERGENCE HAS BEEN OBTAINED FOR EIGENVALUES 1 THROUGH 4

CRITICAL LOAD FACTOR COMBINATION

NO.	EIGENVALUE	LOAD SYSTEM A	LOAD SYSTEM B	@DOF
1	7.294696E-02	1.072947E+00	0.000000E+00	106497
2	9.107782E-02	1.091078E+00	0.000000E+00	106497
3	1.360219E-01	1.136022E+00	0.000000E+00	109377
4	1.411388E-01	1.141139E+00	0.000000E+00	109377

← See Figs 52, 53

(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	0.137371E+00	0.000000E+00	
4	0.193200E+00	0.000000E+00	
5	0.303957E+00	0.000000E+00	
6	0.467402E+00	0.000000E+00	
7	0.704522E+00	0.000000E+00	
8	0.100000E+01	0.000000E+00	

← See Figs. 50, 51