

4th NASA/SAE/DLR Aircraft Interior Noise Workshop
Friedrichshafen, Germany
May 19 - 20, 1992

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Vibro-acoustic FE analyses of the Saab 2000 Aircraft

- Coupled acoustic/structural aircraft FE-model
- Creation of modal database
- BPF pressure field excitation
- Frequency response analyses
- Model validation analysis
- Planned analyses
- Model development

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Vibro-acoustic FE analyses of the Saab 2000 Aircraft

- Coupled acoustic/structural aircraft FE-model
 - Acoustic model
 - Structural model
 - Coupled Acoustic-Structural model
- Creation of modal database
 - Substructuring/Modal synthesis
 - Acoustic eigenmodes
 - Structural eigenmodes
 - Coupled eigenmodes
- BPF pressure field excitation
 - Cruise flight nearfield BPF noise prediction
 - Inclusion of fuselage scattering

- Frequency response analyses
 - Scheme of computation
 - Modal contribution to BPF response
 - Structural response (Operating deflection shape)
 - Cabin cavity response (Pressure field in dB)

- Model validation analysis
 - Experimental modal analysis, Fuselage Test Rig
 - Fuselage Rig shaker test simulation

- Planned analyses
 - Tuned Damper installation and optimization
 - Structure-borne path identification
 - Active Vibration Control analyses

- Model development
 - Fuselage sections with interior
 - Active Noise Control analyses



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VIBRO-ACOUSTIC FE ANALYSES OF THE SAAB 2000 AIRCRAFT

SUMMARY

FE-models of the Saab 2000 fuselage structure and the interior cavity have been created in order to compute the noise level in the passenger cabin due to propeller noise (page 1).

The FE-system ASKA was used for these analyses. The total number of degrees of freedom (dof) for the models is over 400000. To make the analysis possible substructuring was used in addition to several levels of "midnets" and modal component synthesis. This way the number of dof at each level was reduced to give acceptable computer times (page 2 - 6).

Examples are shown of Acoustic modes (page 7 - 8) and dominant structure modes (page 9 - 10) from the modal database.

BPF pressure field at cruise flight was predicted and applied to the aircraft (page 11 - 12).

Scheme of computations (Normal mode analysis and Frequency response analysis) are outlined in page 13.

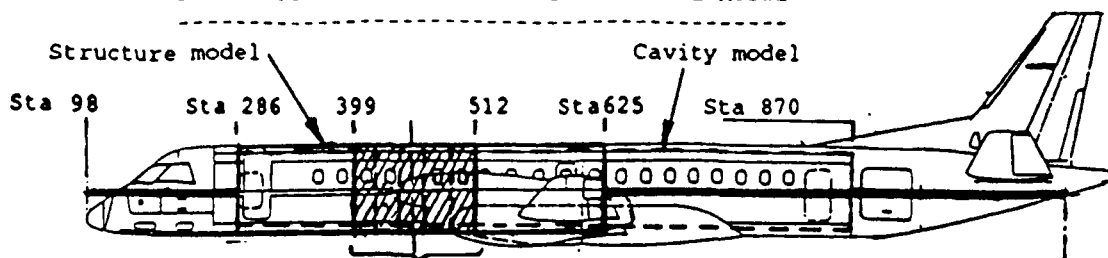
From the frequency response analysis, modal contribution (page 14), structural response (page 15) and cabin cavity response (page 16) are shown.

From Fuselage Test Rig modal analysis a first validation of the FE-model is made (page 17).

Validation with the Frequency Response Function method is under way (page 18 - 19).

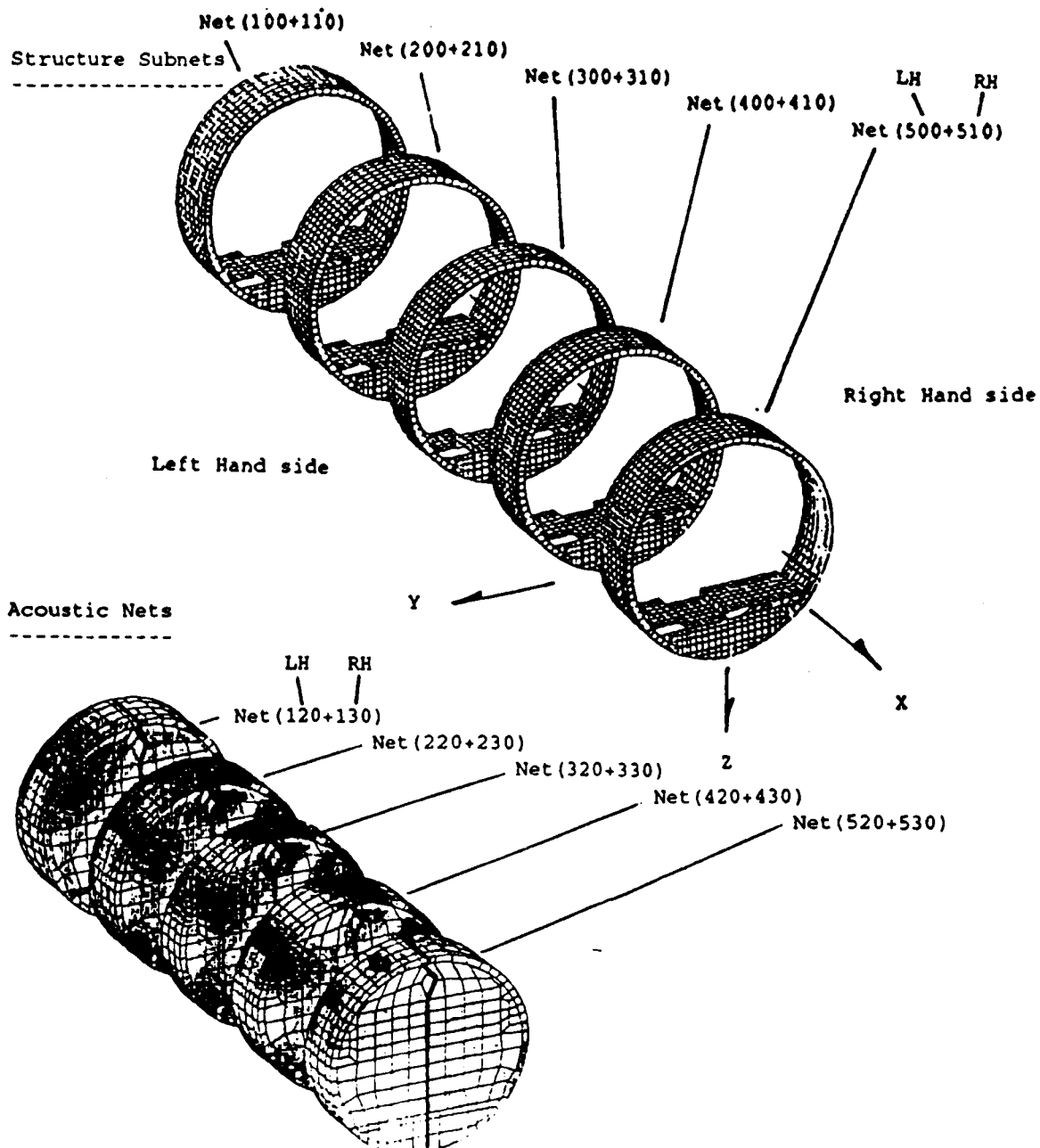
Planned analyses with the Saab 2000 AFEM model is shown in page 20 and proposed model development in page 21.

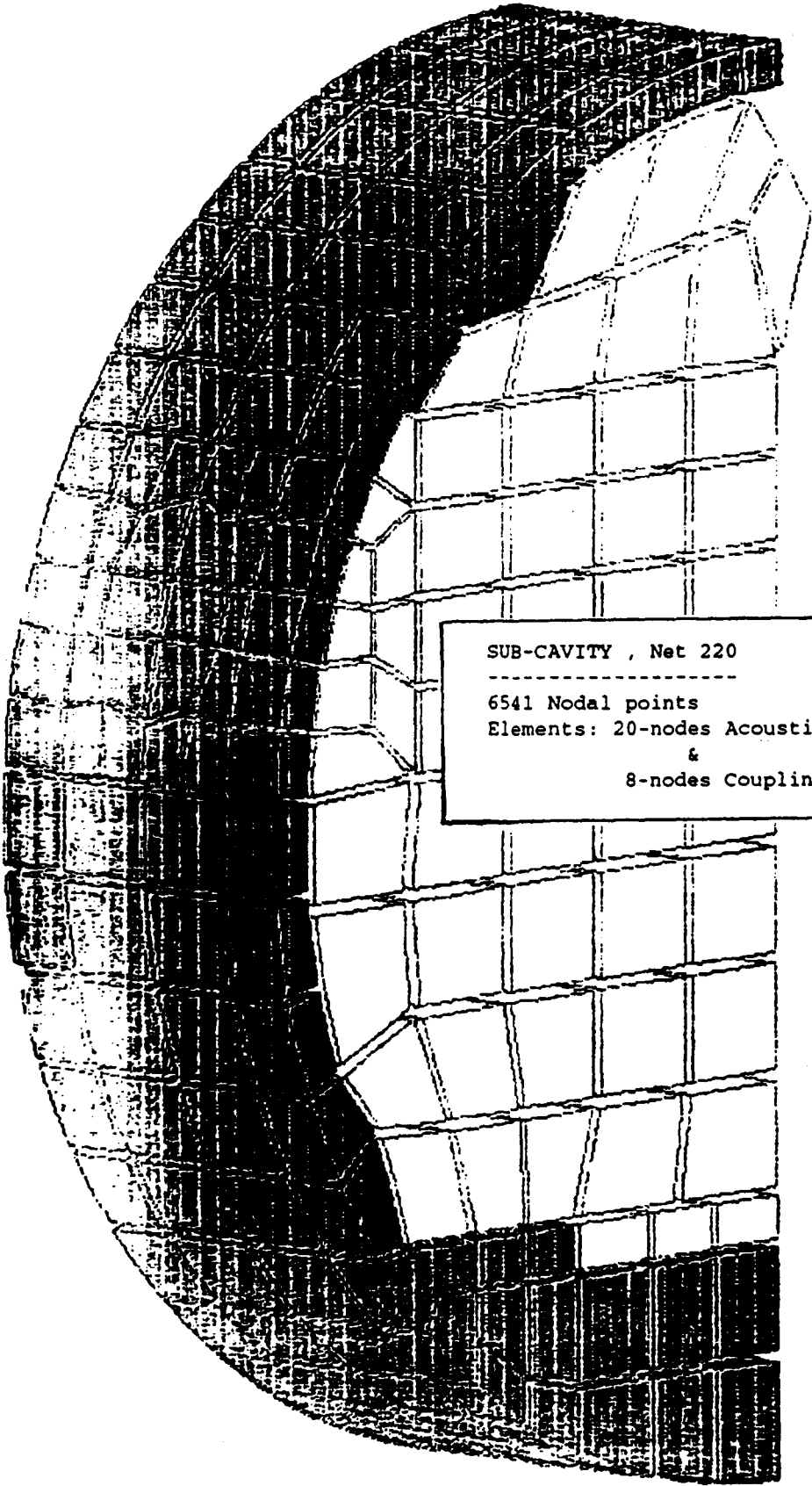
SAAB 2000 COUPLED STRUCTURE-CAVITY FE MODEL



Sta 399 - Sta 512 :	Structure	Cavity	Sta 1151.3
	Main Net 290		
Number of Nodal points :	22681	62118	
Number of Elements :	10153	3599	
Number of Substructures:	10	10	

Database from
Eigenvalue analysis :720 eigenvalues (11.2-342.5 Hz)





MODEL

0.700
0.700
0.140



SCALE 0.009

OBJECT LIMITS

X: 10.744 - 11.354

Y: -0.0770 - 1.1560

Z: -3.6960 - -1.3840

SUB-CAVITY , Net 220

6541 Nodal points

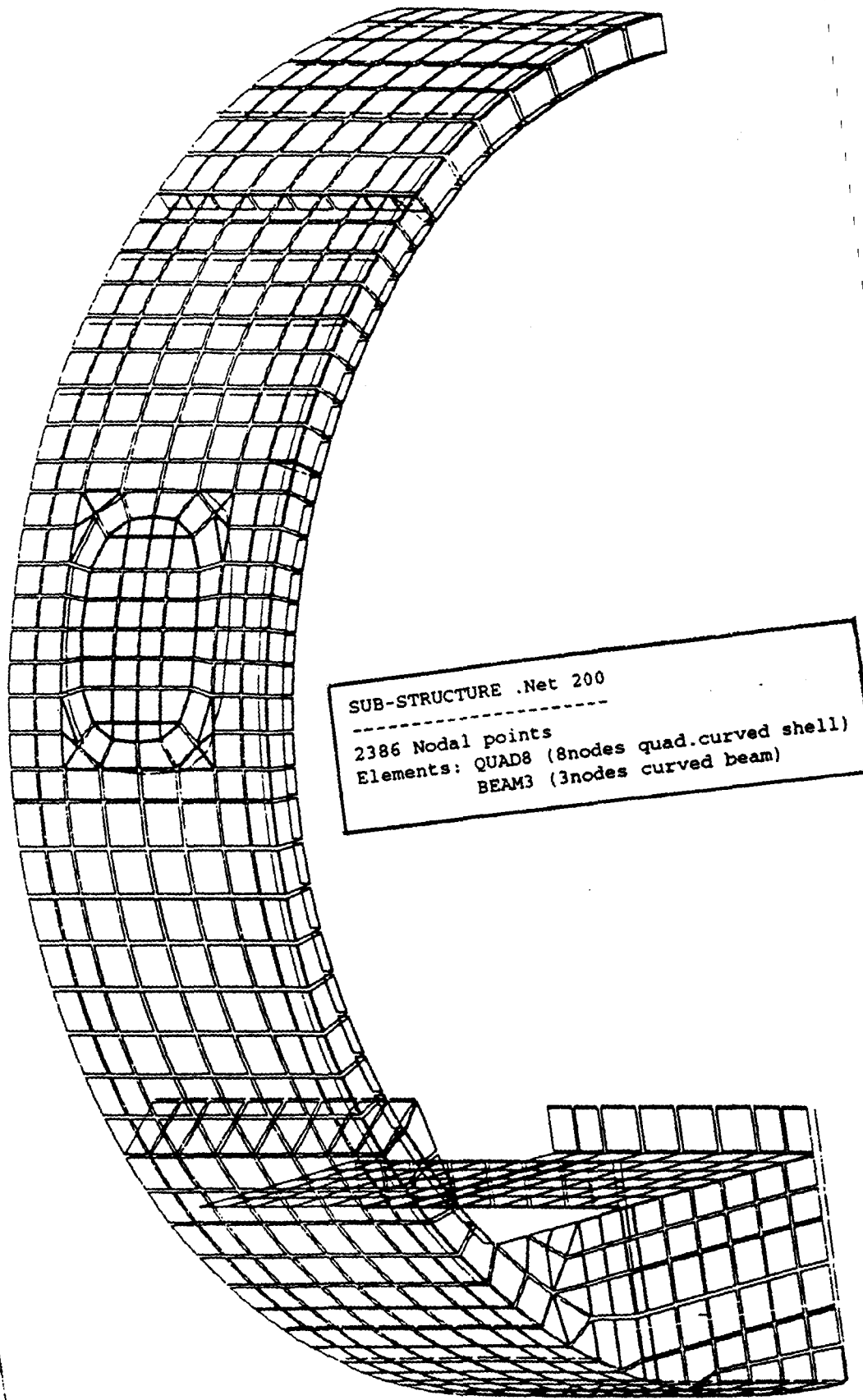
Elements: 20-nodes Acoustic Volume element
&
8-nodes Coupling element

NET 220 HELM KHEINEN

CLASS

07-JUN-85

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SUB-STRUCTURE .Net 200

2386 Nodal points
Elements: QUAD8 (8nodes quad.curved shell)
BEAM3 (3nodes curved beam)

OBJECT LIMITS
X: 10.7440
11.3590
Y: 0.00000
1.15600
Z: -3.69600
-1.38400

SCALE 105 379

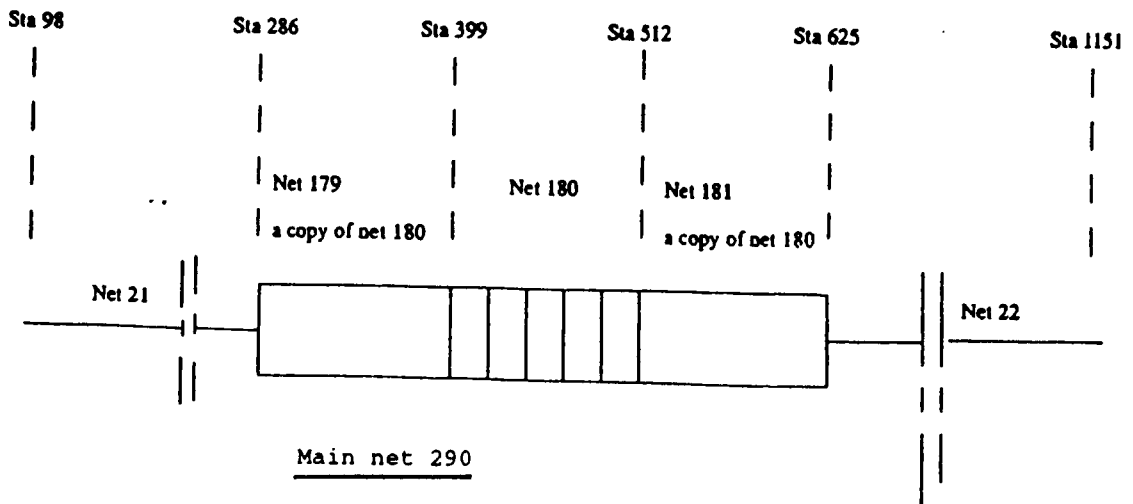
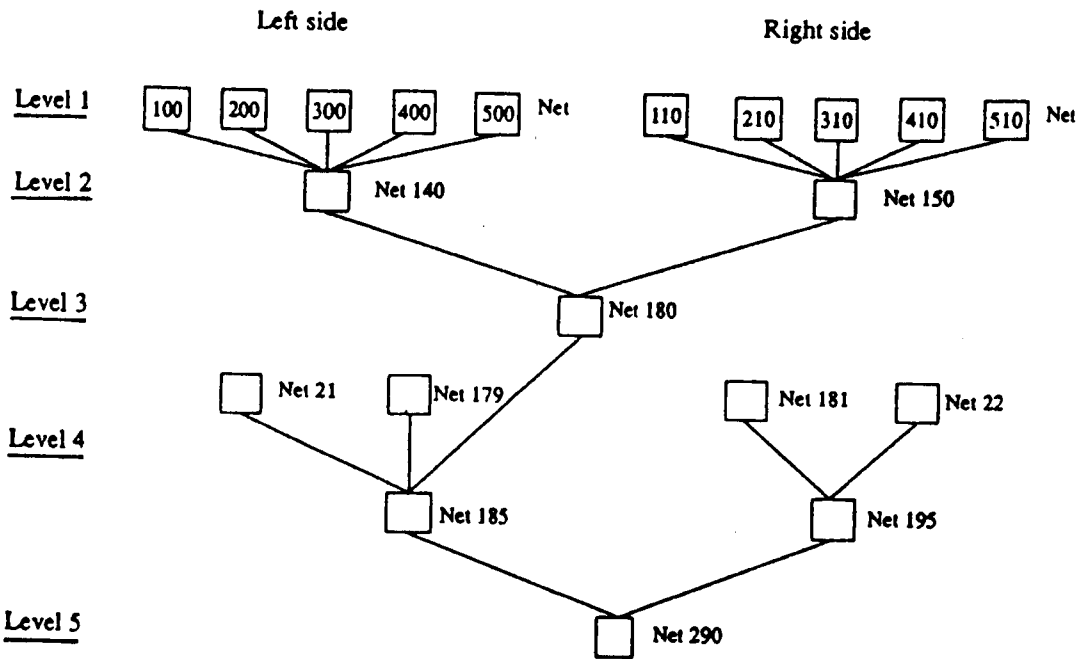
0.700
0.700
-0.140
160.0





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STRUCTURAL MODEL



COUPLED ACOUSTIC-STRUCTURAL MODEL

Coupling only for the master sections Sta 399 - Sta 512 :

Acoustic net 190 + Structure net 180

with rest of the models Main nets 300 and 290 uncoupled.



2000 AFEM.
CREATION OF THE COUPLED ACOUSTIC-STRUCTURAL MODAL DATABASE.

ASKA analyses on CRAY X-MP/416

Total number of DOF's for the models : > 400000

Analyses performed with substructuring (Sub-,Mid-and Main nets) and modal component synthesis for reduction of the number of DOF's at each level.

● ACOUSTIC MODEL (Master section Sta 399-Sta 512)

LEVEL	TOTAL NUMBER UNCONSTRAINED DOF	TOTAL NUMBER NORMAL MODES	TOTAL CPU-TIME IN CRAY (SEC)
1	30300	268	8000
2	3200	284	5700
3	2100	295	7800
4	4000	596	10500

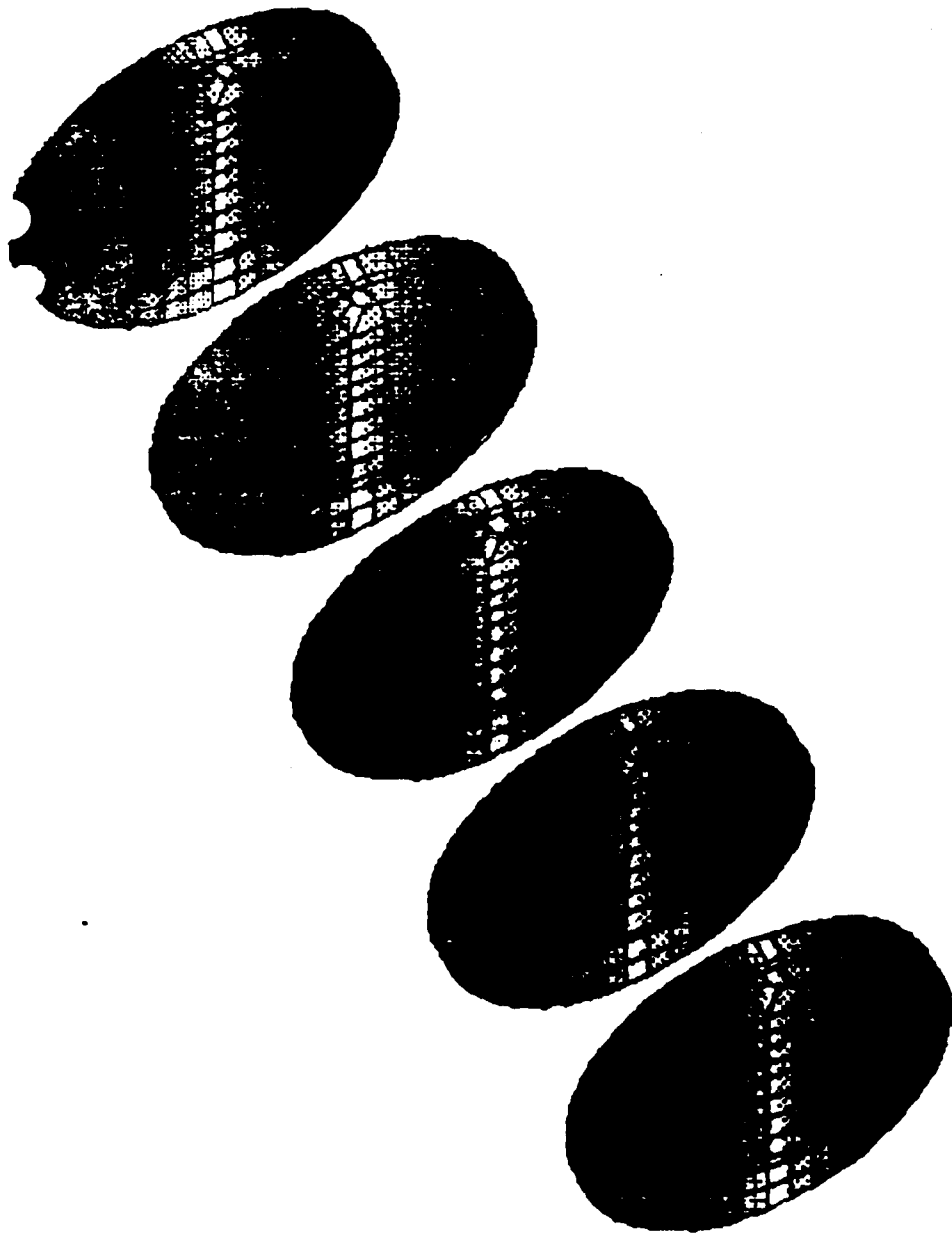
● STRUCTURAL MODEL (Master section Sta 399-Sta 512)

LEVEL	TOTAL NUMBER UNCONSTRAINED DOF	TOTAL NUMBER NORMAL MODES	TOTAL CPU-TIME IN CRAY (SECS)
1	117000	913	44000
2	6860	776	22800
3	2610	720	16000
4	3524	1029	3700
5	2025	720	7250

● COUPLED ACOUSTIC-STRUCTURAL MODEL (Master sections)

Number of Acoustic normal modes: 596 (10.9 - 400 Hz)
Number of Structural normal modes: 720 (11.2 - 342 Hz)
After the coupled analysis,

Number of coupled normal modes: 700 (9.6 - 288 Hz)



PARALLEL

0.535
0.267
-0.802



SCALE 0.036

OBJECT LIMITS

X: 10.872 - 18.049

Y: -1.1560 - 1.1560

Z: -3.6960 - -1.3840

CONTOUR LEVELS

RESULT LDCS COMP OPT

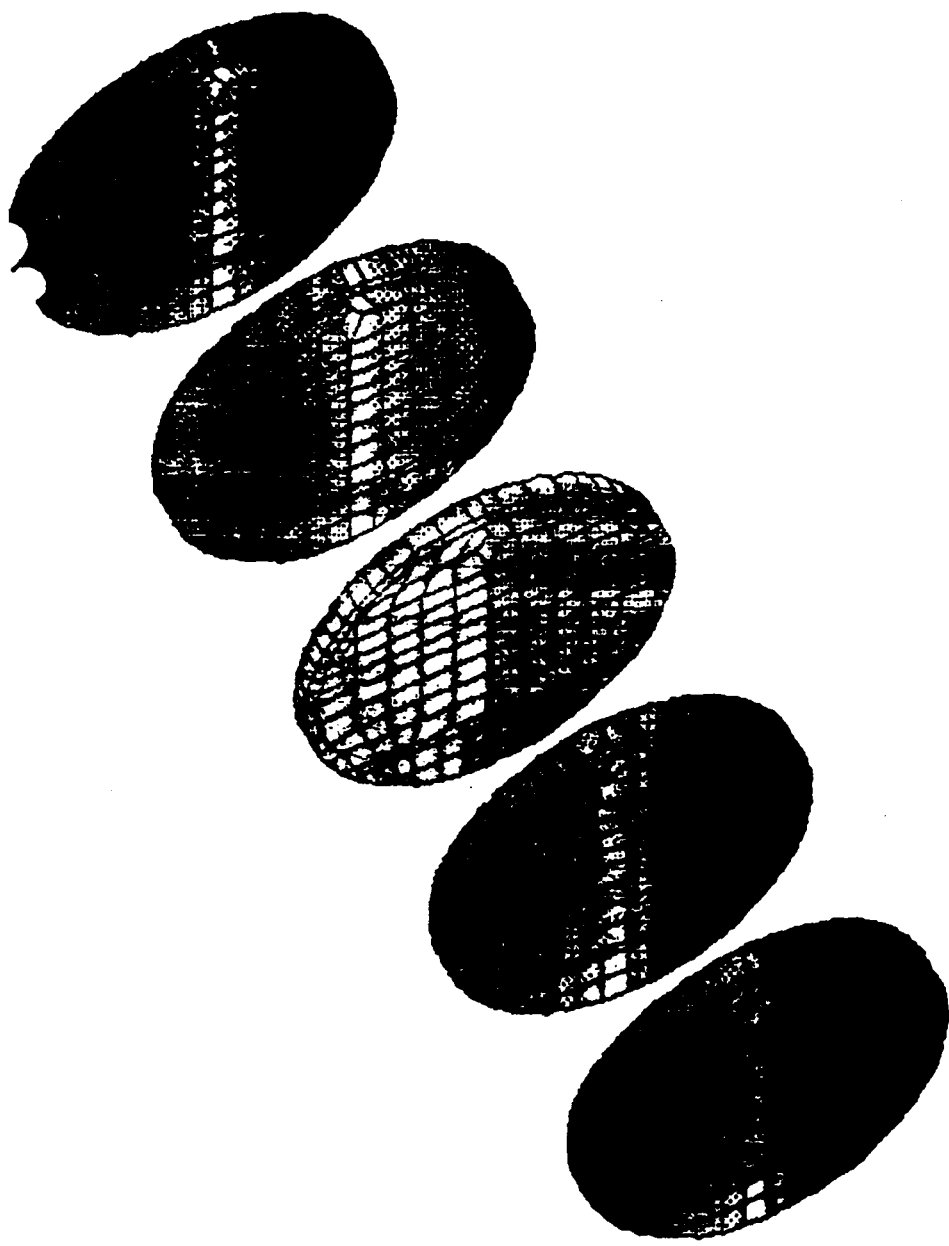
DSP1 4

TOP 10.38*10E-1

ABOVE	9.34
8.31 -	9.34
7.27 -	8.31
6.23 -	7.27
5.19 -	6.23
4.15 -	5.19
3.11 -	4.15
2.08 -	3.11
1.04 -	2.08
0.00 -	1.04
-1.04 -	0.00
-2.08 -	-1.04
-3.11 -	-2.08
-4.15 -	-3.11
-5.19 -	-4.15
-6.23 -	-5.19
-7.27 -	-6.23
-8.31 -	-7.27
-9.34 -	-8.31
BELOW	-9.34

BOTTOM -10.34*10E-1

Fig ACOUSTIC SIDE-SIDE MODE AT 85.3 Hz



PARALLEL

0.535
0.267
-0.802



SCALE 0.036

OBJECT LIMITS

X: 10.872 - 18.049

Y: -1.1560 - 1.1560

Z: -3.6960 - -1.3840

CONTOUR LEVELS

RESULT LDCS COMP OPT

DSP1 6

TOP 10.35E-1

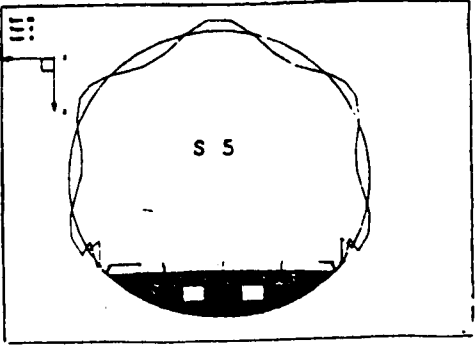
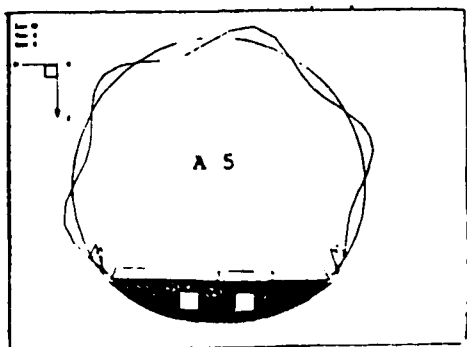
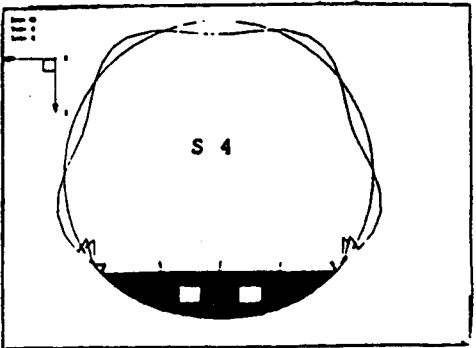
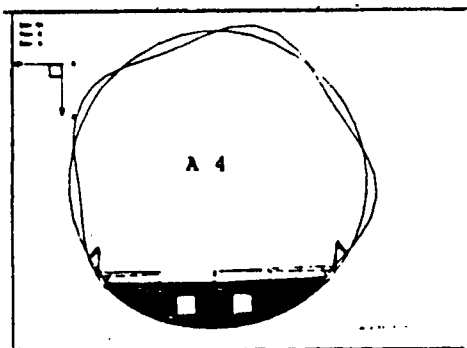
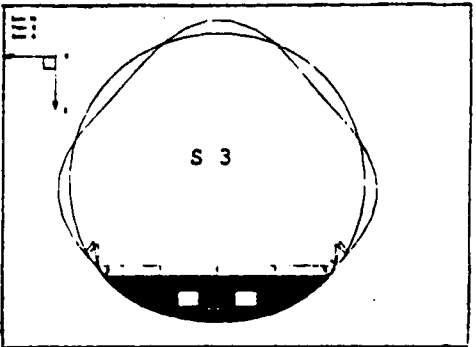
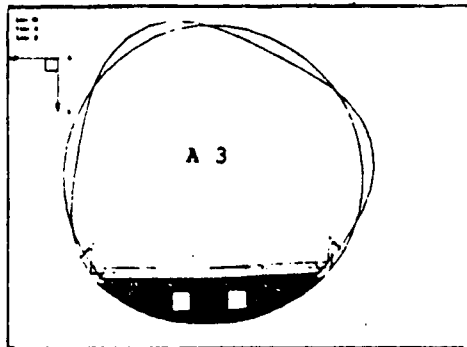
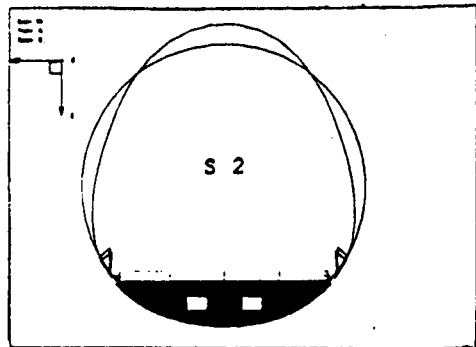
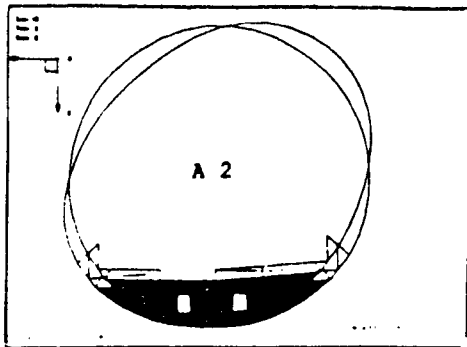
	ABOVE	9.31
	8.28 -	9.31
	7.24 -	8.28
	6.21 -	7.24
	5.17 -	6.21
	4.14 -	5.17
	3.10 -	4.14
	2.07 -	3.10
	1.03 -	2.07
	-0.00 -	1.03
	-1.03 -	-0.00
	-2.07 -	-1.03
	-3.10 -	-2.07
	-4.14 -	-3.10
	-5.17 -	-4.14
	-6.21 -	-5.17
	-7.24 -	-6.21
	-8.28 -	-7.24
	-9.31 -	-8.28
	BELOW	-9.31

BOTTOM -10.35E-1

Fig ACOUSTIC SIDE-SIDE MODE with LH/RH shift AT 101.6 Hz



Cross-sectional mode shapes (Frames).



0.400
2
SCALE 0.022
OBJECT LIMITS
X: 10.119 - 20.0
Y: -1.2943 - 1.17
Z: -3.0107 - -1.30
DEFO OF DISP
LC 24 OF AT 5.0

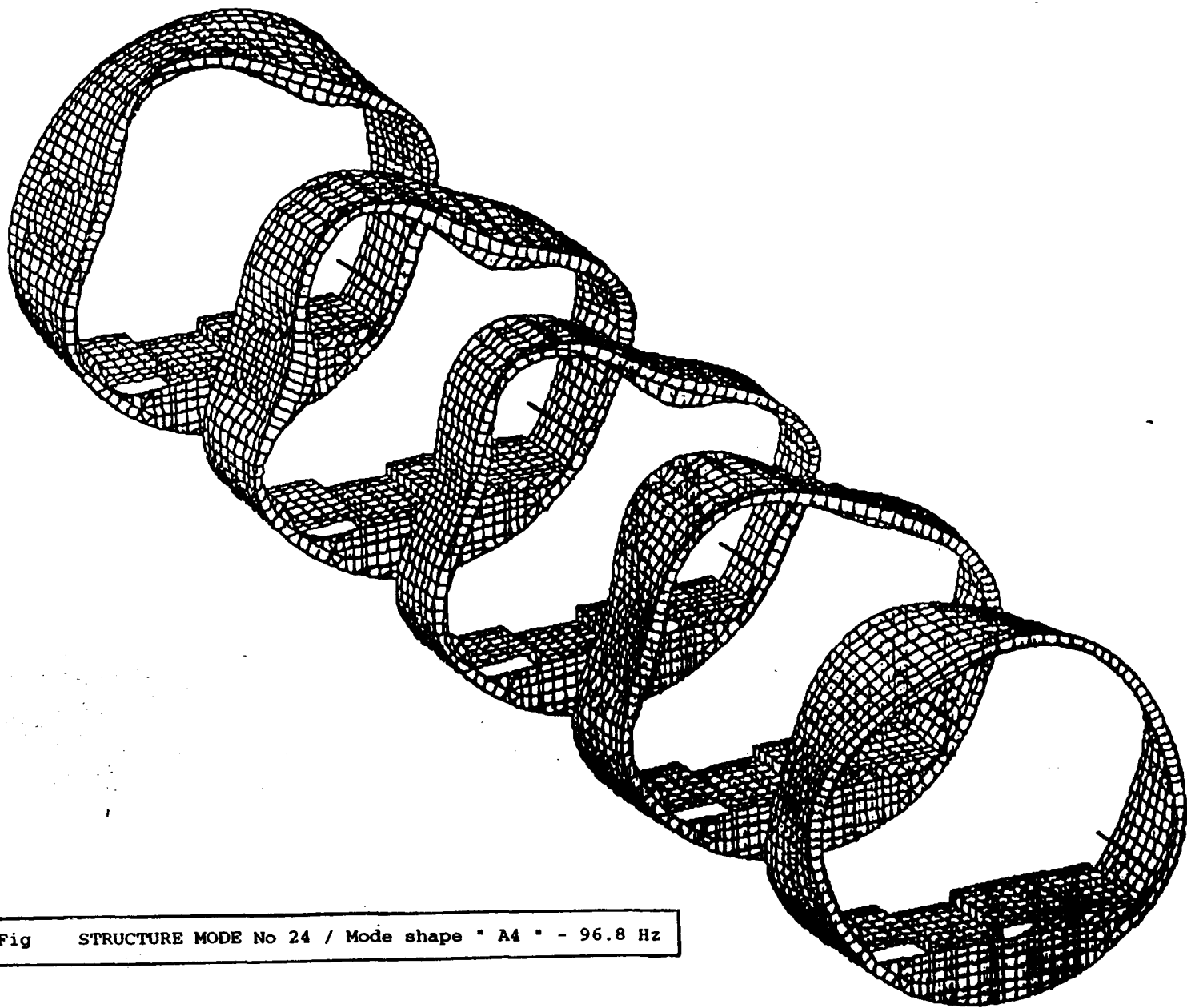


Fig STRUCTURE MODE No 24 / Mode shape " A4 " - 96.8 Hz

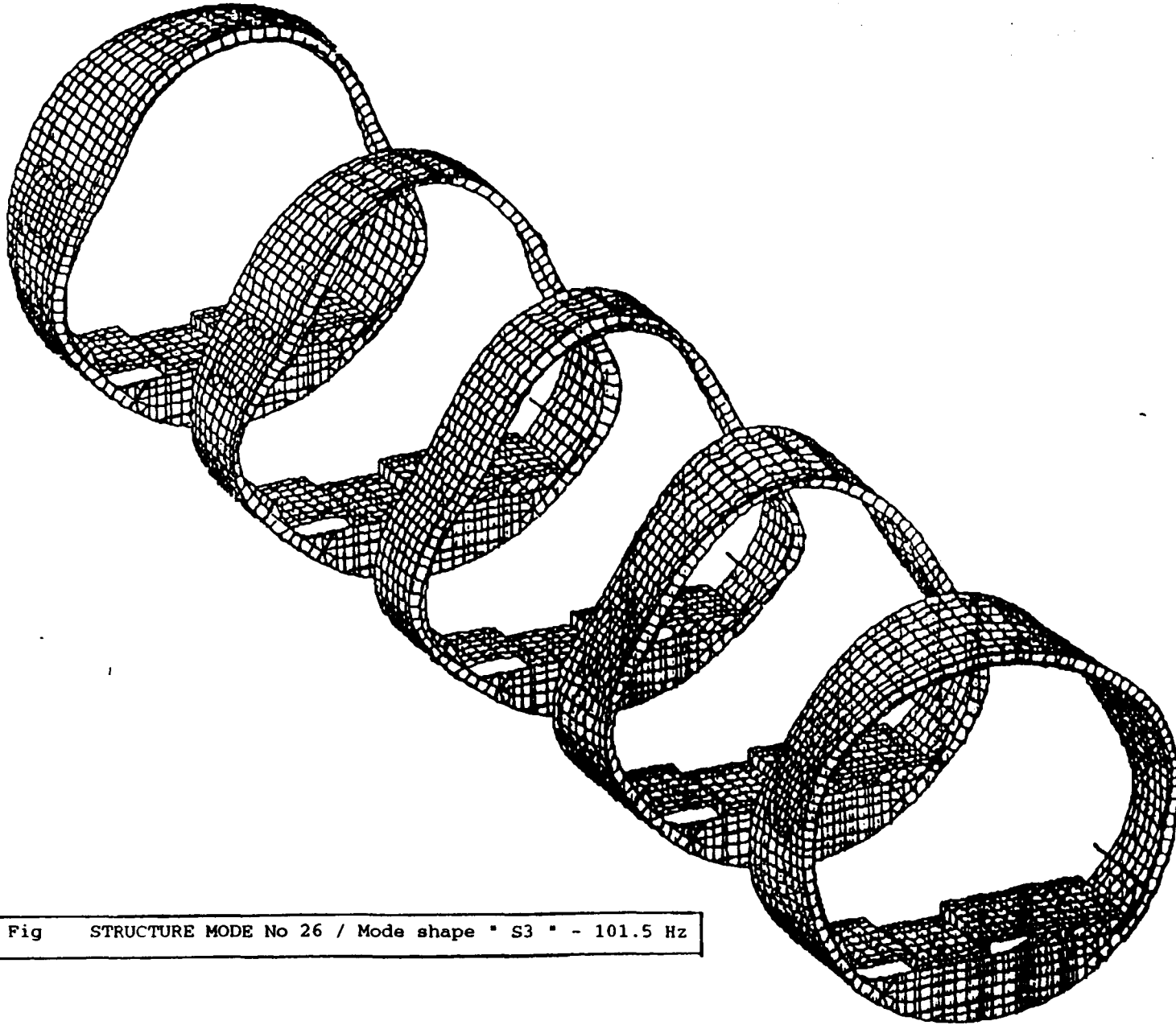


Fig STRUCTURE MODE No 26 / Mode shape " S3 " - 101.5 Hz

U.411
-0.410

L.411
2

SCALE 1:1
OBJECT LIMITS
X: 10.115 - 20.0
Y: -1.206 - 1.22
Z: -3.000 - -1.37

DEFO OF DISP
LC 26 (PART 5.0)

- BPF pressure field excitation
 - Cruise flight nearfield BPF noise prediction
 - Inclusion of fuselage scattering
- Propeller free field prediction program NOISEGEN developed at FFA.
- Program code based on a linearized version of Ffows-Williams-Howkings equation.
- Fuselage scattering and boundary layer effects added.
- Complex pressures converted to Real and Imaginary. pressure fields (Load data).
- Load data applied to Structure Sub-nets.



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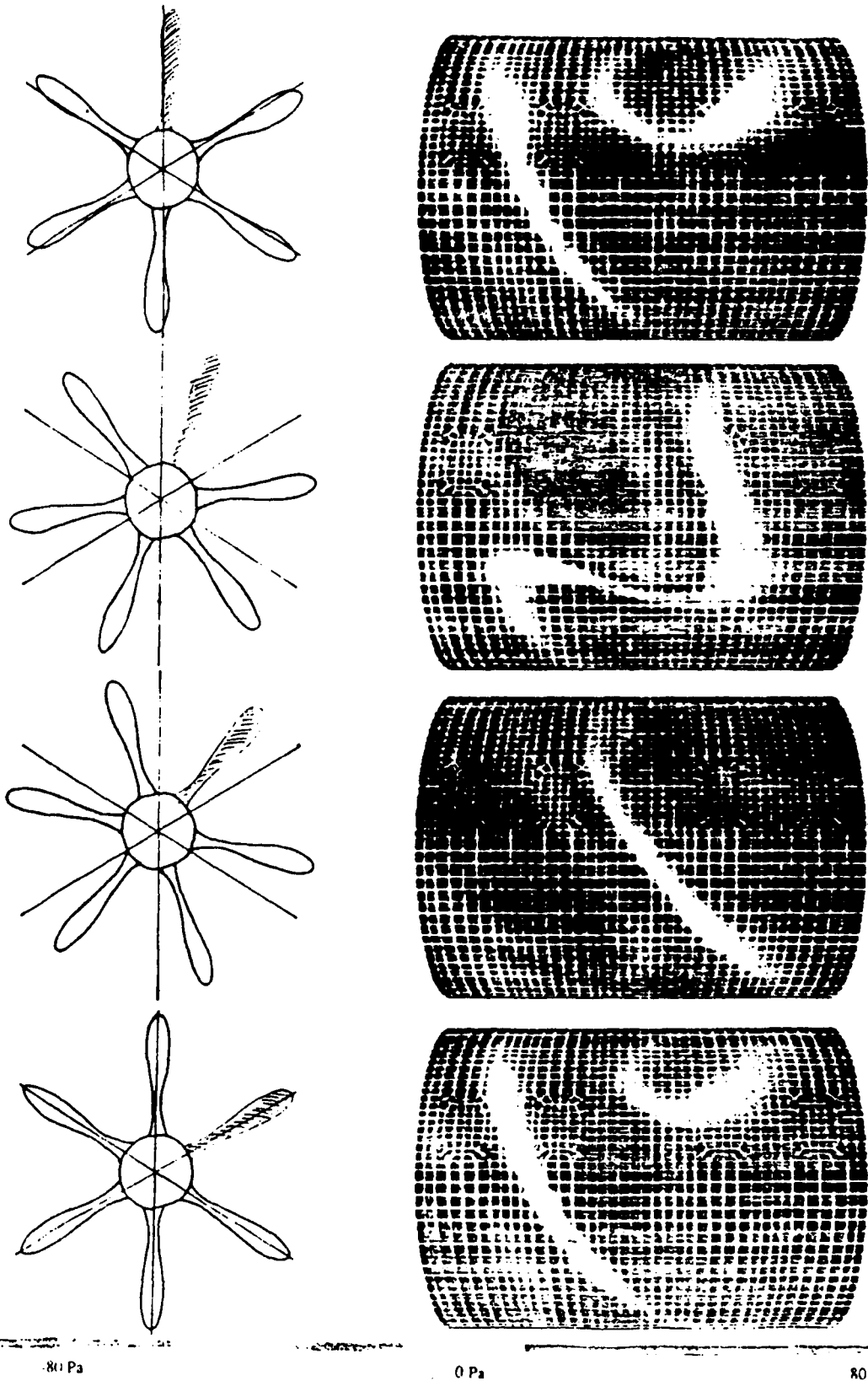


Figure Predicted pressure field on the left hand side of the Seat 200* at different time steps



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• Scheme of computation

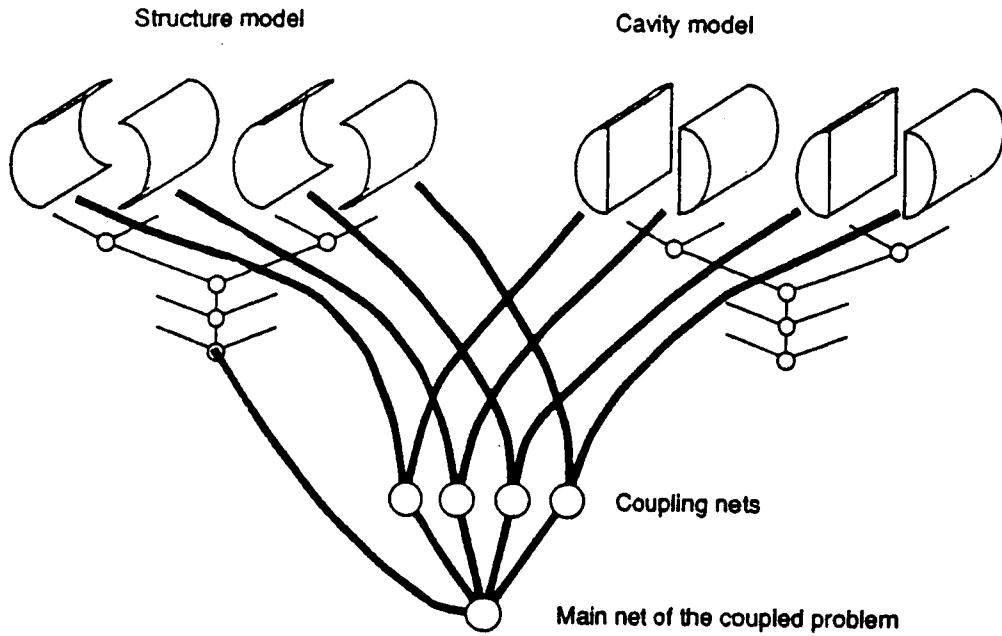


Figure . Natural mode flow of computation

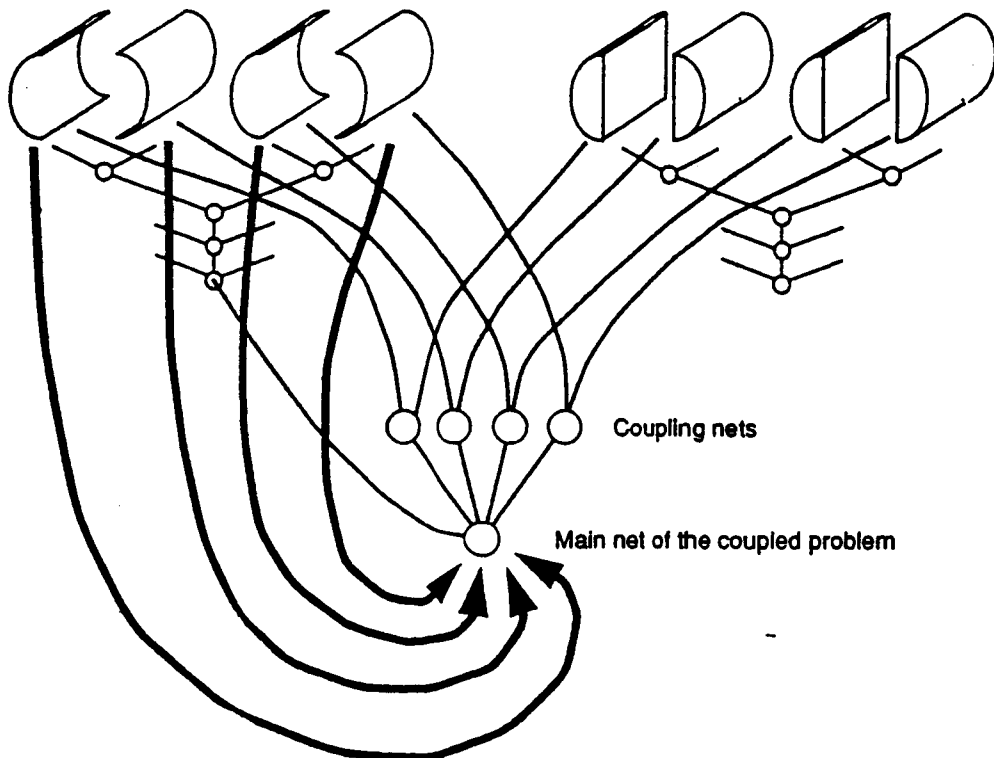
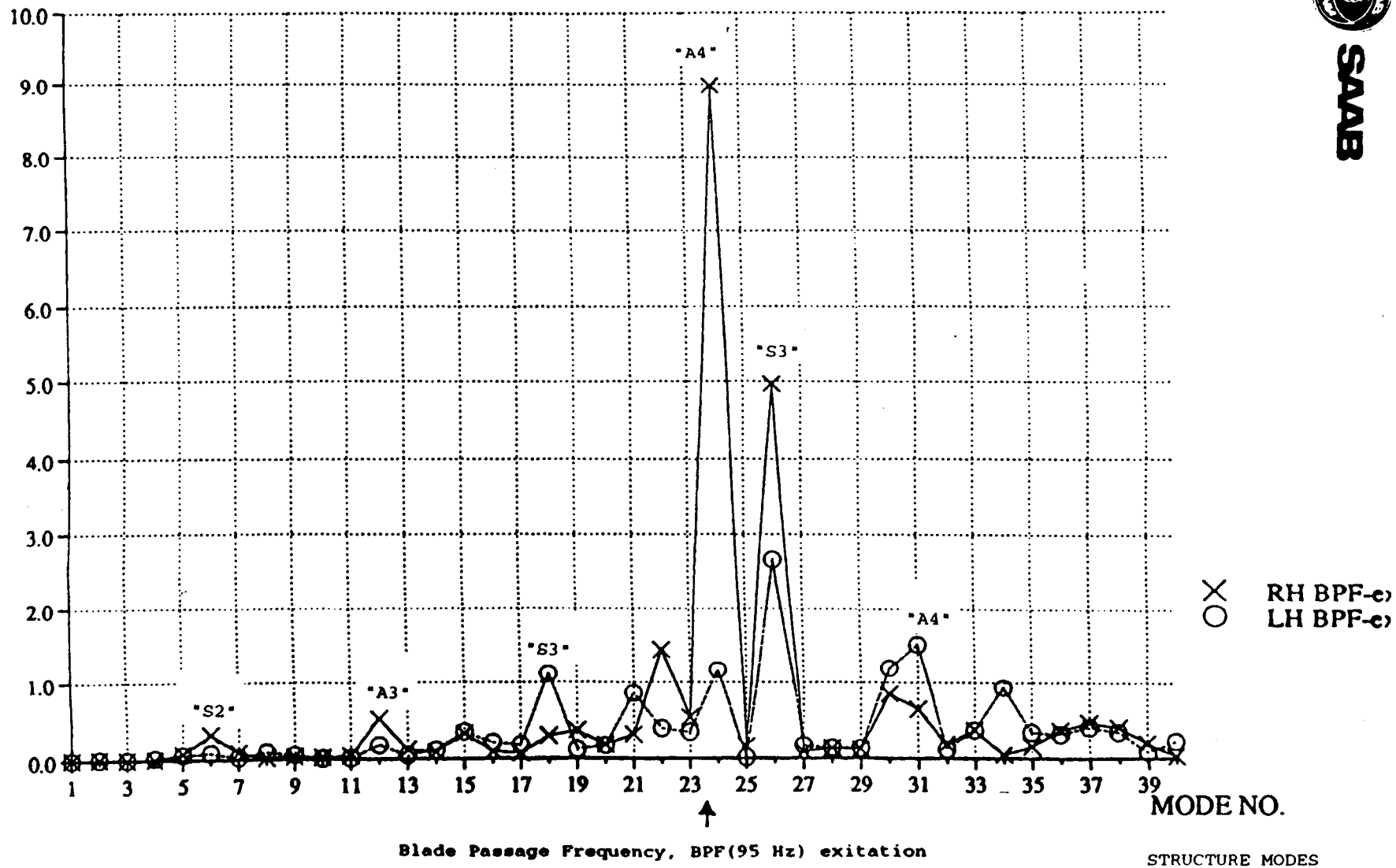


Figure . Frequency response flow of computation

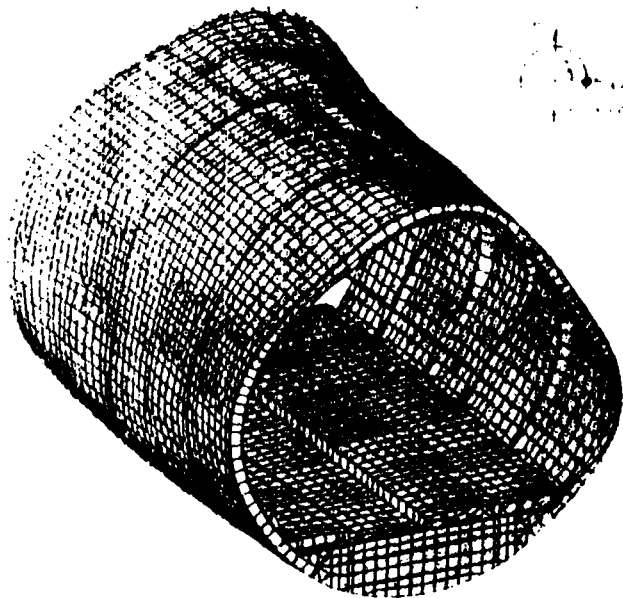
Fig - MODAL CONTRIBUTION TO BPF RESPONSE

CONTR.FACTOR(*10-2)

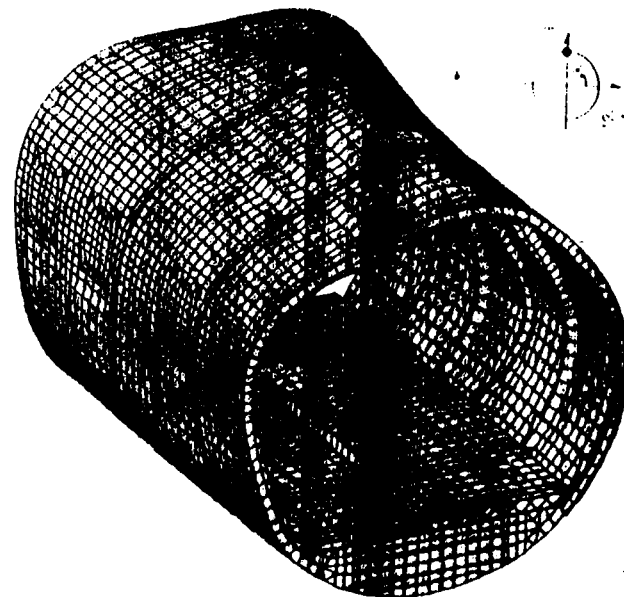


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X RH BPF-c
O LH BPF-c



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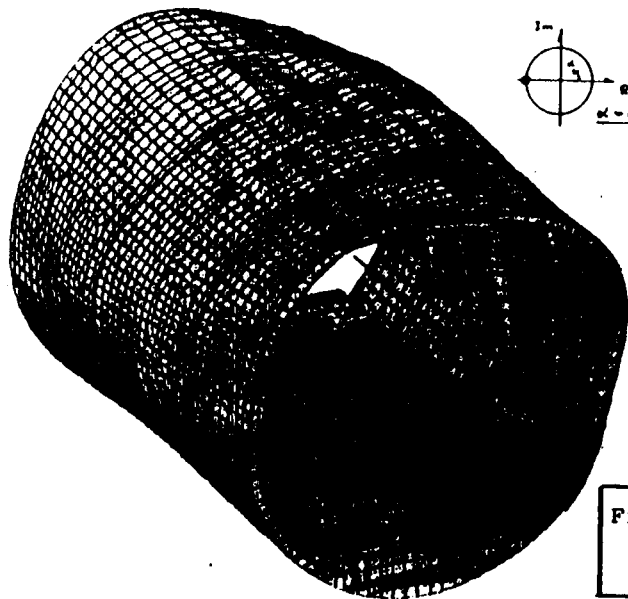
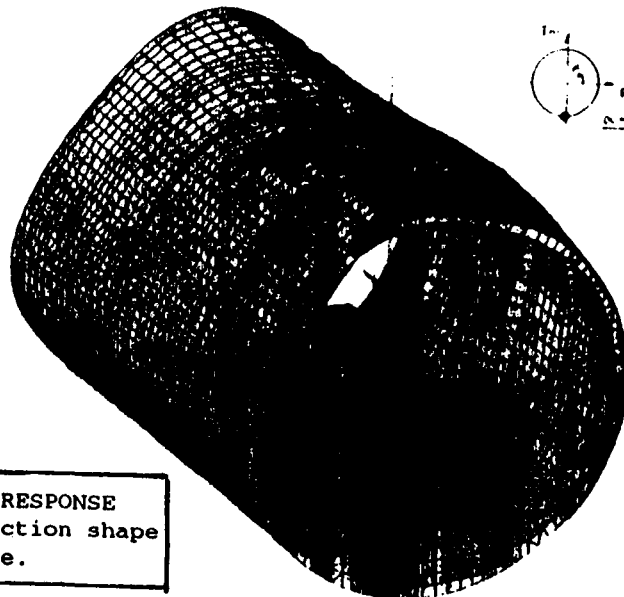
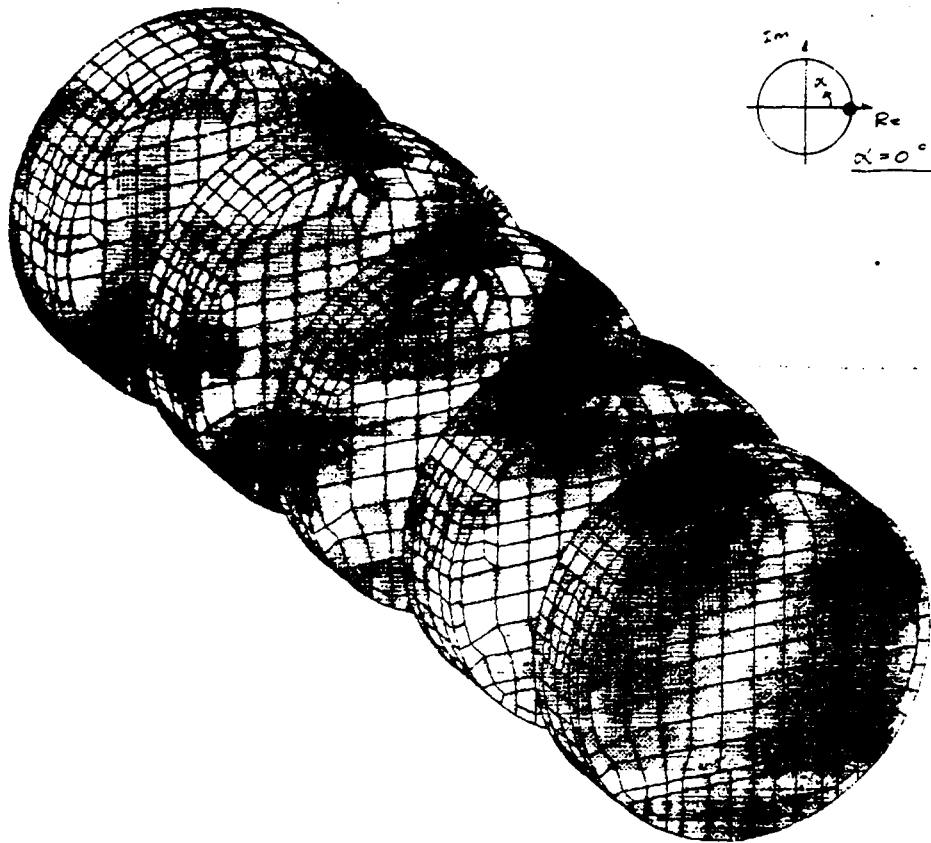


Fig STRUCTURAL BPF RESPONSE
Operating deflection shape
during one cycle.



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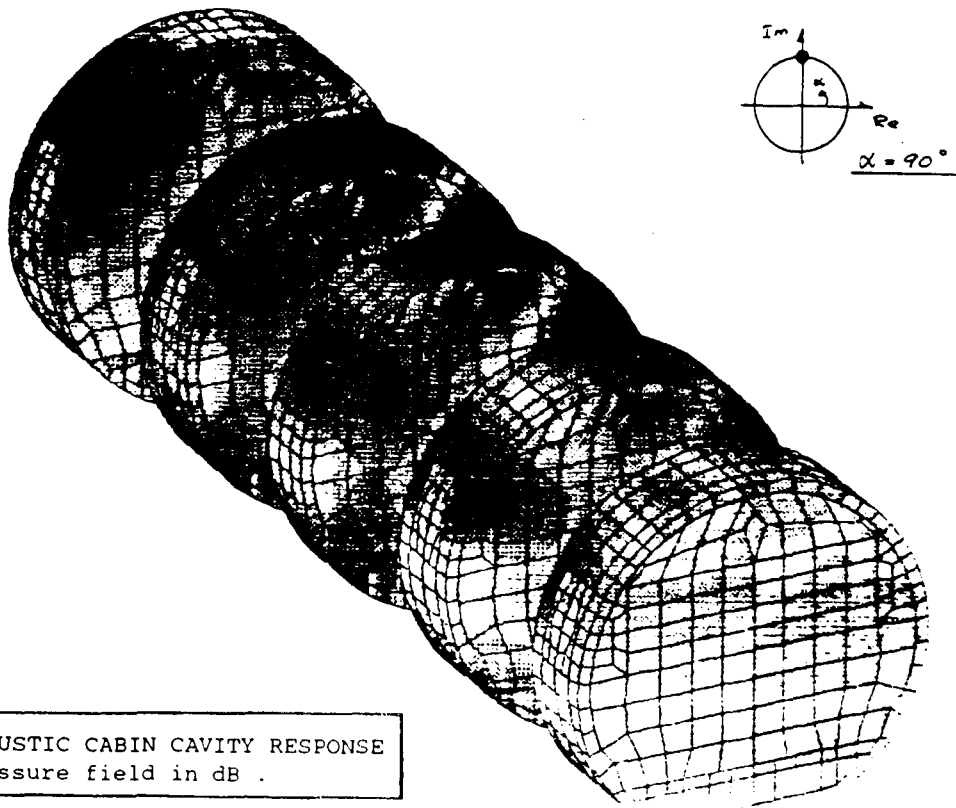
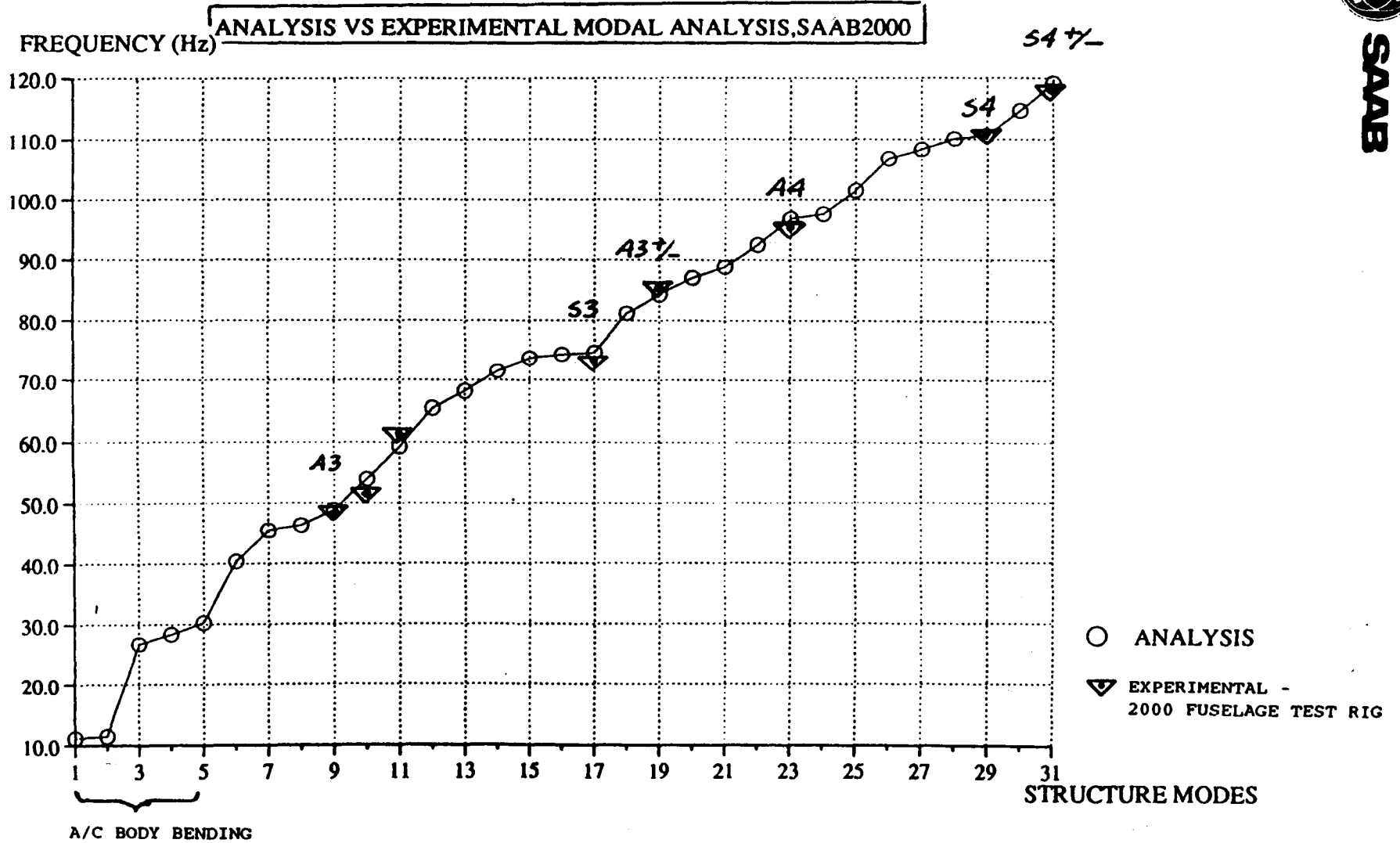


Fig ACOUSTIC CABIN CAVITY RESPONSE
Pressure field in dB .

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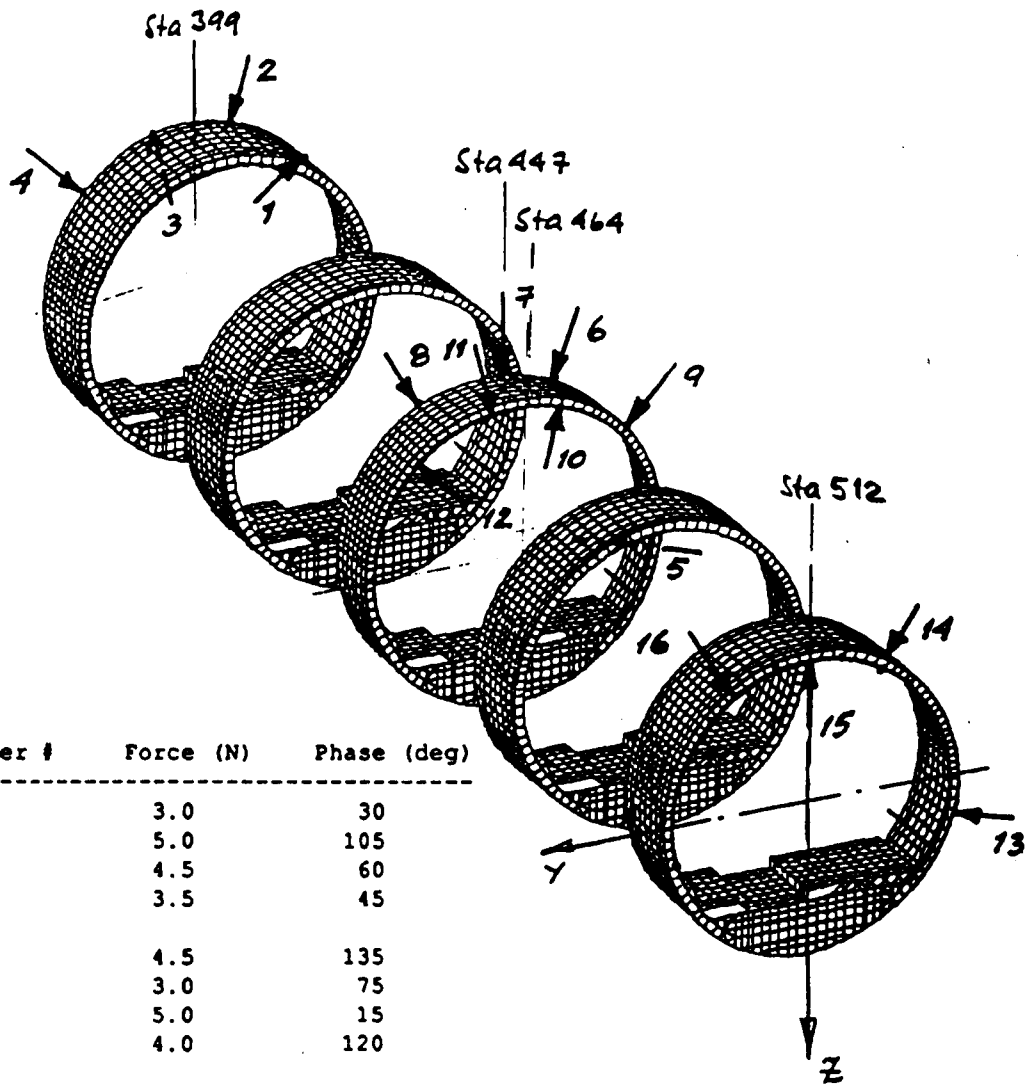




MODEL VALIDATION ANALYSIS

Acoustic Mockup shaker test simulation

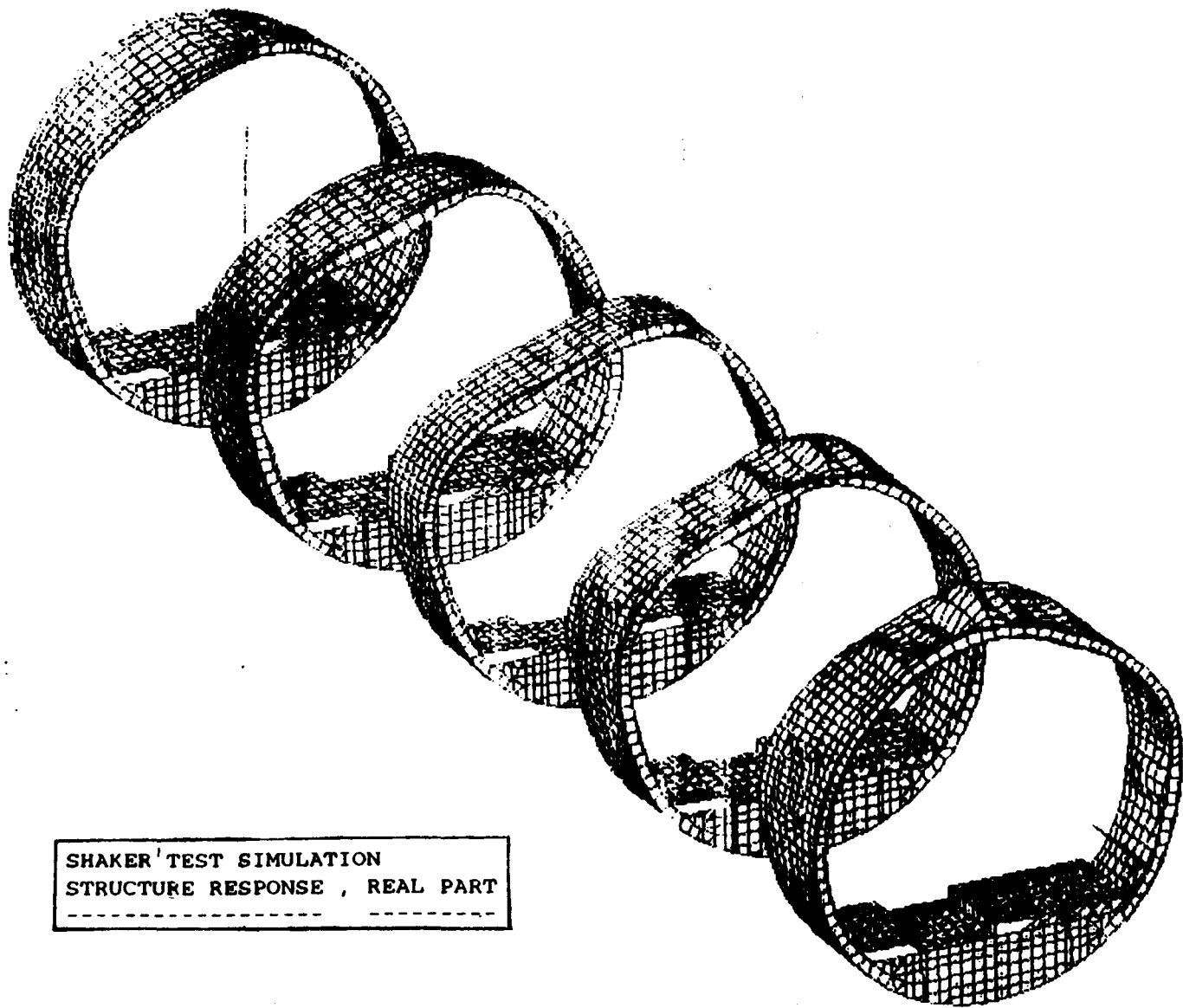
- * 16 shakers with simultaneously sinusoidal force (95 Hz) excitation.
- * Force and phase distribution randomly chosen.



Shaker #	Force (N)	Phase (deg)
1	3.0	30
2	5.0	105
3	4.5	60
4	3.5	45
5	4.5	135
6	3.0	75
7	5.0	15
8	4.0	120
9	3.5	150
10	4.5	120
11	3.5	75
12	5.0	45
13	4.0	15
14	3.5	60
15	5.0	165
16	4.0	105

71 5000 100 000 0100 Problem 10 1200

ORIGINAL PAGE IS
OF POOR QUALITY

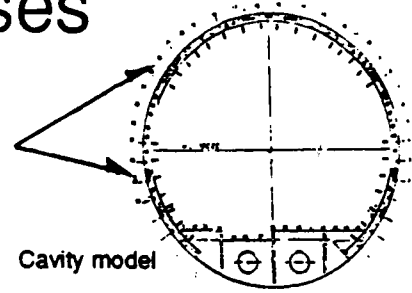


SHAKER TEST SIMULATION
STRUCTURE RESPONSE , REAL PART



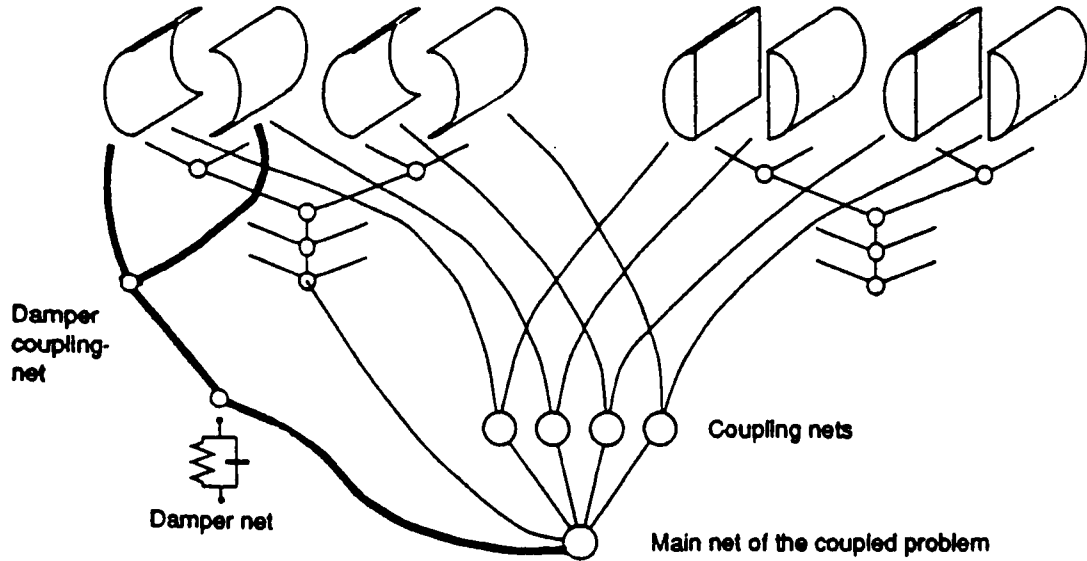
Planned analyses

- Tuned dampers



Structure model

Cavity model



- Structure-borne path identification

- Active Vibration Control

