ACCEPTANCE DATA PACKAGE

NASA CONTRACT NAS8-39409

SXI STEPPER MOTOR/ENCODER

AEROFLEX P/N 16187

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D - STRENGTH ANALYSIS

SECTION D

STRENGTH ANALYSIS

AEROFLEX
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STRENGTH ANALYSIS REPORT

FLIGHT READINESS REVIEW (FRR)

for

SXI STEPPER MOTOR/ENCODER

Prepared by
Aeroflex Laboratories
Farmingdale New York

for

NASA - MSFC

In Accordance with MSFC-HDBK-505A

Summary:

The strength analysis report for FRR shall include only revisions to update the strength analysis reports for the flight design configuration. Since there have been no revisions to the design configuration since the PDR and the CDR this report shall consist of re-submitting the analysis previously performed.

In addition the motors have been subjected to Sine vibration, Random vibration, and shock per the SXI specification. Both motor/encoders have passed all three tests. There was no evidence of damage to the motor/encoder and the motor/encoder performed as required by the Acceptance test procedure. No degradation was seen between the before and after performance tests. The testing verified the analysis that there were adequate safety margins with regard to structural integrity. Separate reports are available from the test facility and are apart of the FRR submittal.

STEPPER MOTOR/ENCODER

SOLAR X-RAY IMAGER (SXI)

STRESS ANALYSIS

(ARX P/N 16187)

March 16, 1994

AEROFLEX

SXI STEPPER MOTOR/ENCODER

VIBRATION STRESS ANALYSIS

EXTRACT

An FEA stress analysis was performed on the Aeroflex design to assure that the motor will withstand the random vibration spectrum shown in Figure 11. The program used was ALGOR with updated releases to 5/21/93. The results are tabulated in Table I. Constants and values used for the analysis are listed in Table II.

The analysis focused on:

* ... The Housing (with special regard paid to the three mounting posts). A slug of dense material was cantilevered from the bearing mounting surface to simulate an unbalanced load on the mounting screws equaling the rotor weight. (It was necessary to use this simplified load and not use the actual rotor model so as not to exceed the disk space required for temporary storage files in the FEA processing). The housing was constrained on the inner surface of the mounting holes to simulate the insert contact area. All other volume was free to move in 6 axes (three translation and three rotation).

* ... The Rotor with encoder disk. The assembly was constrained on the outer bearing surface area.

* ... The large PC Board with tantalum shields attached in their 4 locations. The PC Board was constrained on the inner surface of the 4 mounting holes.

* ... The stress introduced by the shrink fit of the bearing liner in the housing. The outer housing was heated to +71C and the insert cooled to -40C. The stress was measured at 0 degrees C.

The vibration energy was applied in the x direction and in the y direction independently.

The summary of results is shown in Table I.

CONCLUSIONS

The stress induced by vibration and thermal differentials were within the material linear ratings. However, the shrink fit of the bearing retainer sleeve into the housing was deemed to be too tight. It was necessary to press fit the two sections even at temperature. The fit now has a 2 tenths clearance at temperature. The stress reflected in the Figure 6 reflect this change.

The design is satisfactory and no further changes are necessary.

* Please note that figure displacements are highly exaggerated to make the small displacements visible.

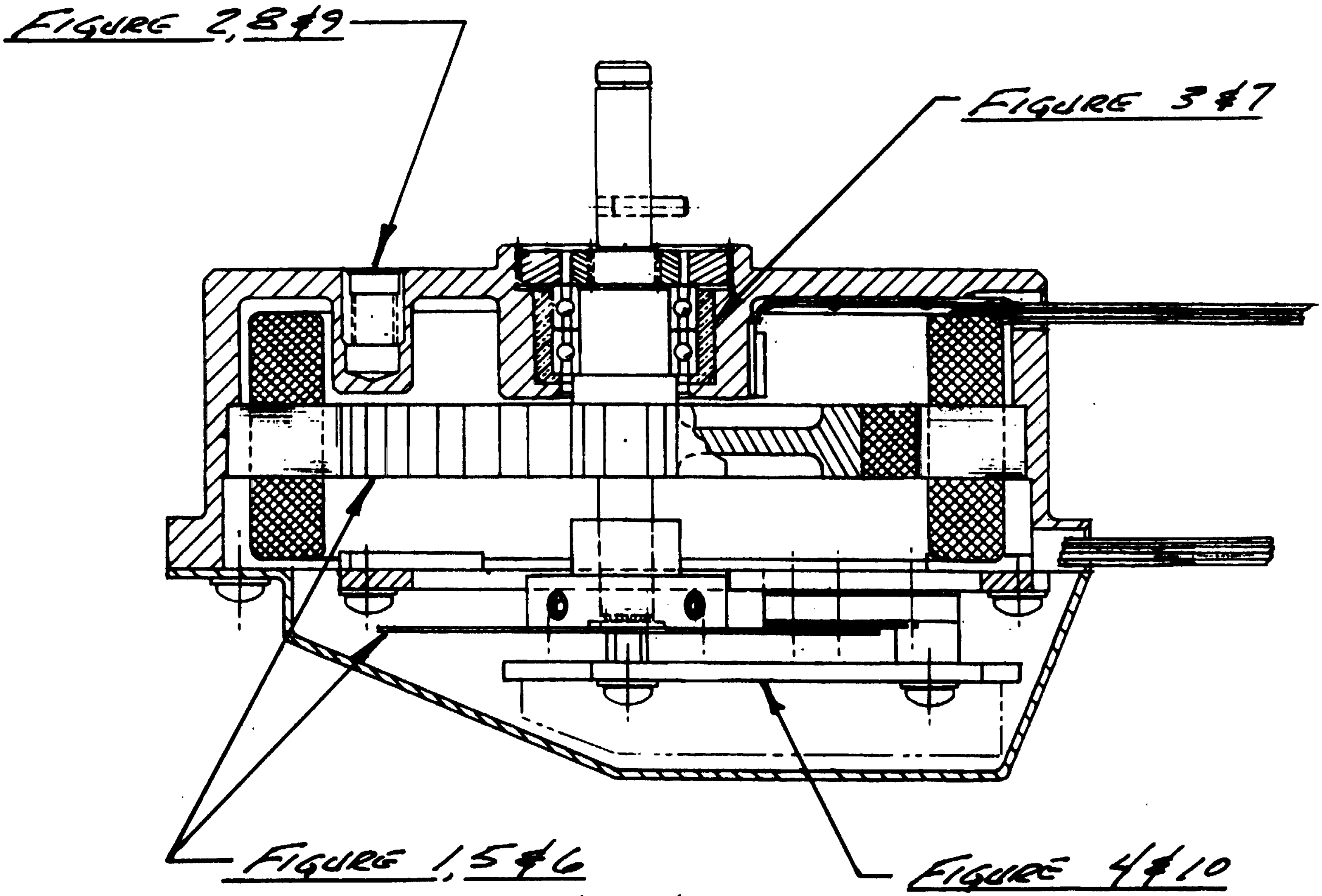
* Not all stress and displacement results were plotted but they are shown in Table I

TABLE I

ITEM DESCRIPTION	RESONANCE (Fund)	
1) ROTOR/ENCODER DISC	1096 Hz (rotary)	
	1238 Hz (X & Y)	
2) HOUSING	2509 Hz	
3) PC BOARD	1240 Hz	
	X VIBRATION	
	MAX STRESS (PSI)	MAX DISP (IN)
1) ROTOR/ENCODER DISC	0.94 (ROTARY)	9.8E-8
	0.187 (X)	1.7E-8
2) HOUSING	211	7.9E-5
3) PC BOARD	11.9	6.4E-6
	Y VIBRATION	
1) ROTOR/ENCODER DISC	0.0012 (ROTARY)	1.2E-10
	1442 (Y)	1.3E-4
2) HOUSING	1.2	4.5E-7
3) PC BOARD	11.4	6.4e-6

TABLE II

MATERIAL	DENSITY	YOUNGS MOD	LIN EXP
ALUMINUM	0.11 LBS/IN^3	10E6 PSI	23.4E-6 IN/IN/C
STEEL	0.29	29E6	10.6E-6
BeCu	0.298	18.5E6	N/A
G10 EPOXY	0.065	22E5	N/A
TANTALUM	0.6	27E6	N/A
SIM WGT(HSG)	5.5	29E6	N/A



MOTOR/ENCODER
(ARX P/N 16187)

AEROFLEX

ROTOR/ENCODER DIS. / SHAFT ASSEMBLY

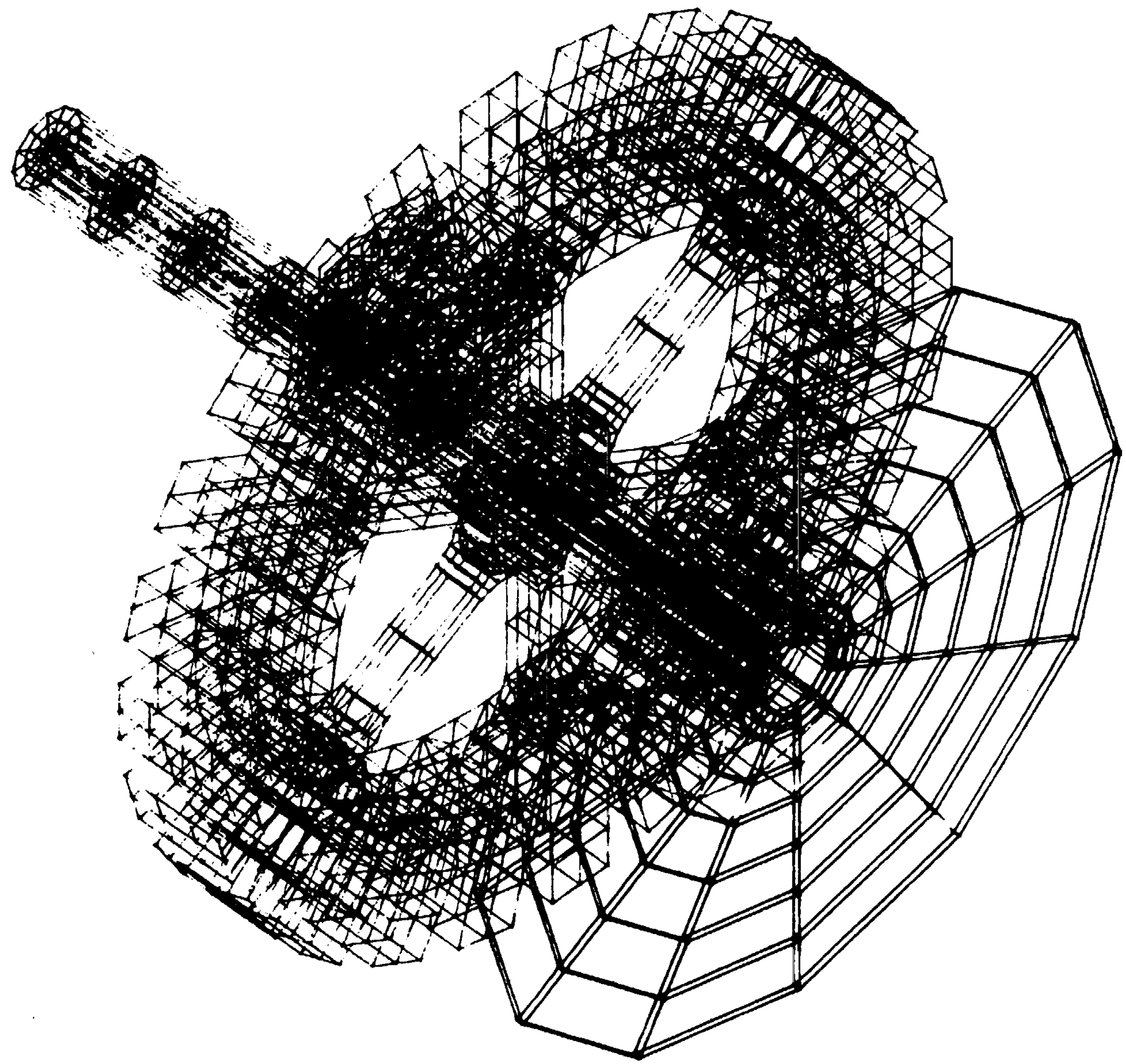


FIGURE I

HOUSING ASSEMBLY

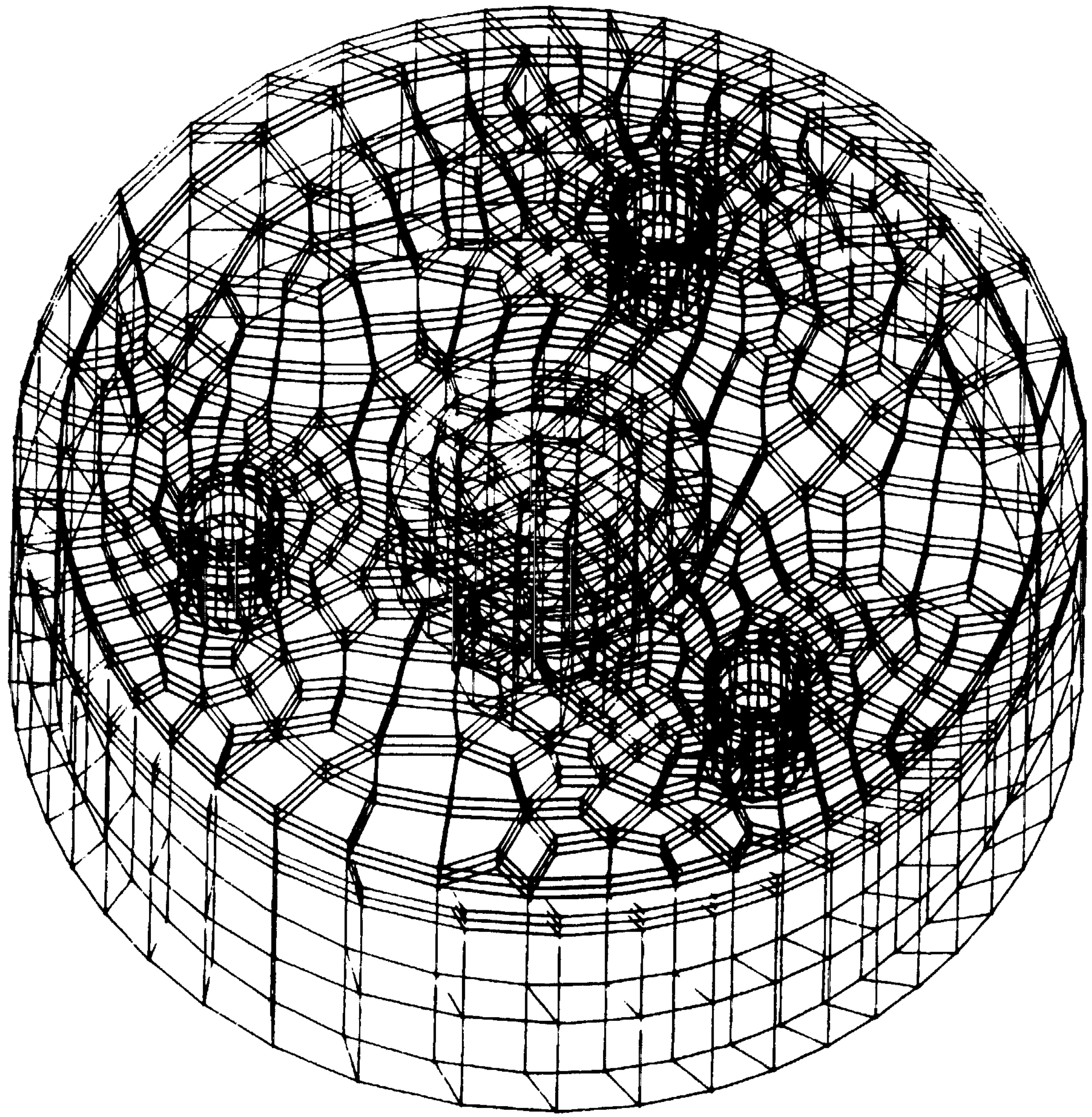


FIGURE 2

BEARING SLEEVE INSERT

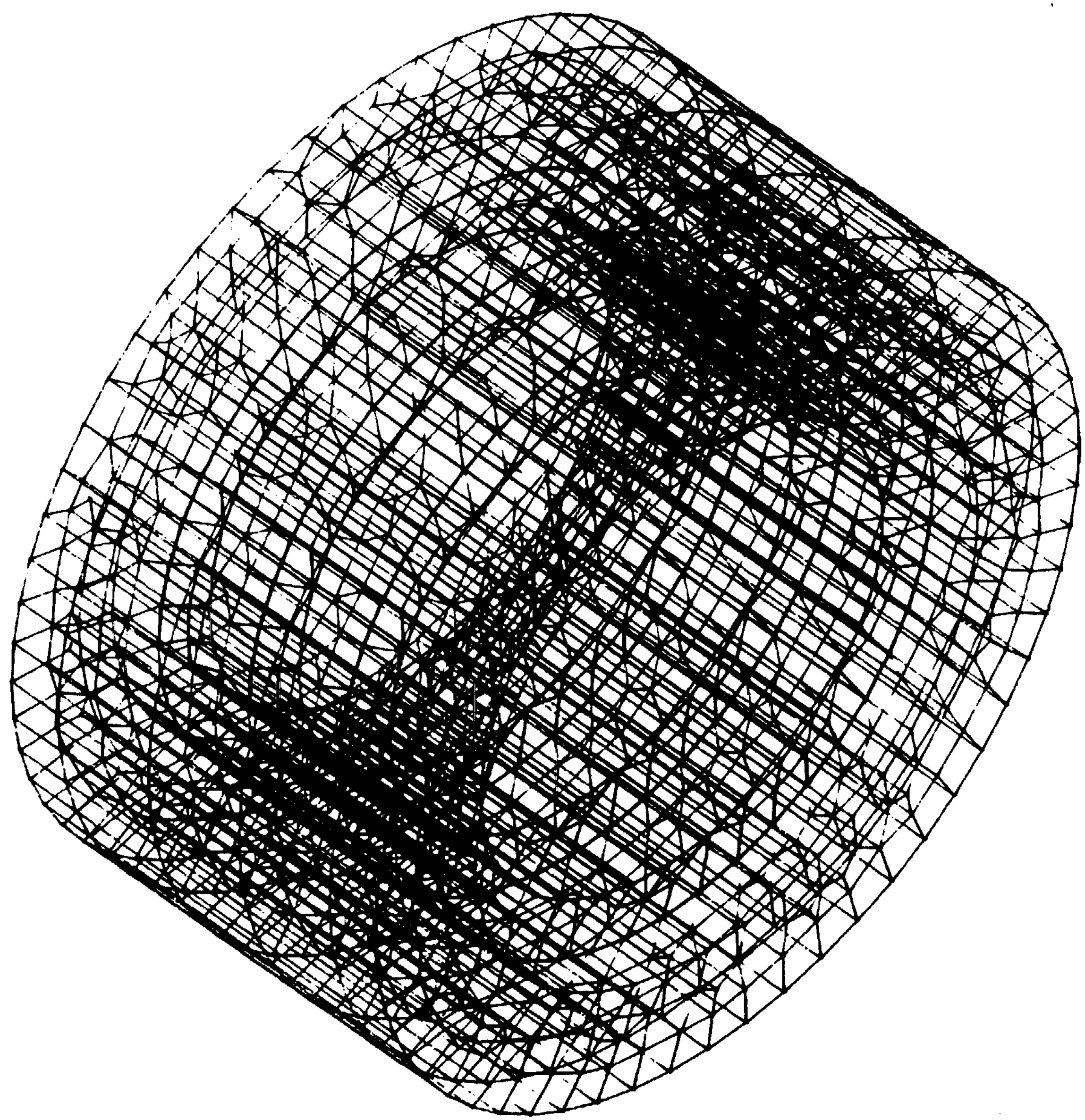


FIGURE 3

PC BOARD WITH TANTALUM

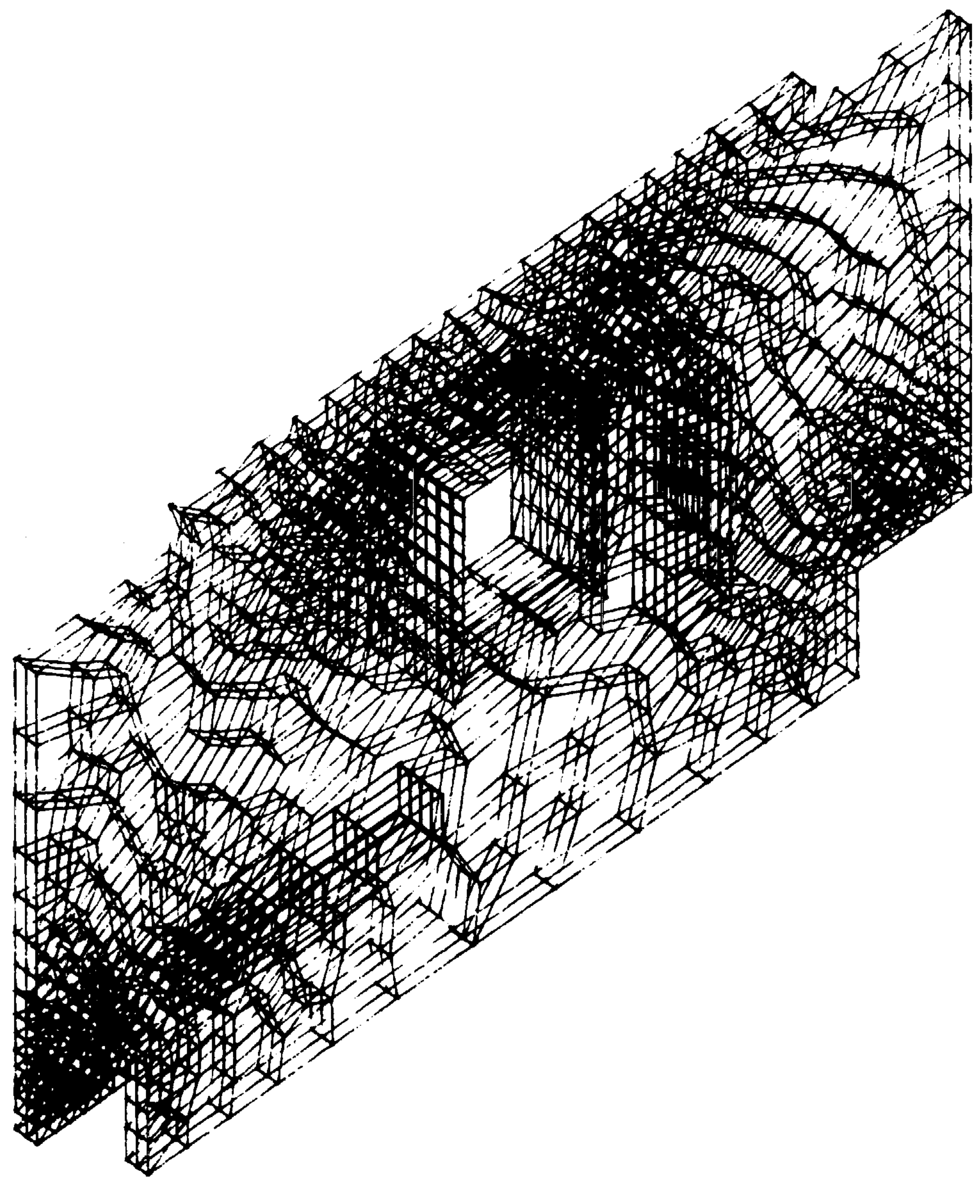


FIGURE 4

ROTOR DISPLACEMENT FOR X DIRECTION VIBRATION

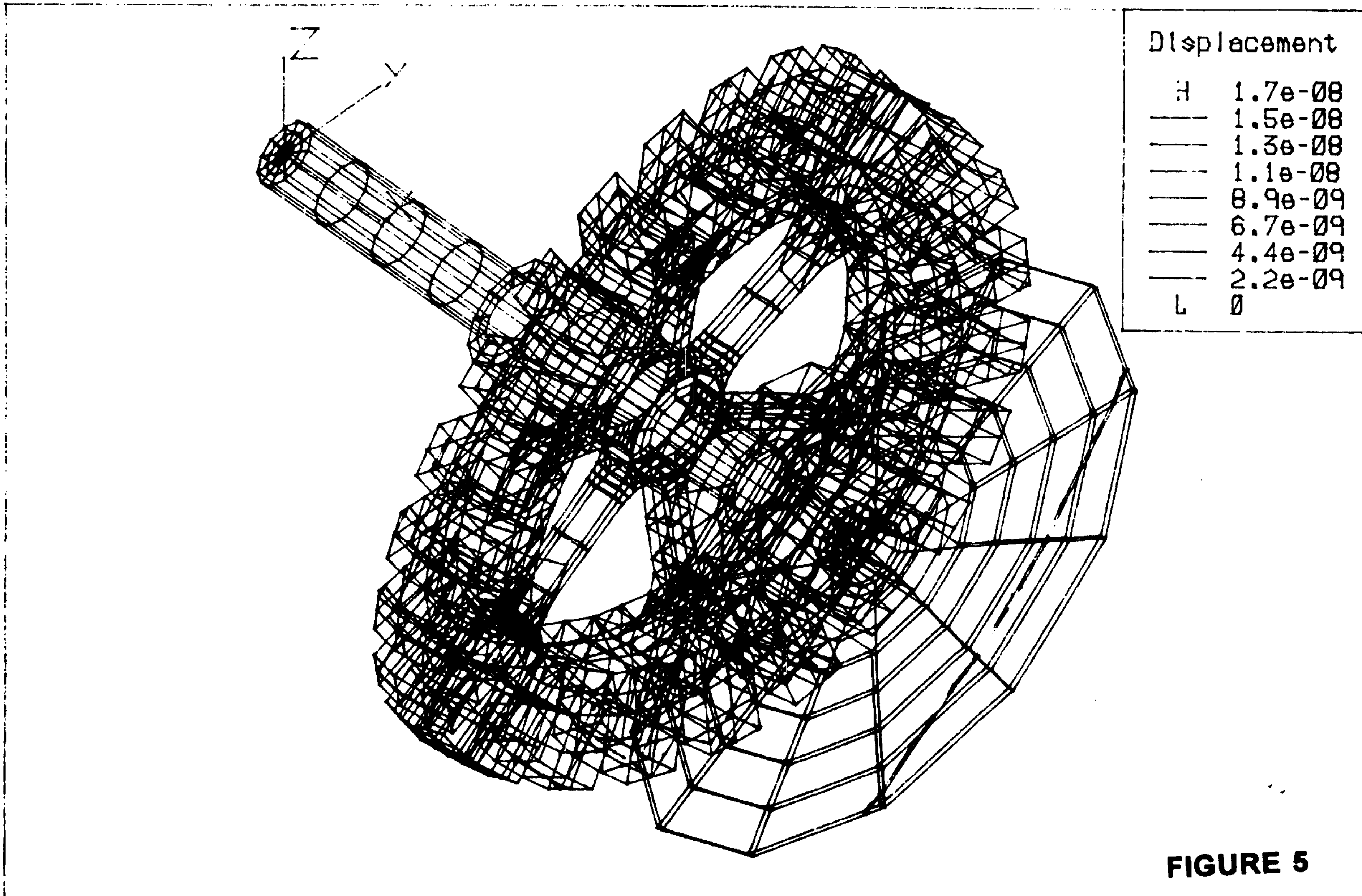


FIGURE 5

ROTOR STRESS (WITH DISPLACEMENT) FOR Y DIRECTION VIBRATION

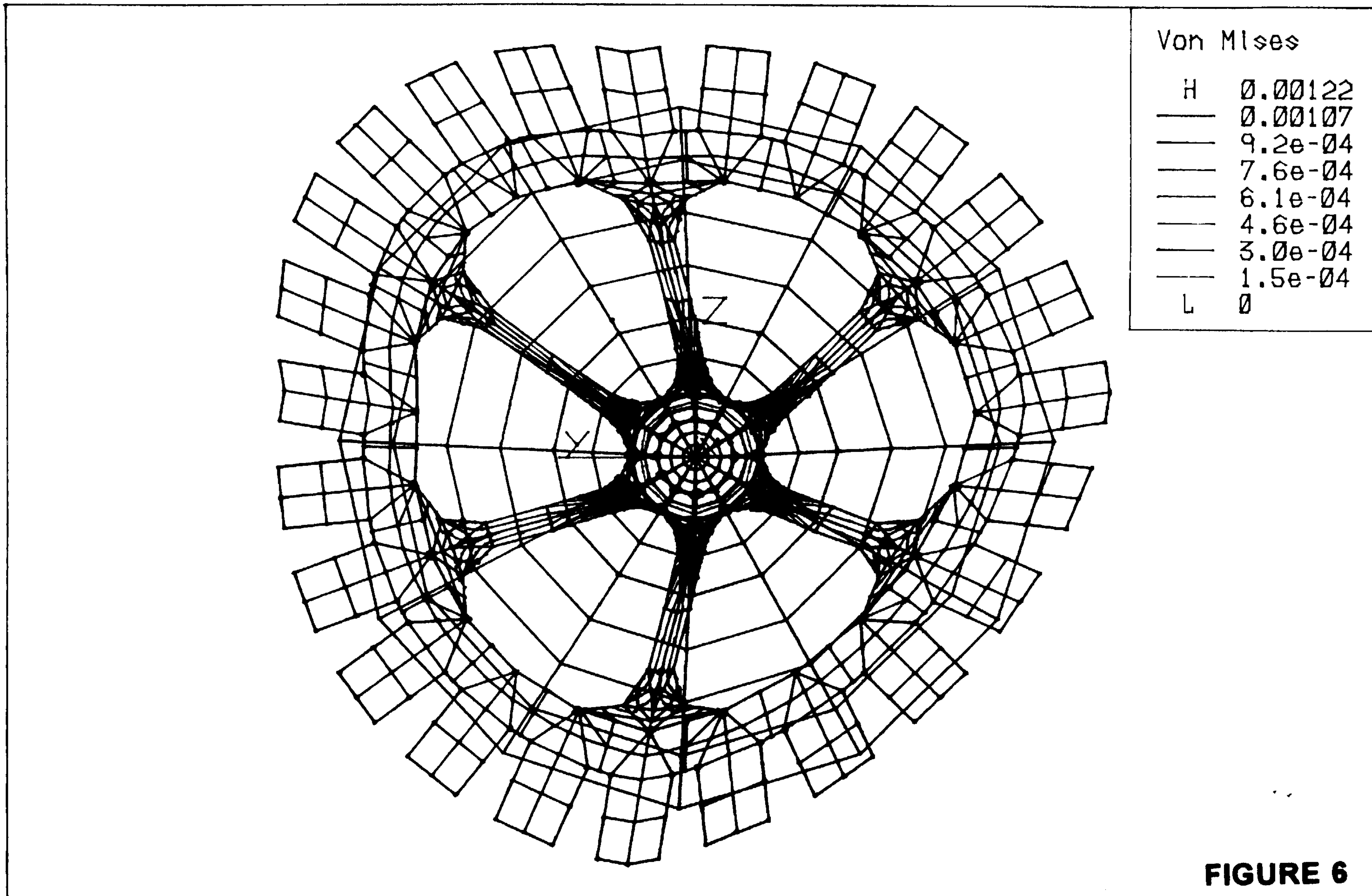


FIGURE 6

BEARING SLEEVE STRESS (CUT AWAY)

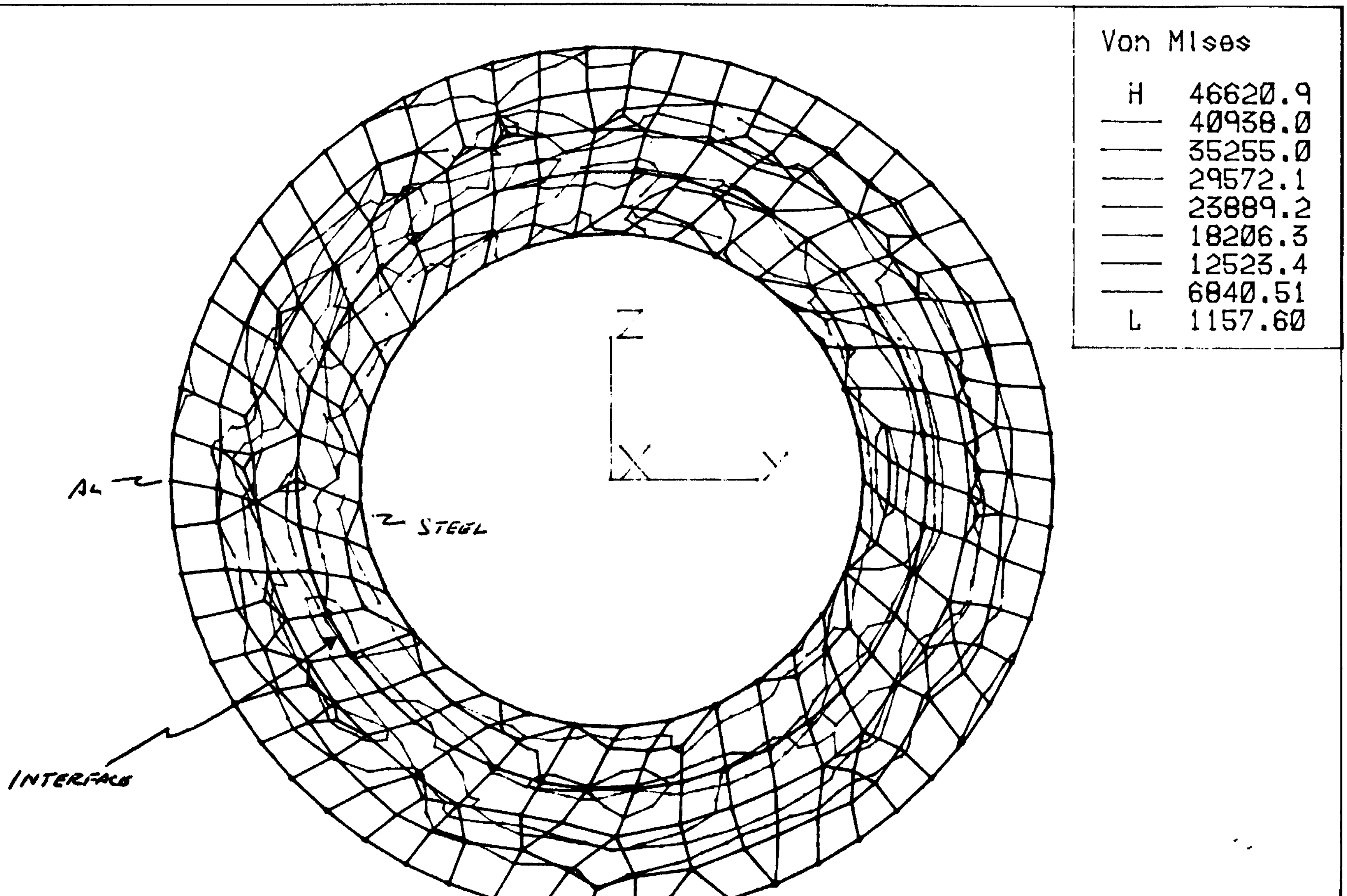


FIGURE 7

HOUSING INSERT POCKET STRESS (ENLARGED)

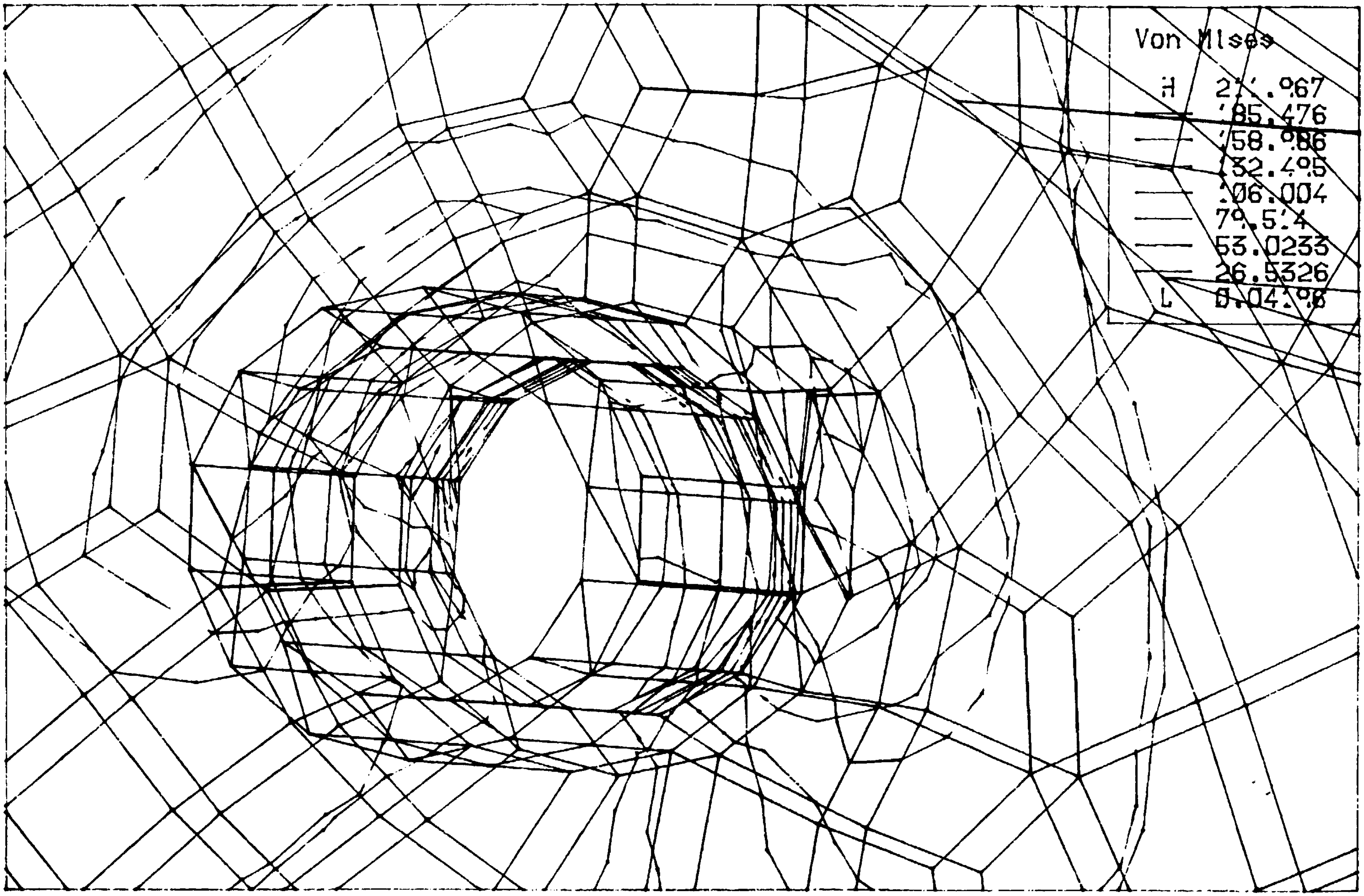


FIGURE 8

HOUSING INSERT CONSTRAINTS

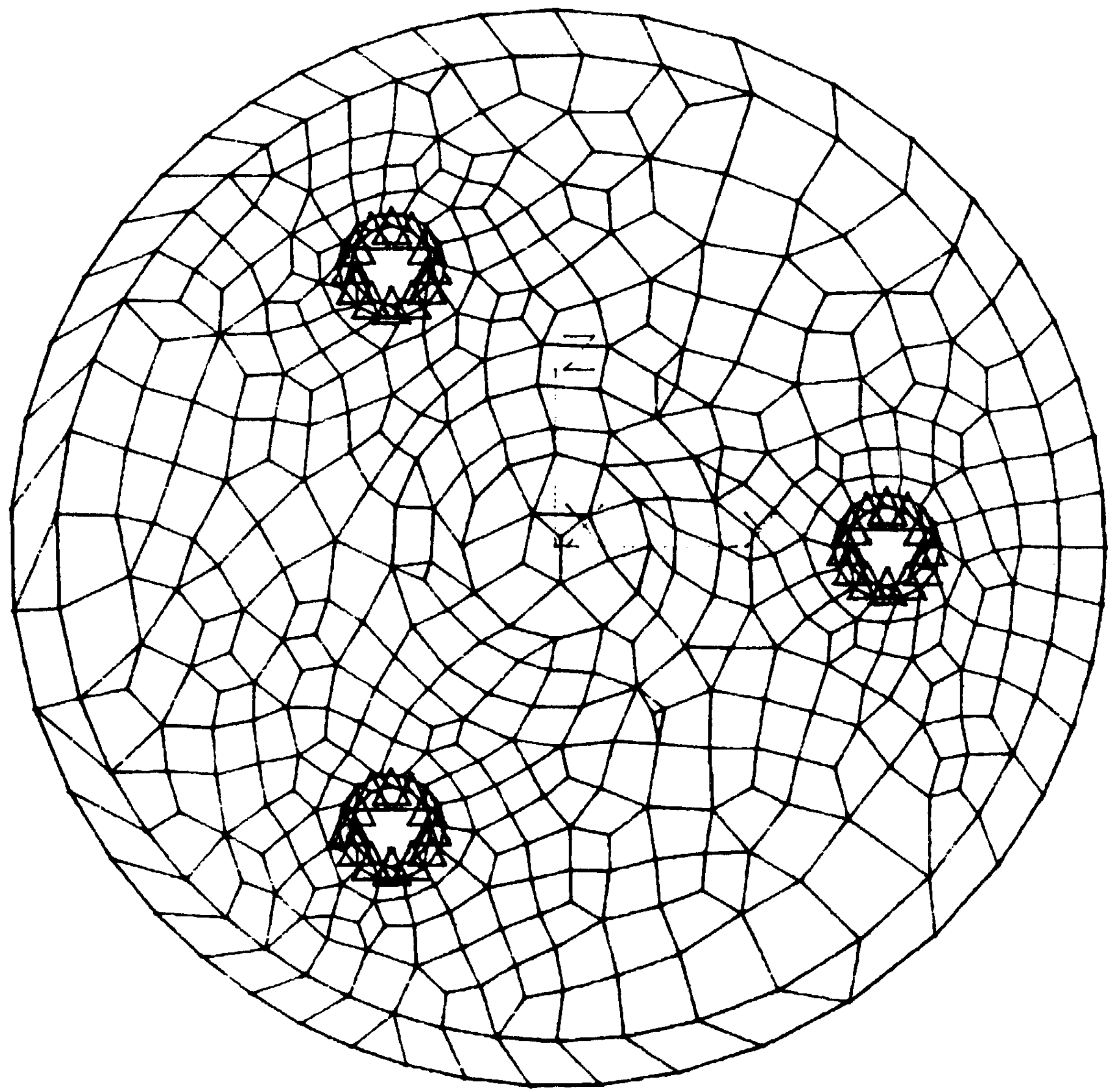


FIGURE 9

PC BOARD DISPLACEMENT FOR X AXIS VIBRATION

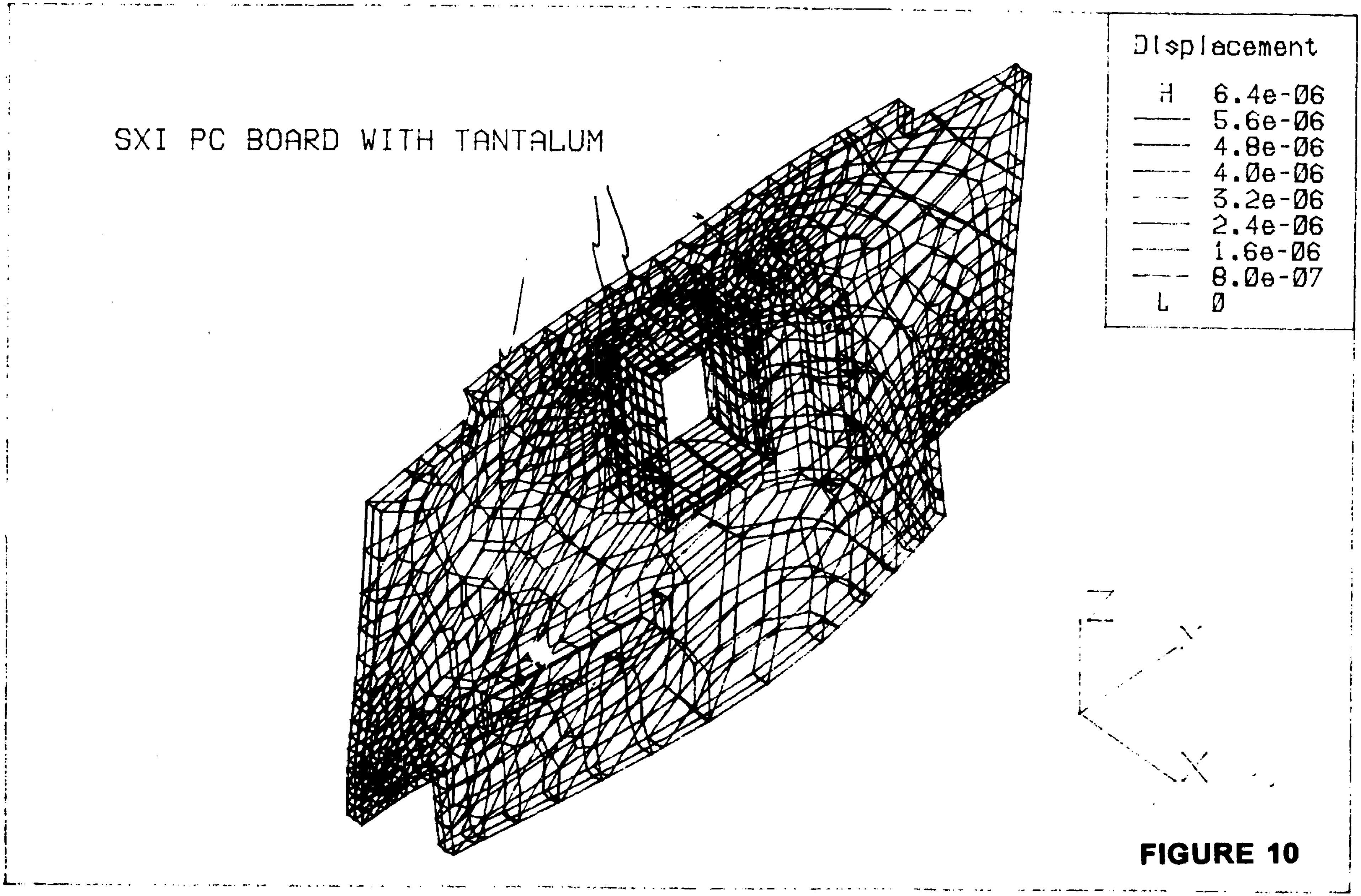


FIGURE 10

M021492.XLC

SXI MOTOR RANDOM VIBRATION CRITERIA 2/14/94 26.1 Grms

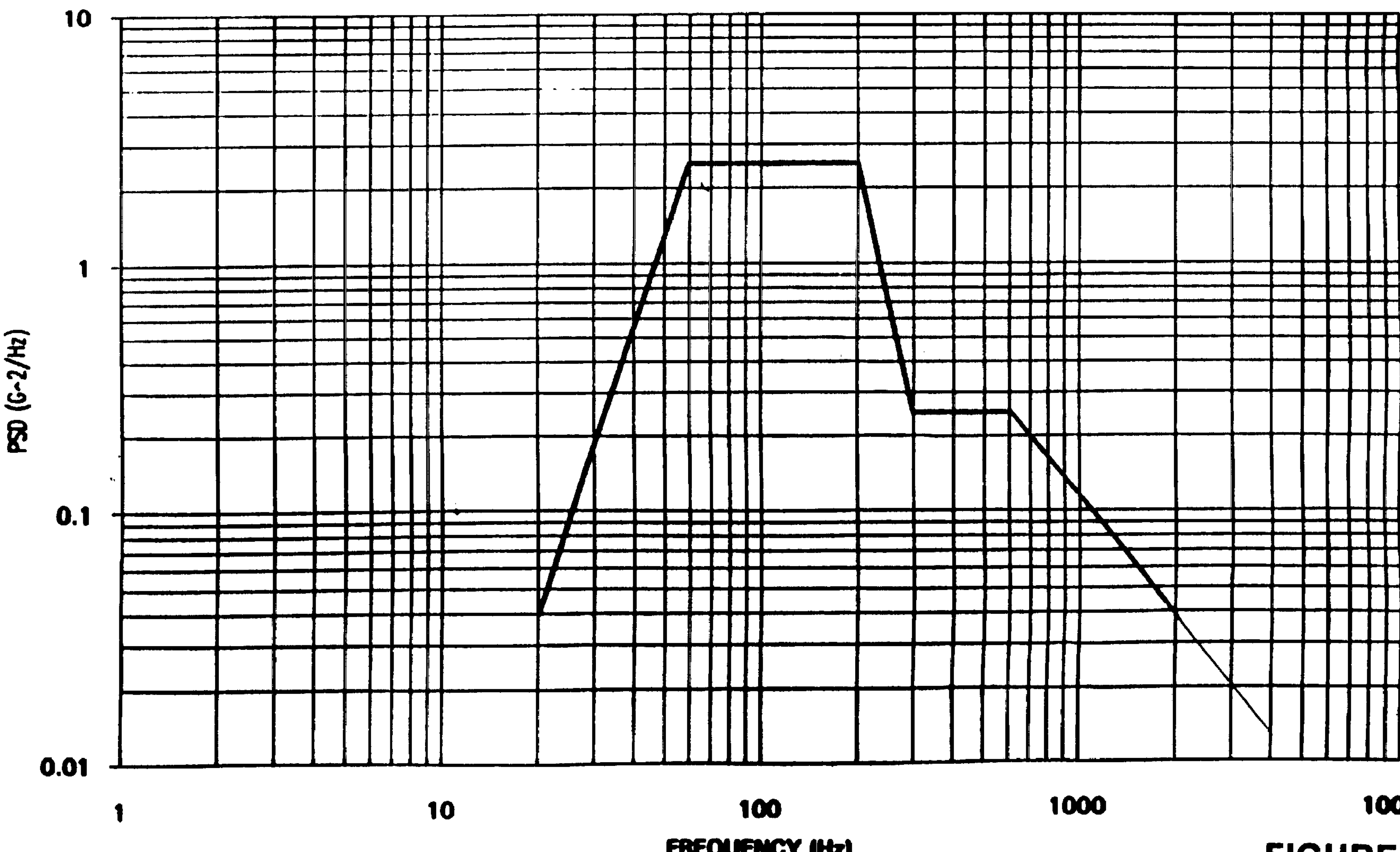


FIGURE 11

ADDENDUM: Response to NASA 3/30/94 comments on stress analysis for the SXI motor.

Additional analysis added static loads, combined loads and sine vibration to the existing random vibration analysis.

The stress and displacement calculations are performed by the ALGOR FEA program. The ALGOR program allows the excitation of static accelerations in each of three axis or combinations of these axis to be applied to the model. This feature was used to determine the stresses and displacements for the static and combined loads. The program also allows a single frequency at a given acceleration be applied to the model in any of three axis. This feature was used to apply the sinusoidal excitation to the models.

The models were created using the dimensions of the drawing and were decoded into 3 dimensional "bricks" for the finite element analysis.

The rotor and hub assembly was constructed with a manual mesh to control densities so that reasonable computer space was available for calculation. The model was constrained at the bearing surface which prevented rotational or translational motion. All vibration inputs were relative to this base.

The Housing was constrained at the inner surface of the three mounting holes. A dense weight was cantilevered off the outer bearing surface to produce moments which would be applied by the actual rotor and stator during vibrations and accelerations.

The PC board was constrained at the inner surface of the 4 mounting holes. The tantalum shields were mounted to the pc board and IC's as shown in the drawings.

A series of 4 Tables show the type excitation, stress, displacement, yield strength used for the analysis, Safety factor used, safety margin between stress produced and yield strength reduced by the safety factor. (ie (yield strength/safety factor)/stress induced:1)

The material properties are shown in Table II of the original report.

Not every combination of load or every type of axis excitation was calculated because inspection of the data shows that the device is clearly well within yield limits with large safety margins for the materials and configurations designed. E.G. 14.7 G's was used for every axis in the analysis and not reduced as it could have been for the other axes. The displacements seen will be well clear of hitting other adjacent structures. In addition, the motor/encoder will undergo vibration testing.

SXI STRESS ANALYSIS

Component

ROTOR, MOTOR

Comments: $R_x = 3 * (\pi/2 * 1 * 1232 * .08)^{1/2} = 37.4$

Type excitation	Stress	Disp	Yield	Safty F	Safty M	Plt
STATIC, 14.7G's, X AXIS	595 PSI	2.7E-5 IN	2.45E5 PSI	1.25	325:1	FIG 1A
STATIC, 14.7G's, Y AXIS	422 PSI	1.7E-5	"	"	464:1	
COMBINED $R_x + S_x = 52.14$, $S_y = S_o = 14.7G$	.2169	2.4E-4	"	"	90:1	FIG 2A
SINE, X AXIS, 14.7G @ 50 HZ	.11	1.1E-8	"	"	1.78E6:1	
Random, X AXIS	.187	1.7E-8	"	"	1.5E5	FIG 5
Random, Y AXIS	1442	1.3E-4	"	"	139.4:1	FIG 6

SXI STRESS ANALYSIS

Component

Rotor, Encoder

Comments:

Type excitation	Stress	Disp	Yield	Safty F	Safty M	Plt
Static, 14.76's, X axis	100 PSI	4.6E-5 inch	3.6E4	1.25	288.1	Fig 1A
Static, 14.76's, Y axis	< 35 PSI	7.1E-5	"	"	> 1028:1	
Combined $R_x \cdot S_x$: 52.16, $S_y \cdot S_z$ · 14.74	542	2.3E-4	"	"	53:1	Fig 2A
Random, X	< .187	< 1.7E-8	"	"	> 1.5E5:1	Fig 5
Random, Y	< 1442	< 1.3E-4	"	"	> 139:1	Fig 6

SXI STRESS ANALYSIS

Component

Housing

Comments: $R_x = 3 * (\frac{1}{2} * 1 + 2509 * .015)^{1/2}$

Type excitation	Stress	Disp	Yield	Softy F	Softy M	Plt
STATIC, X AXIS	197 PSI	8.5E-6	4.0E4 PSI	1.25	162:1	FIG 3A
Combined $R_x + S_x = 37.7$, $S_y = S_z = 14.7$	889	4.1E-5	"	"	36:1	FIG 4A
Random, X, Fig 11	211	7.8E-5	"	"	133:1	FIG 8
Random, Y, Fig 11	1.2	4.5E-7	"	"	2.3E4:1	

SXI STRESS ANALYSIS

Component

PC Board, Lg

Comments: $R_x = 3 * (\pi/2 * 1 * 1240 * .08)^{1/2}$

Type excitation	Stress	Disp	Yield	Safty F	Safty M	Plt
STATIC, 14.7G's, X AXIS	37.1 PSI	1.9E-4 INCH	3.5E4 PSI	1.25	75:1	FIG 5A
STATIC, 14.7G's, Y AXIS	48.7	1.9E-6	"	"	574:1	
COMBINED $S_x + R_x = 52.1$ $S_y \cdot S_x \cdot 14.7$	1321	6.9E-4	"	"	21:1	
SINE, X, 14.7G @ 50Hz	384	2.0E-4	"	"	73:1	
SINE, X, 5G @ 100 Hz	132	7.1E-5	"	"	265:1	
RANDOM, X, FIG 11	11.9	6.4E-6	"	"	2353:1	FIG 10
RANDOM, Y, FIG 11	11.4	6.4E-6	"	"	2452:1	

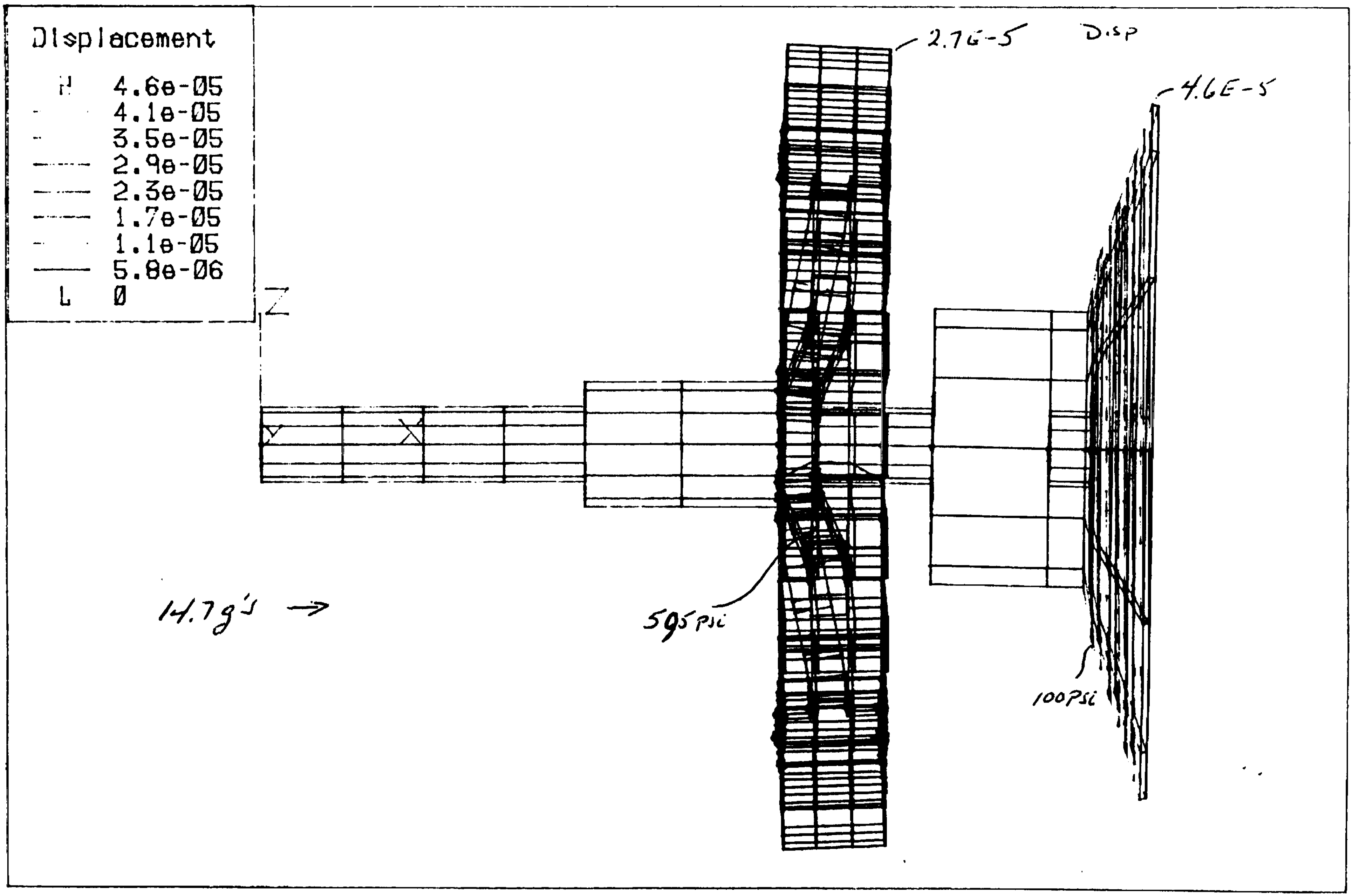

Displacement
H 4.6e-05
4.1e-05
3.5e-05
2.9e-05
2.3e-05
1.7e-05
1.1e-05
5.8e-06
L 0
Z
Y
X
2.76-5
Disp
4.6E-5
595 psi
100 psi
14.7g's →

Fig 1A

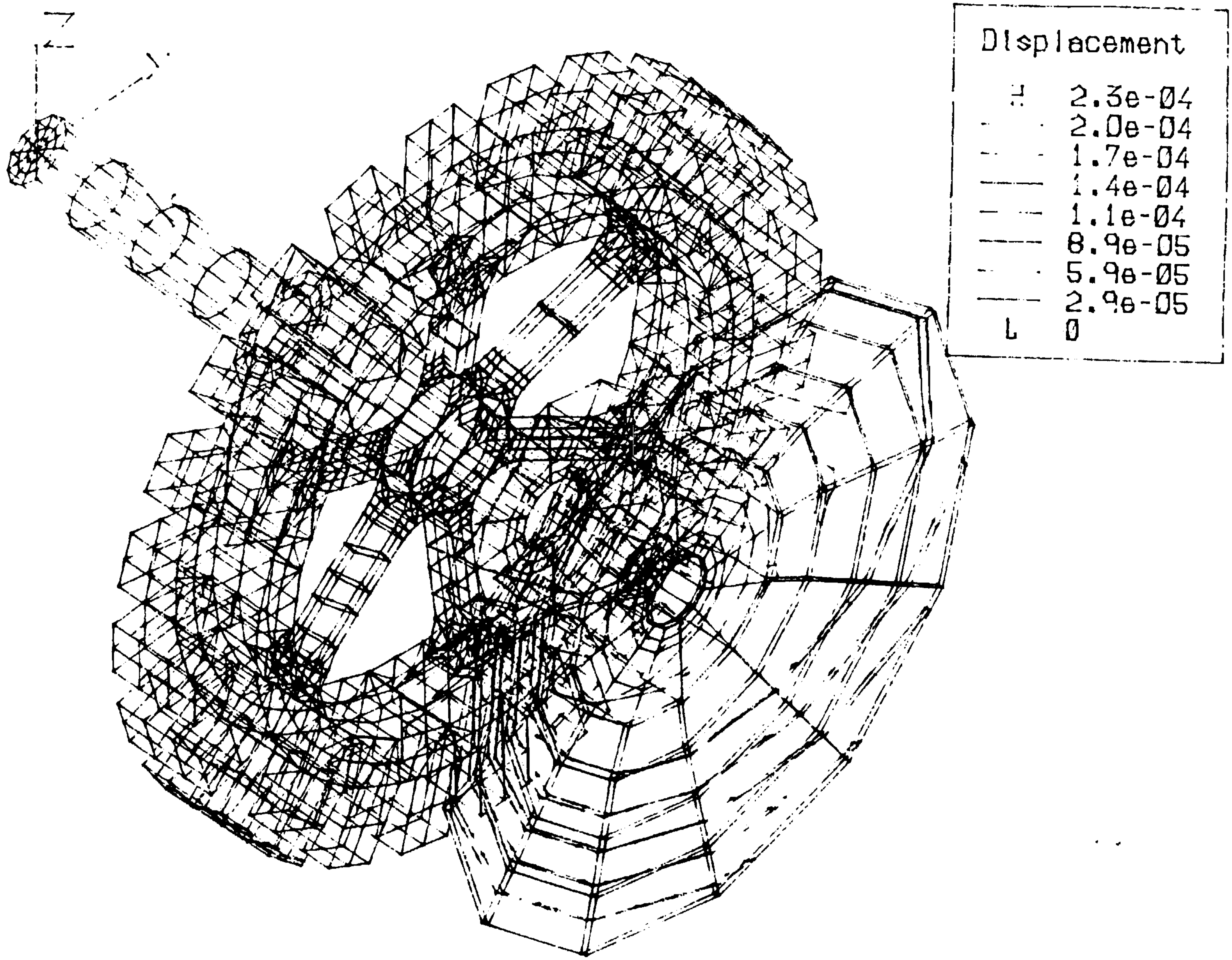

Displacement
2.3e-04
2.0e-04
1.7e-04
1.4e-04
1.1e-04
8.9e-05
5.9e-05
2.9e-05
0
Z

FIG. 2A

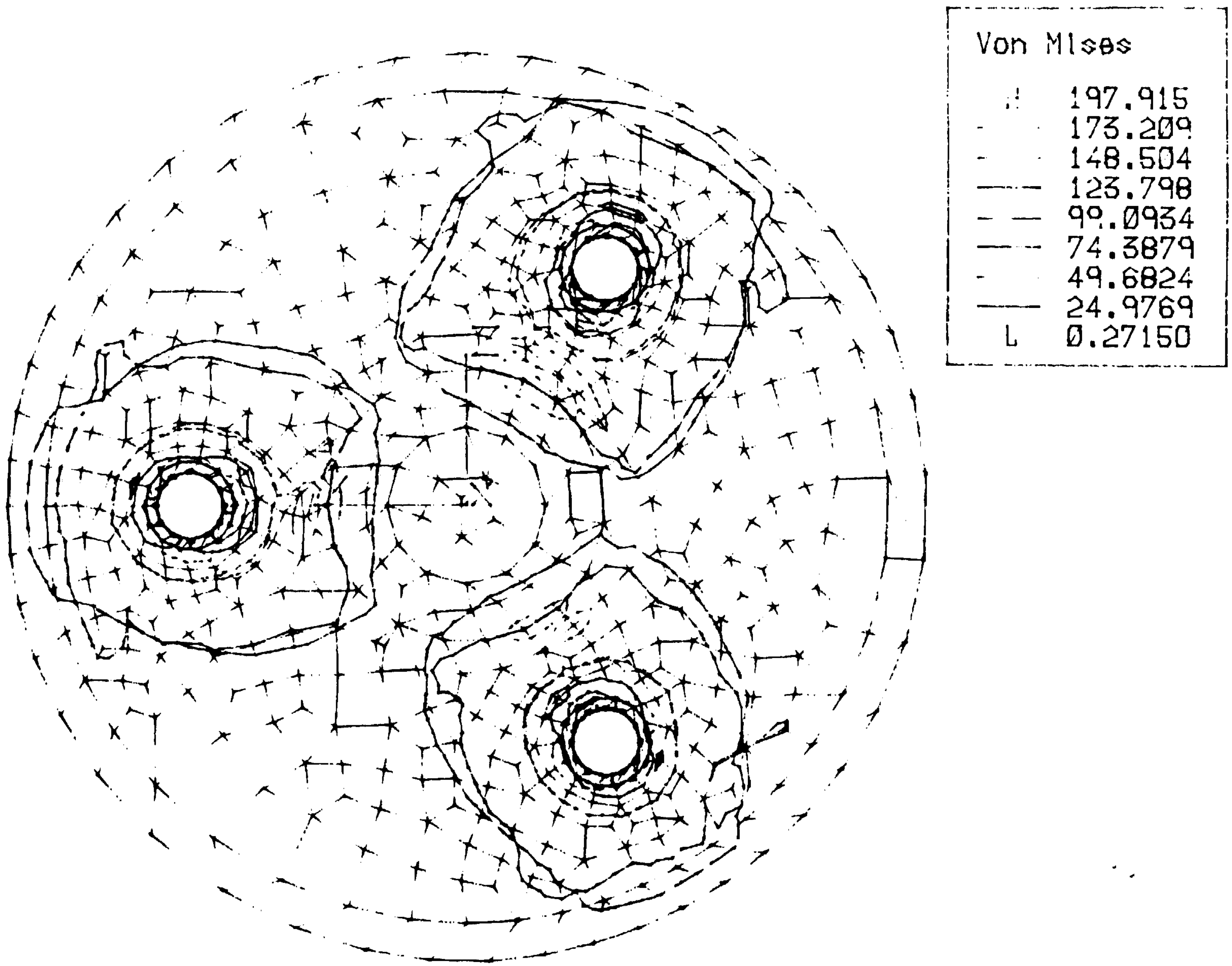

Von Mises
197.915
173.209
148.504
123.798
99.0934
74.3879
49.6824
24.9769
0.27150

FIG. 30

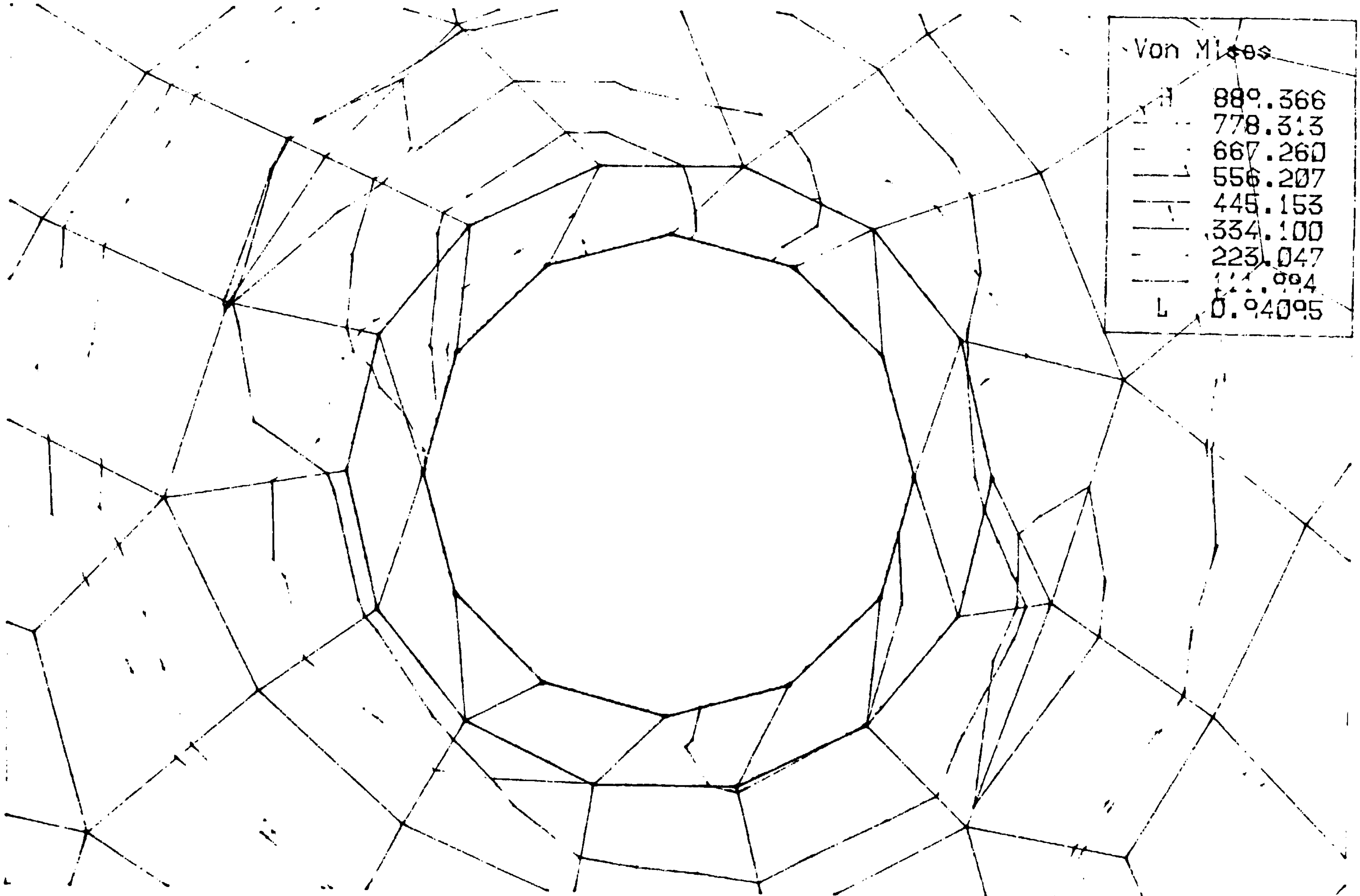
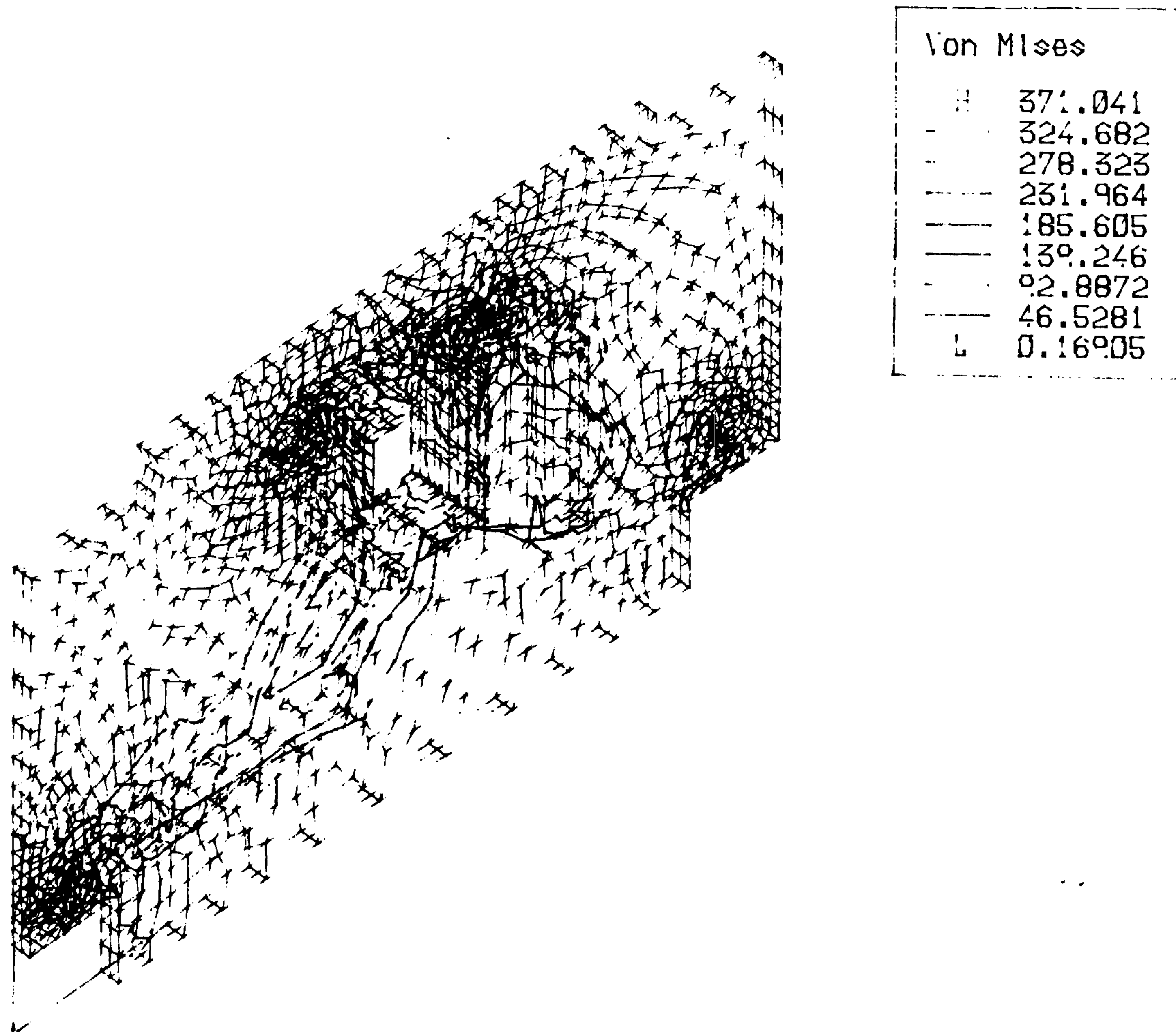
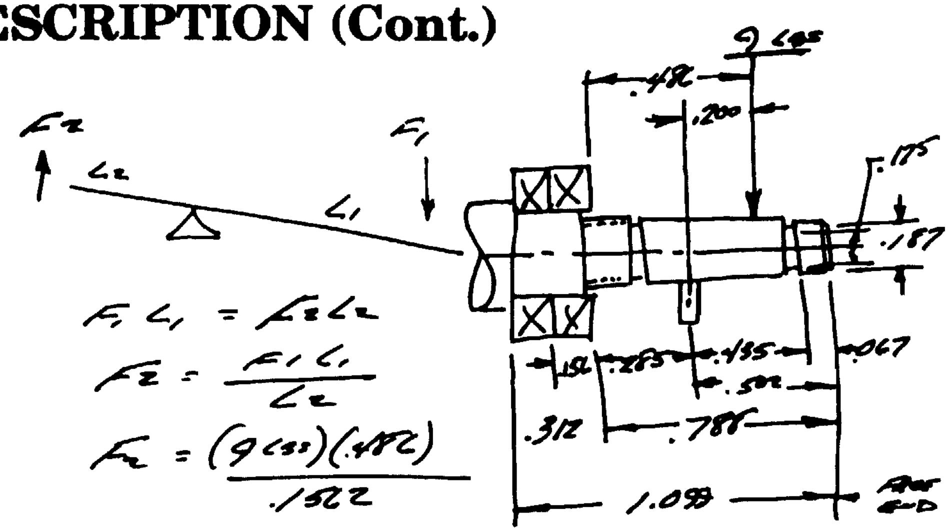

Von Mises
889.366
778.313
667.260
556.207
445.153
334.100
223.047
0.0405

FIG. 4A


Von Mises
371.041
324.682
278.323
231.964
185.605
139.246
92.8872
46.5281
0.16905

● DESIGN DESCRIPTION (Cont.)

– MOTOR



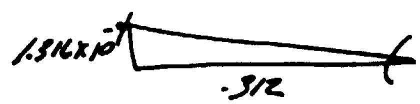
$F_1 L_1 = F_2 L_2$

$F_2 = \dfrac{F_1 L_1}{L_2}$

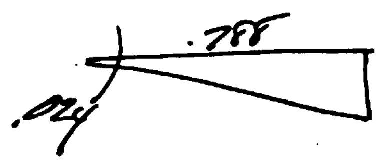
$F_2 = \dfrac{(9\ \text{LBS})(.482)}{.1522}$

28 LBS

$(28\ \text{LBS})(.0000047\ \text{RADIANS/LBS}) = 1.316 \times 10^{-4}$



$\text{TAN}\ \dfrac{1.316 \times 10^{-4}}{.312} = .024$



$\text{SIN}\ .024\ \dfrac{X}{.788} = .00033$

.00033	BEARING/LBS
.00055	M/A'L
.00088	TOTAL FREE END

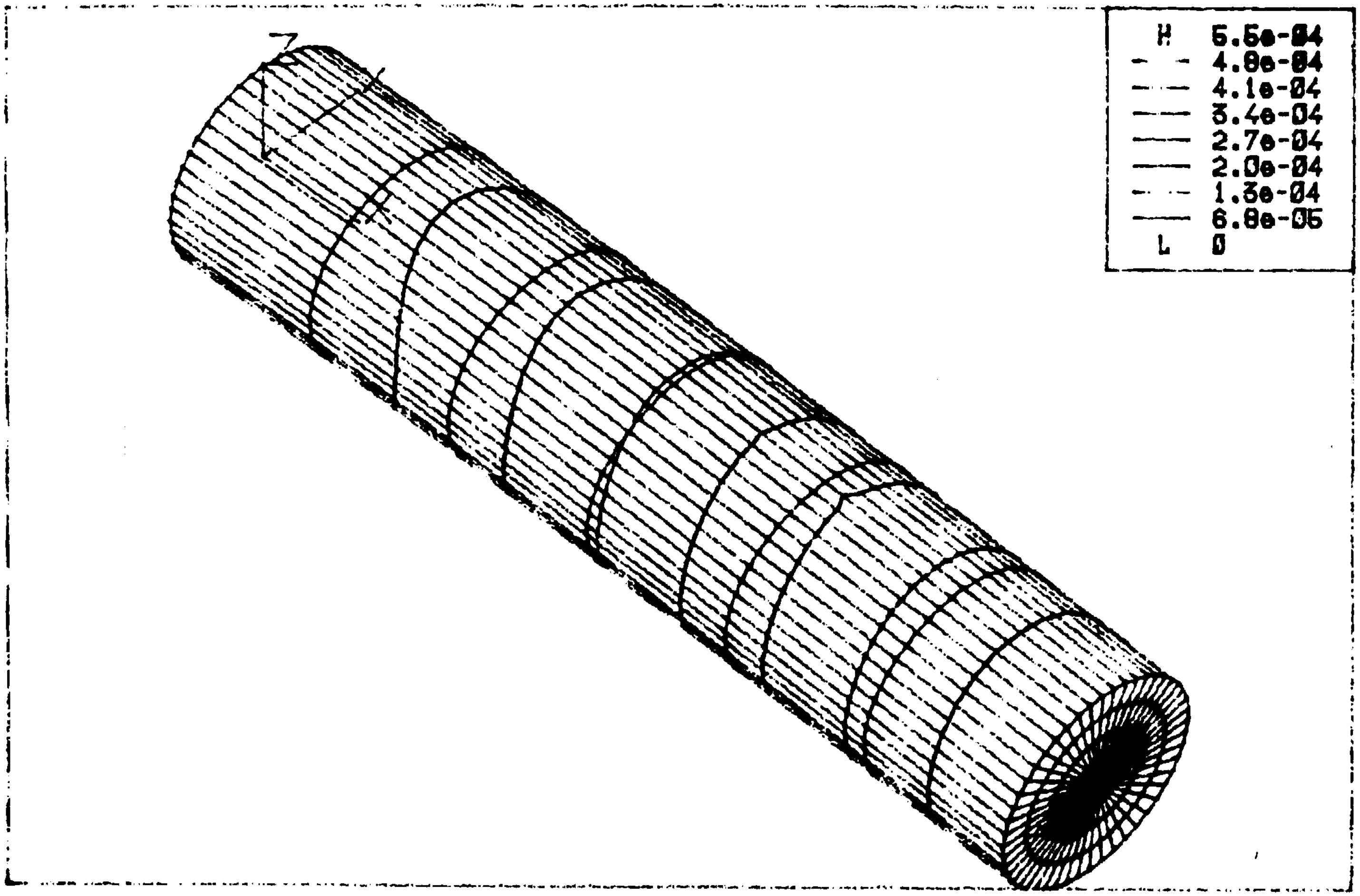
SPEC .0015 / .00088

1.7X

SHAFT DEFLECTION

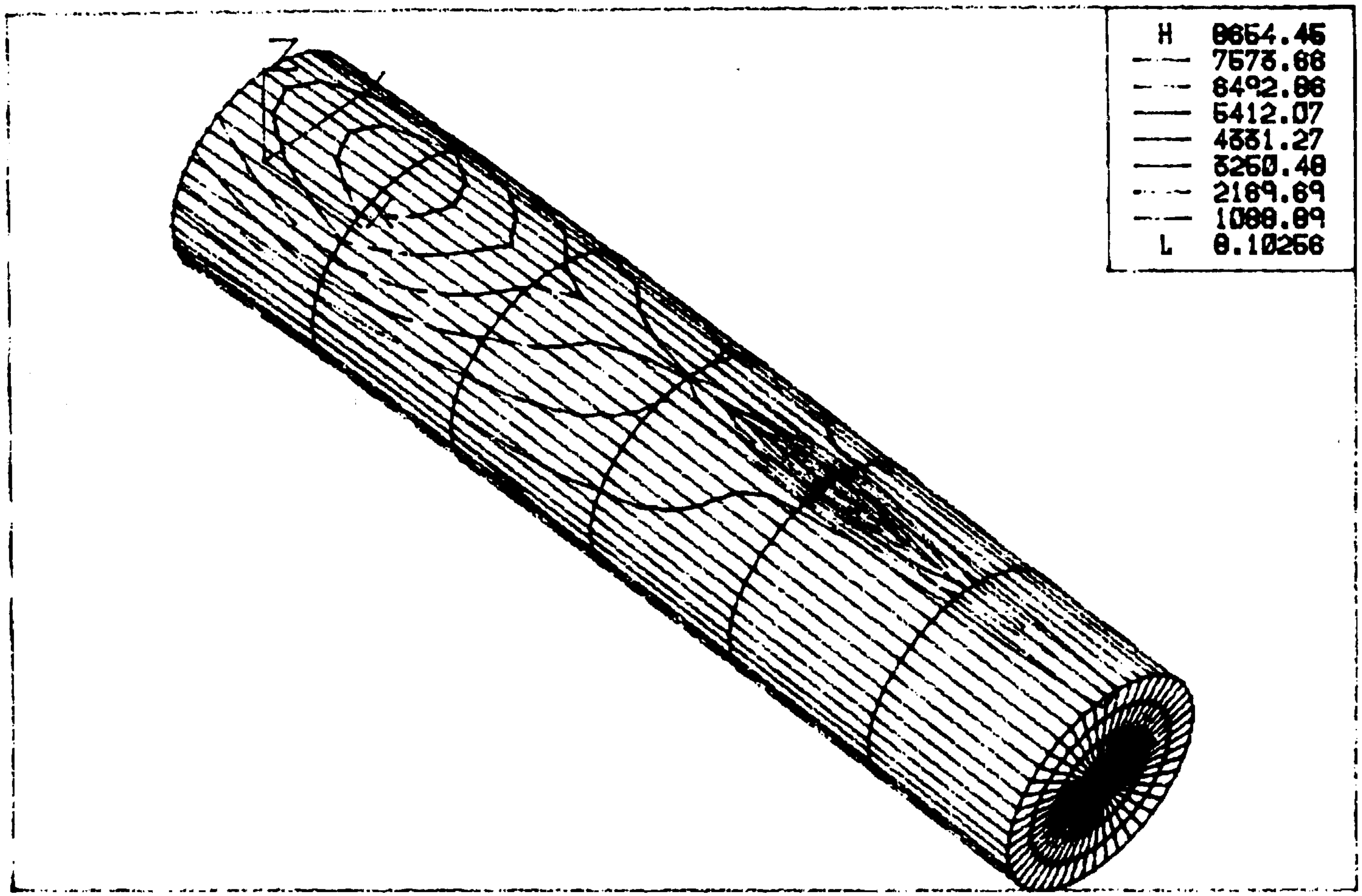
AEROFLEX

- **DESIGN DESCRIPTION (Cont.)**
  - **MOTOR**



SHAFT DEFLECTION

- **DESIGN DESCRIPTION (Cont.)**
  - **MOTOR**



SHAFT STRESS

AEROFLEX