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RAL-7482 Rev 0
Design Modification Report

PSEG Nuclear LLC
Hope Creek Generating Station

Customer P.O. No: 4500257459
Size 12 Class 900 Carbon Steel Gate Valve
S.O. 31042-01
Assembly Drawing 93-15122

Prepared by: _____ Date: _____

Reviewed by: _____ Date: _____

Approved by: _____ Date: _____

"I, the undersigned, a Registered Professional Engineer experienced in the design of valves, verify that to the best of my knowledge, information, and belief, this design report complies with the requirements of the ASME Code for Nuclear Power Plant Components Section III, 1974 Edition with Summer 1975 Addenda and the conditions of the design specifications. Pursuant to paragraph NCA-3350 of said Code, this certification is solely for the purpose of complying with paragraph NB-3560 of said Code and is not to be construed as involving, modifying, or changing contractual relationships or legal liabilities."

Certified By: _____ Date: _____

Design Source: Customer P.O.: 4500257459

Design Inputs: Design Specification: BFN-50-C-7105 Rev. 7

ASME Section III, 1974 Edition, Summer 1975 Addenda.

Literature Searches: Not Applicable

Assumptions: None

Computer Calculations/Programs: ANSYS Workbench 8.1

Valve Data:

Size 12 Class 900 Carbon Steel Gate Valve
Sales Order 31042-01
Assembly Drawing 93-15122 Rev. G

RECORD OF REVISIONS

Rev.	Pages	Description
0, 10-25-04	All	Initial Issue

1 DISCUSSION

This report is prepared to provide analysis results that support a proposed modification (see Attachment 1) to the subject valve. The goal of the modification is to reduce the effect that vibration due to pump induced chugging has on the valve's bevel gear actuator cover assembly. Based on historical damage, the original configuration is subject to fatigue damage and fretting contact due to the vibration. It is assumed that, because the valve's natural frequency is in a range that matches chugging frequencies, significant accelerations can result.

This analysis may be considered a supplement to the existing Class 1 design and seismic analysis prepared by Anamet Laboratories Inc., Lab No. 78.183. It is concluded here that the valve can withstand the specified chugging loading in addition to the seismic loading addressed in the Anamet report.

The analysis was performed using the finite element based design simulation package called Workbench by ANSYS, Inc. along with the solid model design package Pro/E. The procedure involved creating the solid model of the valve extended structure in Pro/E, porting the model into Workbench, setting up analysis scenarios, solving the model, and preparing a report.

Attachment 2 contains the report that was generated from Workbench that documents the analysis performed. The report contains six scenarios: the first three address the proposed modification, while the last three address the original state. Each set of three scenarios address (1) natural frequencies of the valve extended structure, (2) response of the extended structure due to a broad spectrum acceleration input at the base of the extended structure, and (3) stress analysis due to conservative accelerations based on broad spectrum response at the top of the extended structure.

In addition to the workbench analysis, the capscrews that mount the actuator cover are investigated in section 2 using classical methods using input from the Workbench results.

The broad spectrum acceleration input (0.3 g's) is based on accelerometer measurements. Measurements were taken at low frequency and high frequency pump speeds, and the high frequency speed resulted in the higher acceleration. The 0.3 g's input envelopes the square root of two times RMS measured values, which all parties involved have agreed is adequate input for evaluating fatigue damage. In addition, results are such that it may be concluded that response to peak input is not a critical design concern without performing additional analyses.

Due to the valve's extended structure height, the input acceleration is greatly amplified. The analysis uses the response at the top of the structure as input for the static stress analysis. This is conservative as the amplification decreases rapidly from structure top to bottom. For instance, results show that the amplification at the base of the stem protector is about half that at the top of the stem protector. Thus, results are extremely conservative for portions lower on the structure such as the yoke legs and body; even so, stress is shown to be low in these structures.

Section 1.1 provides an overview of results. It is concluded that the proposed modification would significantly increase the topworks natural frequency and reduce deflections such that the possibility of fatigue damage and fretting contact is reduced. In addition, it is demonstrated that the modified assembly can withstand the measured high cycle loading without experiencing fatigue damage. The given stress limits are based on allowed fatigue stress at one million cycles, which is considered infinite fatigue life, from the ASME Boiler and pressure vessel code, Section III appendicies, Appendix 9. Note that these fatigue curves are conservative by the greater of a factor of two on stress or a factor of 10 on number of cycles (RE Section III Code Appendix III).

1.1 SUMMARY

Description	Value (original/modified)	Limit Criteria
Natural Frequency [Hz]	First: 60.5 / 92. Second: 62.2 /131.	> 90 Hz
Peak Acceleration Response [g's]	G_V: 11.9 / 0.36 G_{H1}: 11.9 / 11.0 G_{H2}: 11.4 / 13.7	N/A
Stress Range in Topworks (Conservative), other than bolting [ksi]	6.0 / 2.	12.5 (re fig. I-9.2)
Capscrew Stress Range [ksi]	5.425 / 5.68	20. (re fig. I-9.1)
Deflection at Top [in]	0.95 / 0.33	

Other Conclusions:

- Because stress in the added struts is low at the locations of required welding, it is not required to provide weld metal equal in cross-section to the area of the strut. Conservatively, since the maximum topworks stress is less than one forth the limit, it is permissible to provide weld area equal to only one forth the strut area. However, it is important to place the welds at the corners of the struts for maximum strength.
- Because the handwheel is loosely connected to the impactor by a retaining ring, it is highly recommended to remove the handwheel so as to remove potential fretting contact.

12"

2. ACTUATOR COVER MOUNTING BOLTING ANALYSIS

The basic approach is to determine the axial force due to bending and thrust for one bolt located at the maximum distance from the pivot point. This assures that the maximum force is considered. Reaction forces are determined using data from the solid model and from the analysis input.

Assumptions:

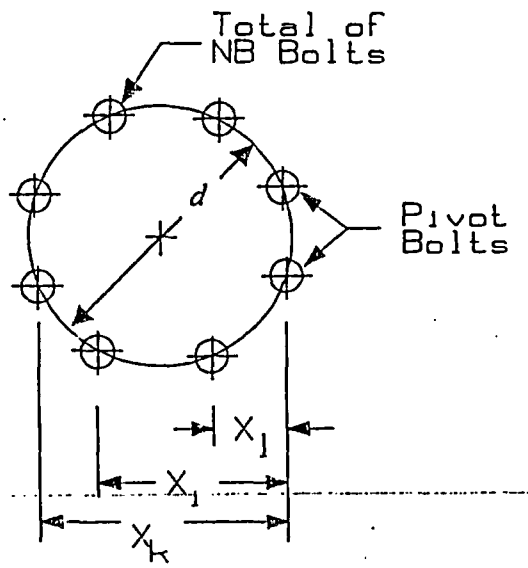
1. The stiffness of the flange is much greater than the stiffness of the bolts. Hence, Hooke's law and bolt spacing geometry are used to determine bolt forces.

2. The bending pivot point is located on the bolt circle.

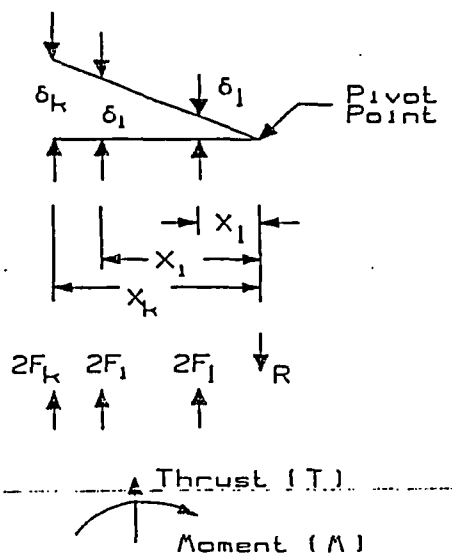
Maximum Reaction Force Due to Moment (*M*) for One Bolt:

1. Sum of Moments about pivot = 0 yields:

$$M = \sum_{j=1}^{K} 2F_jX_j, \quad K = n/2 - 1 \qquad 2.1$$



Top View Showing Typical Bolt Pattern



Side View Showing Assumed Bolt Deflections and Reaction Forces

Maximum Reaction Force Due to *M*: *(Cont'd)*

2. Applying Hooke's Law:

$F = EA_I(\delta_I/L)$

$F_I/F_J = (A_I\delta_I)/(A_J\delta_J) = (A_IX_I)/(A_JX_J)$ 2.2

where $A_{I,J}$ = Bolt area = $2A_B$ for all i,j

E = Young's Modulus

L = Bolt Length (All Assumed equal)

3. Maximum Moment Induced Bolt Force:

$F_K = M(A_KX_K)/(\sum_{I=1}^{K} 2X_I^2A_I)$ 2.3

For a four-bolt flange with all bolt areas equal, this reduces to $F_K = M/(2X_I)$.

Stress in Bolt:

$\sigma = F_K/A_B + Thrust/[nA_B]$ 2.5

$\tau = Shear/[nA_B] + 2*Torque/[ndA_B]$ 2.6

2.1 COVER CAPSCREWS ANALYSIS RESULTS (MODIFIED)

Top Works Data

	Parameter Description		Value	Units	Ref.
W	Weight	=	73.	lb	Solid Model
X_V	Vertical C.G.	=	6.3	in	Solid Model
X_H	Horizontal C.G.	=	1.1	In	Solid Model
G_{RH}	Acceleration (resultant of horizontal values)	=	17.6	g's	Analysis
G_{RV}	Acceleration (resultant of horizontal values)	=	.33	g's	Analysis

External Forces

	Parameter Description		Value	Units
V_N	Shear Force (WG_{RH})	=	1285.	lb
T_N	Thrust Force (WG_{RV})	=	24.1	lb
M_N	Moment ($WG_{RH}X_V$)	=	8094.	in-lb
Q_N	Torque ($WG_{RH}X_H$)	=	1413.	in-lb

Bolting Properties

	Parameter Description		Value	Units
n	Number of Bolts	=	8.	
D	Bolt Size	=	.25	in
A_B	Stress Area of One Bolt	=	3.182E-2	in^2
d	Bolt Circle Diameter	=	27.75	in
X_1	Bolt Group 1 Pivot	=	7.509	in
X_2	Bolt Group 2 Pivot	=	18.13	in
X_3	Bolt Group 3 Pivot	=	25.64	in

Bolting Statics Analysis Results

	Parameter Description		Value	Units	Ref.
F_K	Max. Bolt Force From Moment	=	99.54	lb	2.3

Bolting Stress Analysis Results

	Stress Description		Value	Units	Ref.
σ	Bolt Axial	=	3.223	ksi	2.5
τ	Bolt Shear	=	5.448	ksi	2.6
S_{MAX}	Stress Intensity	=	11.36	ksi	
S_A	Stress Range ($S_{MAX}/2$)[1]	=	5.68	ksi	

[1] Since the capscrews experience tension only, it is appropriate to divide the resulting stress by two to yield the appropriate alternating stress range for entering the design fatigue curve.

2.2 COVER CAPSCREWS ANALYSIS RESULTS (ORIGINAL)

Top Works Data

	Parameter Description		Value	Units	Ref.
W	Weight	=	65.	lb	Solid Model
X_V	Vertical C.G.	=	6.0	in	Solid Model
X_H	Horizontal C.G.	=	1.5	In	Solid Model
G_{RH}	Acceleration (resultant of horizontal values)	=	16.5	g's	Analysis
G_{RV}	Acceleration (resultant of horizontal values)	=	11.9	g's	Analysis

External Forces

	Parameter Description		Value	Units
V_N	Shear Force (WG_{RH})	=	1073.	lb
T_N	Thrust Force (WG_{RV})	=	773.5	lb
M_N	Moment ($WG_{RH}X_V$)	=	6435.	in-lb
Q_N	Torque ($WG_{RH}X_H$)	=	1609.	in-lb

Bolting Properties

	Parameter Description		Value	Units
n	Number of Bolts	=	8.	
D	Bolt Size	=	.25	in
A_B	Stress Area of One Bolt	=	3.182E-2	in^2
d	Bolt Circle Diameter	=	27.75	in
X_1	Bolt Group 1 Pivot	=	7.509	in
X_2	Bolt Group 2 Pivot	=	18.13	in
X_3	Bolt Group 3 Pivot	=	25.64	in

Bolting Statics Analysis Results

	Parameter Description		Value	Units	Ref.
F_K	Max. Bolt Force From Moment	=	79.14	lb	2.3

Bolting Stress Analysis Results

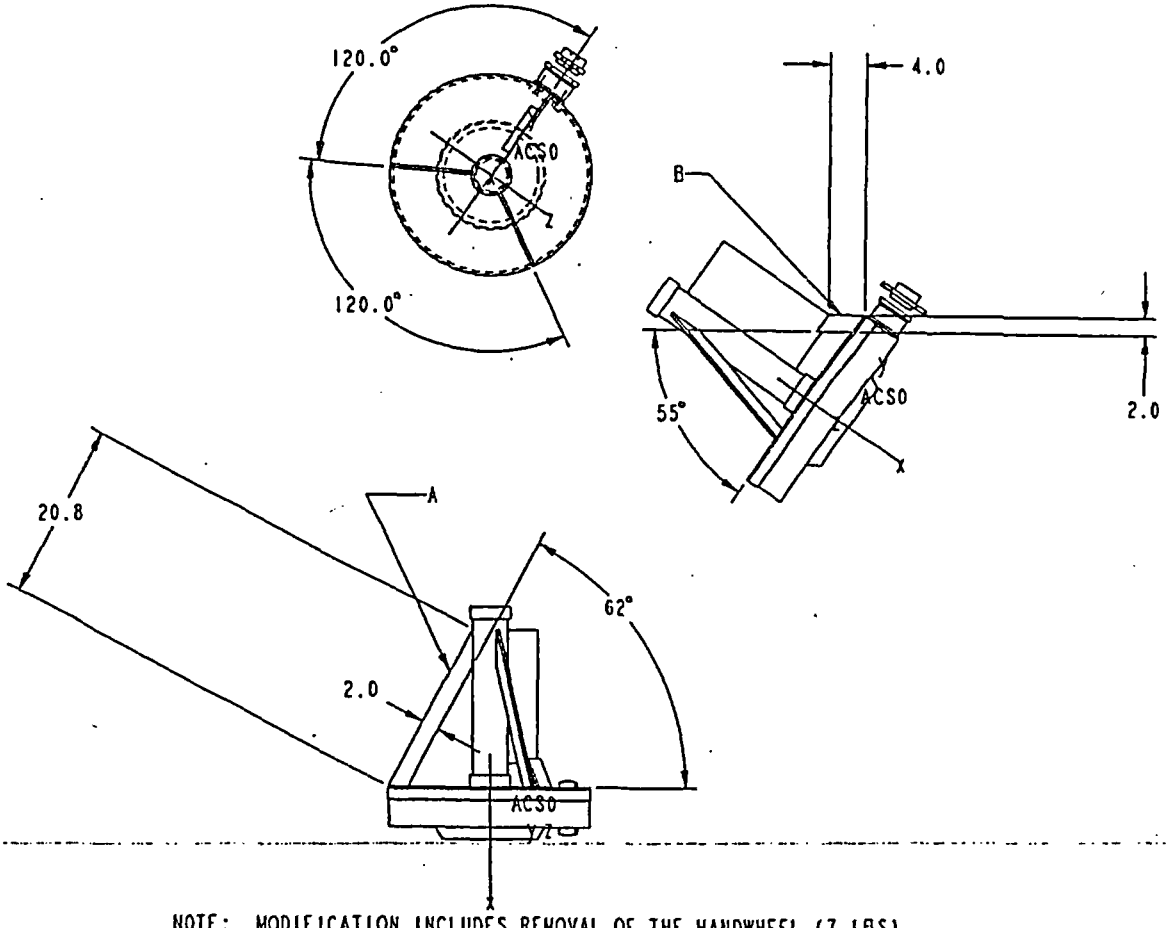
	Stress Description		Value	Units	Ref.
σ	Bolt Axial	=	5.526	ksi	2.5
τ	Bolt Shear	=	4.671	ksi	2.6
S_{MAX}	Stress Intensity	=	10.85	ksi	
S_A	Stress Range ($S_{MAX}/2$)[1]	=	5.425	ksi	

[1] Since the capscrews experience tension only, it is appropriate to divide the resulting stress by two to yield the appropriate alternating stress range for entering the design fatigue curve.

ATTACHMENT 1

SKETCH OF PROPOSED MODIFICATION

FIND	DESCRIPTION	MATERIAL	QTY
A	PLATE (2 x .375)	C.S.	2
B	PLATE (2 x .375)	C.S.	1



NOTE: MODIFICATION INCLUDES REMOVAL OF THE HANDWHEEL (7 LBS).
NET ADDED WEIGHT EQUALS 3 LBS.

TOPWORKS MODIFICATION
SIZE 12 CLASS 900 GATE VALVE

ATTACHMENT 2

ANSYS SIMULATION REPORT

1. Summary

This report documents design and analysis information created and maintained using the ANSYS® engineering software program. Each scenario listed below represents one complete engineering simulation.

Scenario 1

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact and structural supports.
- Calculated frequency results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 1 below for supporting details and Appendix A1 for corresponding figures.

Scenario 2

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact, acceleration and structural supports.
- Calculated harmonic results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 2 below for supporting details and Appendix A2 for corresponding figures.

Scenario 3

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact, acceleration and structural supports.
- Calculated structural results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 3 below for supporting details and Appendix A3 for corresponding figures.

Scenario 4

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact and structural supports.
- Calculated frequency results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 4 below for supporting details and Appendix A4 for corresponding figures.

Scenario 5

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact, acceleration and structural supports.
- Calculated harmonic results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 5 below for supporting details and Appendix A5 for corresponding figures.

Scenario 6

- Based on the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.
- Considered the effect of body-to-body contact, acceleration and structural supports.
- Calculated structural results.
- No convergence criteria defined.
- No alert criteria defined.
- See Scenario 6 below for supporting details and Appendix A6 for corresponding figures.

2. Scenario 1

2.1. "Supported"

"Supported" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.

- *"HW[10]"* was suppressed. Suppressed parts do not effect the results in this scenario in any way.
- The bounding box for all positioned bodies in the model measures 67.06 by 23.51 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,384.89 lbm.
- The model has a total volume of 4,552.75 in^3.

Table 2.1.1. Bodies

Name	Material	Bounding Box (in)	Mass (lbm)	Volume (in^3)	Nodes	Elements
"BODY[1]"	*"Structural Steel"*	17.0, 18.13, 18.13	428.3	1,509.01	4776	2446
"YOKE[2]"	*"Structural Steel"*	23.0, 18.13, 18.13	208.06	733.06	3334	1575
"GEARBOX[3]"	*"Structural Steel"*	5.94, 23.5, 26.29	82.06	289.13	4598	2241
"HWSTEM[4]"	*"Structural Steel"*	3.0, 3.0, 7.06	8.27	29.15	1138	658
"IMPACTOR[7]"	*"Structural Steel"*	6.25, 4.0, 2.0	4.93	17.36	680	316
"GEARBOXCOVER[13]"	*"cover"*	21.25, 23.51, 23.5	73.34	258.41	7201	3450
"BONNET_LUMP[23]"	*"bonnet lump"*	6.0, 13.5, 13.5	320.14	829.38	1431	260
"GEAR_LUMP[31]"	*"gear lump"*	1.5, 20.58, 20.58	147.53	491.78	904	117
"STEM[35]"	*"Structural Steel"*	50.5, 5.49, 6.35	61.96	218.29	981	446
"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 2.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in^3)	Nodes	Elements

2.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 2.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 2"	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

"Contact Region 3"	Bonded	*"GEARBOX[3]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	*"HWSTEM[4]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	*"GEARBOXCOVER[13]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	*"GEAR_LUMP[31]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	*"IMPACTOR[7]"* and *"HWSTEM[4]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	*"STEM[35]"* and *"GEARBOXCOVER[13]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	*"STEM[35]"* and *"BONNET_LUMP[23]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	*"STEM[35]"* and *"GEAR_LUMP[31]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	*"RHN017[46]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	*"RHN017[50]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	*"RHN002[51]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	*"CLAMP[171]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	*"CLAMP[175]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	*"CLAMP[171]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 20"	Bonded	*"CLAMP[175]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 21"	Bonded	*"CLAMP[175]"* and *"CLAMP[171]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2.1.2. Mesh

- *"Mesh"*(Figure A1.3) , associated with *"Supported"* has an overall relevance of 0.
- *"Mesh"* contains 36553 nodes and 17929 elements.

No mesh controls specified.

2.2. "Natural Frequency"

"Natural Frequency" contains all loading conditions defined for *"Supported"* in this scenario.

The following tables list local loads and supports applied to specific geometry.

2.2.1. Structural Supports

Table 2.2.1.1. Structural Supports		
Name	**Type**	**Associated Bodies**
"Fixed Support"	Fixed Surface	*"BODY[1]"*

2.3. "Solution"

"Solution" contains the calculated response for *"Supported"* given loading conditions defined in *"Natural Frequency"*.

It was selected that the program would choose the solver used in this solution.

2.3.1. Frequency Results

Frequency results apply to all active bodies in *"Supported"*.

Table 2.3.1.1. First 6 Natural Frequencies				
Name	**Figure**	**Mode**	**Frequency**	**Alert Criteria**
"1st Frequency Mode In Range"	A1.4	1	92.12 Hz	none
"2nd Frequency Mode In Range"	A1.5	2	130.66 Hz	none
"3rd Frequency Mode In Range"	None	3	162.82 Hz	none
"4th Frequency Mode In Range"	None	4	230.28 Hz	none
"5th Frequency Mode In Range"	None	5	234.61 Hz	none
"6th Frequency Mode In Range"	None	6	280.48 Hz	none

- Convergence tracking not enabled.

3. Scenario 2

3.1. "Supported"

"Supported" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.

- *"HW[10]"* was suppressed. Suppressed parts do not effect the results in this scenario in any way.
- The bounding box for all positioned bodies in the model measures 67.06 by 23.51 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,384.89 lbm.
- The model has a total volume of 4,552.75 in³.

Table 3.1.1. Bodies

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"BONNET_LUMP[23]"	*"bonnet lump"*	6.0, 13.5, 13.5	320.14	829.38	1431	260
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"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 3.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements

3.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 3.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2"									
"Contact Region 3"	Bonded	*"GEARBOX[3]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	*"HWSTEM[4]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	*"GEARBOXCOVER[13]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	*"GEAR_LUMP[31]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	*"IMPACTOR[7]"* and *"HWSTEM[4]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	*"STEM[35]"* and *"GEARBOXCOVER[13]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	*"STEM[35]"* and *"BONNET_LUMP[23]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	*"STEM[35]"* and *"GEAR_LUMP[31]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	*"RHN017[46]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	*"RHN017[50]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	*"RHN002[51]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	*"CLAMP[171]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	*"CLAMP[175]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	*"CLAMP[171]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 20"	Bonded	*"CLAMP[175]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 21"	Bonded	*"CLAMP[175]"* and *"CLAMP[171]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

3.1.2. Mesh

- *"Mesh"*(Figure A1.3) , associated with *"Supported"* has an overall relevance of 0.
- *"Mesh"* contains 36553 nodes and 17929 elements.

No mesh controls specified.

3.2. "Frequency Response"

"Frequency Response" contains all loading conditions defined for *"Supported"* in this scenario.

Acceleration - Constant Linear Acceleration

- Magnitude: 200.92 in/s²
- Vector: [116.0 in/s² x, 116.0 in/s² y, 116.0 in/s² z] in the global coordinate system
- The time type is harmonic

The following tables list local loads and supports applied to specific geometry.

3.2.1. Structural Supports

Table 3.2.1.1. Structural Supports		
Name	**Type**	**Associated Bodies**
"Fixed Support"	Fixed Surface	*"BODY[1]"*

3.3. "Solution"

"Solution" contains the calculated response for *"Supported"* given loading conditions defined in *"Frequency Response"*.

It was selected that the program would choose the solver used in this solution.

3.3.1. Harmonic Results

Table 3.3.1.1. Definition						
Range Minimum	**Range Maximum**	**Solution Method**	**Cluster Number**	**Cluster Results**	**Damping Ratio**	**Beta Damping**
0.0	250.0	Mode Superposition	15	Yes	0.03	0.0

Table 3.3.1.2. Frequency Response Values										
Name	**Type**	**Scope**	**Multiple Entities**	**Minimum Frequency**	**Maximum Frequency**	**Maximum Amplitude**	**Frequency at Max Amplitude**	**Phase Angle at Max Amplitude**	**Real at Max Amplitude**	**Imaginary at Max Amplitude**
"top axial"	Directional Acceleration, X Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	136.69in/s²	237.19Hz	14.48°	132.35in/s²	34.17in/s²
"top beam"	Directional Acceleration, Y Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	4,201.09in/s²	92.2Hz	-91.93°	-141.32in/s²	-4,199.51in/s²
"top frame"	Directional Acceleration, Z Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	5,240.92in/s²	130.85Hz	-94.06°	-371.33in/s²	-5,227.75in/s²
"base	Directional	Surface(s) on	Use	0.0Hz	250.0Hz	143.21in/s²	235.18Hz	27.15°	127.43in/s²	65.34in/s²

axial"	Acceleration, X Axis	*"GEARBOXCOVER[13]"*	Average							
"base beam"	Directional Acceleration, Y Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	1,916.31in/s²	92.2Hz	-91.48°	-49.48in/s²	-1,915.67in/s²
"base frame"	Directional Acceleration, Z Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	2,037.89in/s²	130.77Hz	-91.49°	-52.82in/s²	-2,037.2in/s²
"finger frame"	Directional Acceleration, Z Axis	Surface(s) on *"STEM[35]"*	Use Average	0.0Hz	250.0Hz	4,124.56in/s²	130.85Hz	-93.42°	-246.04in/s²	-4,117.22in/s²

Table 3.3.1.3. top axial

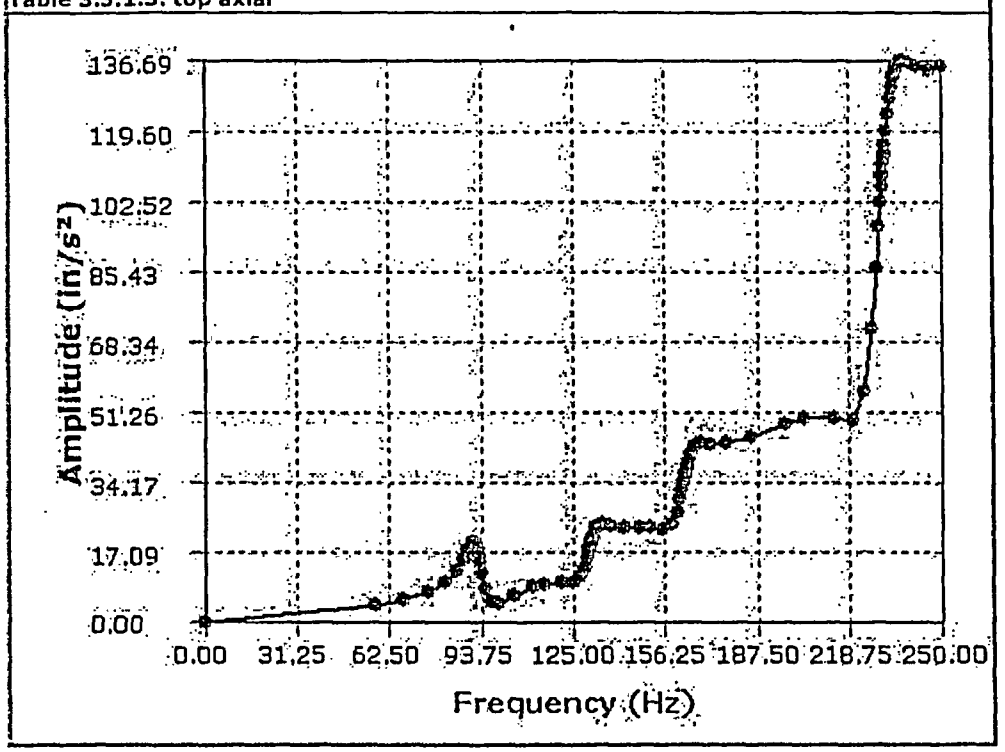


Table 3.3.1.4. top axial

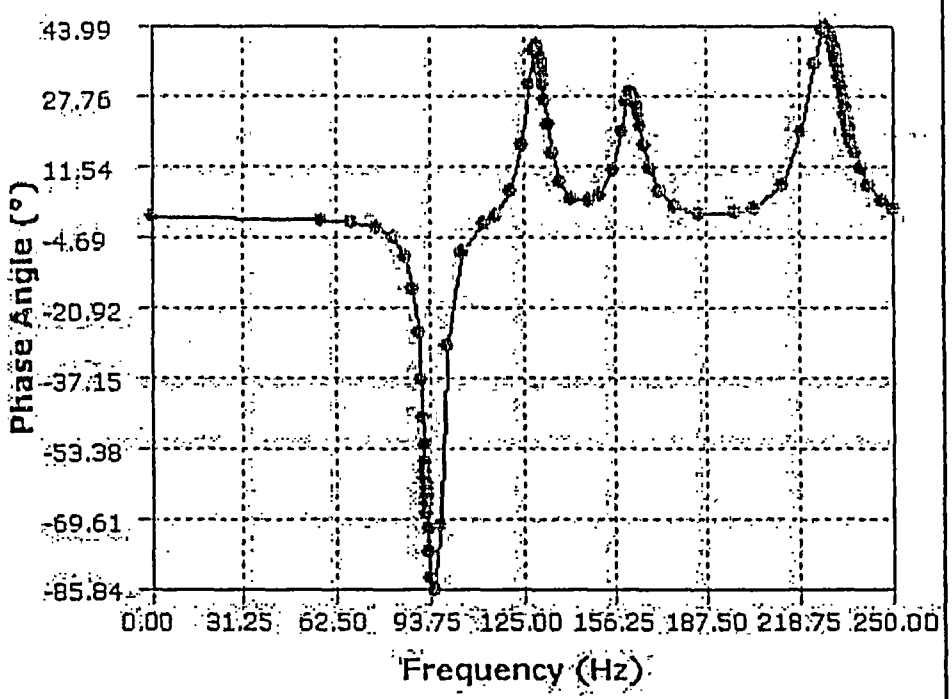


Table 3.3.1.5. top beam

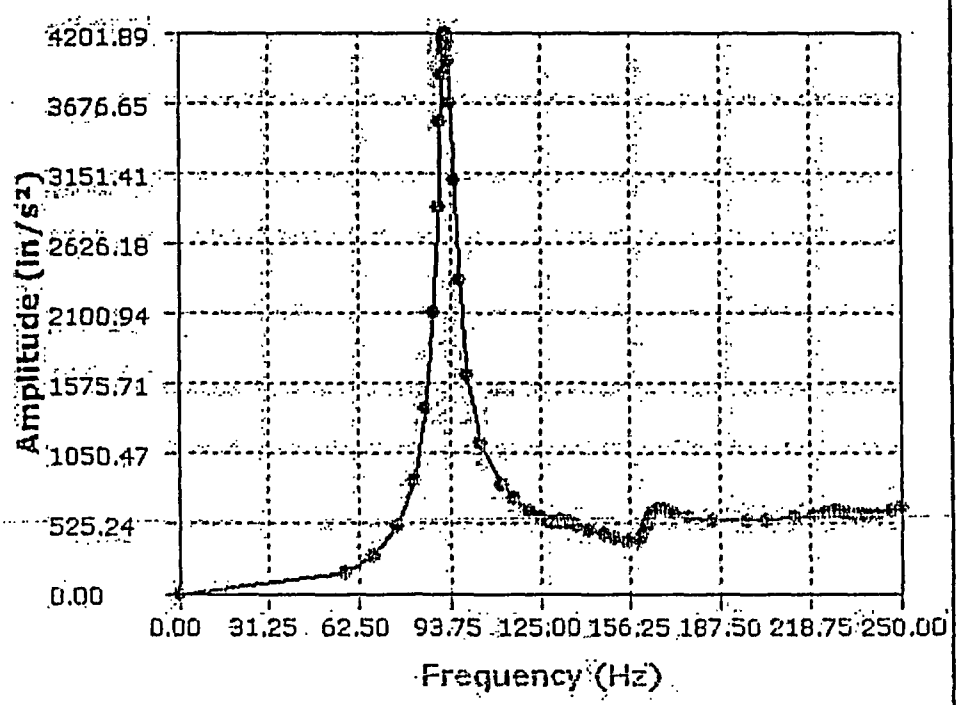


Table 3.3.1.6. top beam

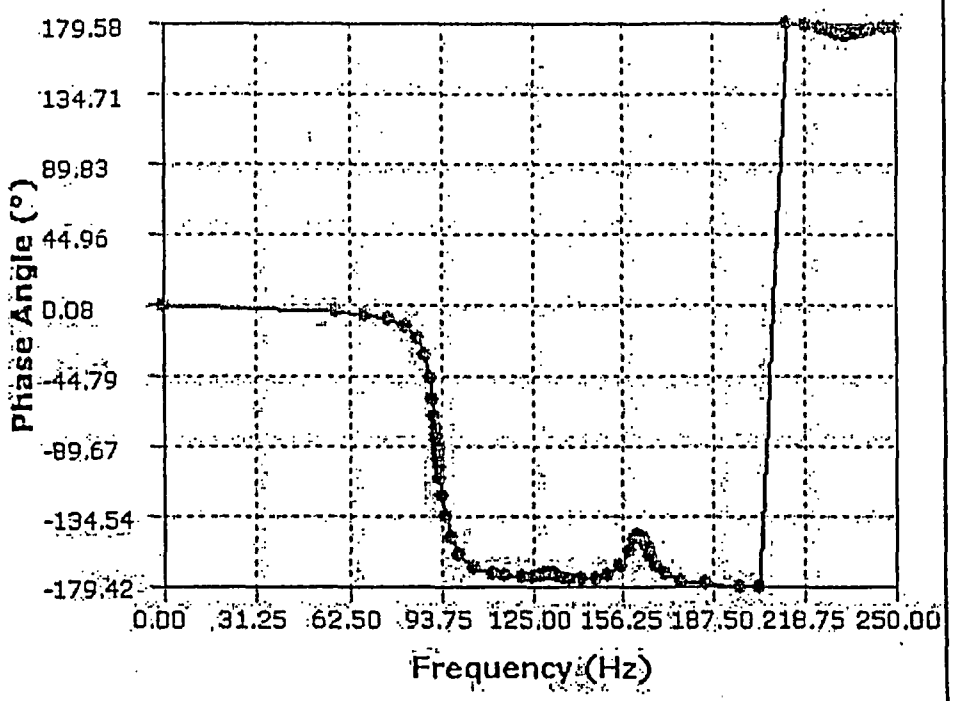


Table 3.3.1.7. top frame

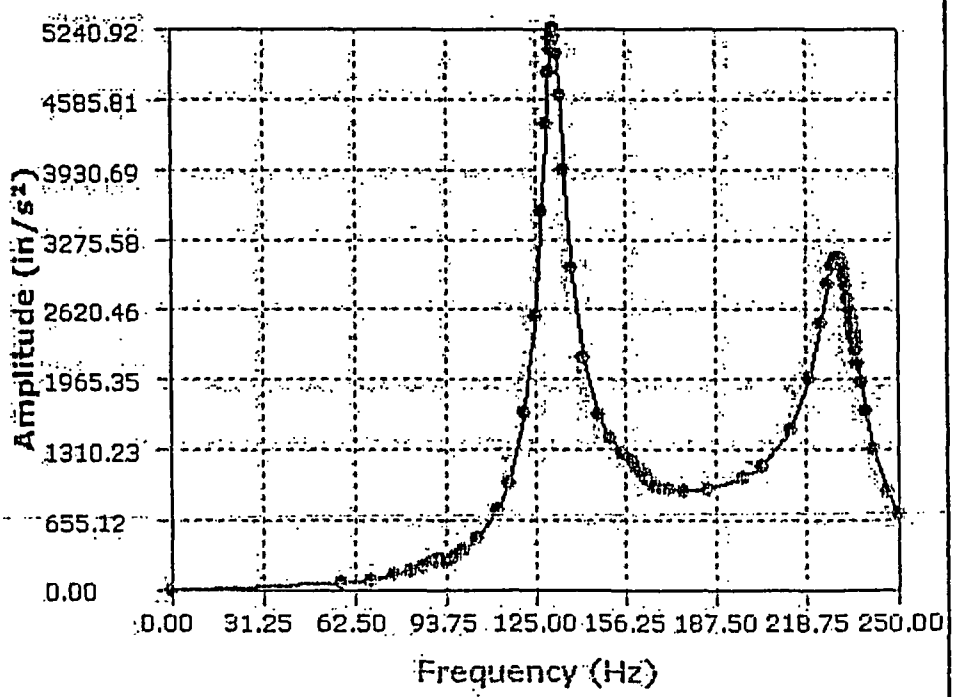


Table 3.3.1.8. top frame

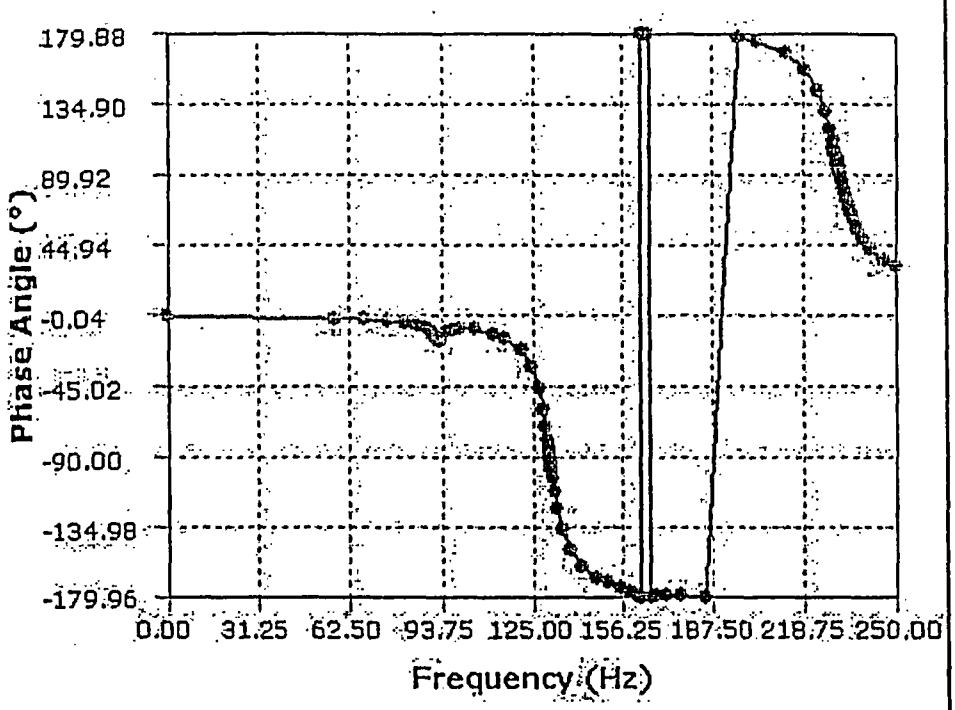


Table 3.3.1.9. base axial

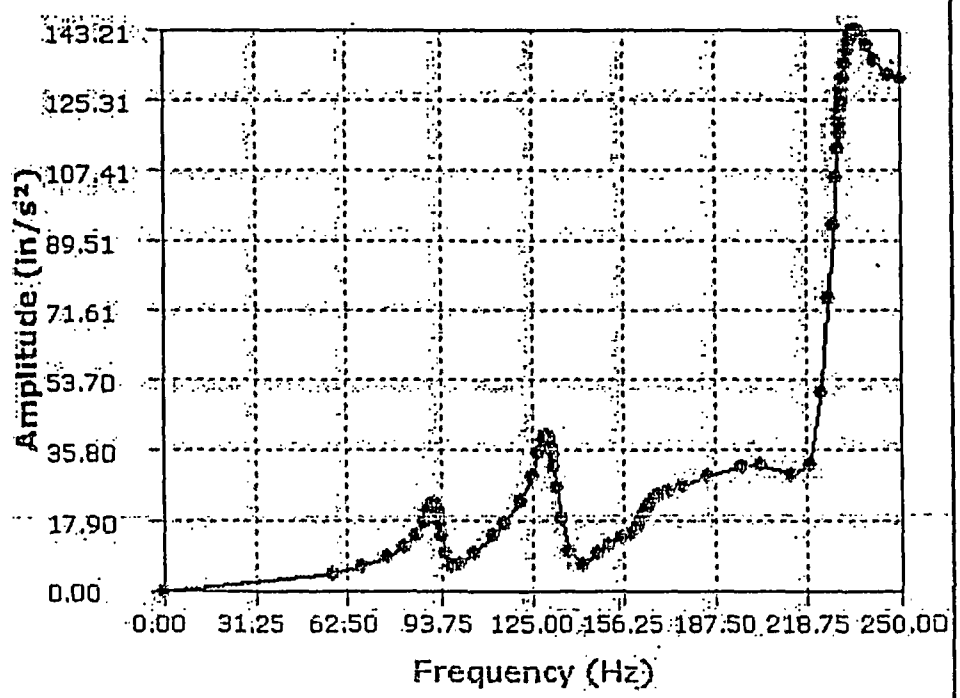


Table 3.3.1.10. base axial

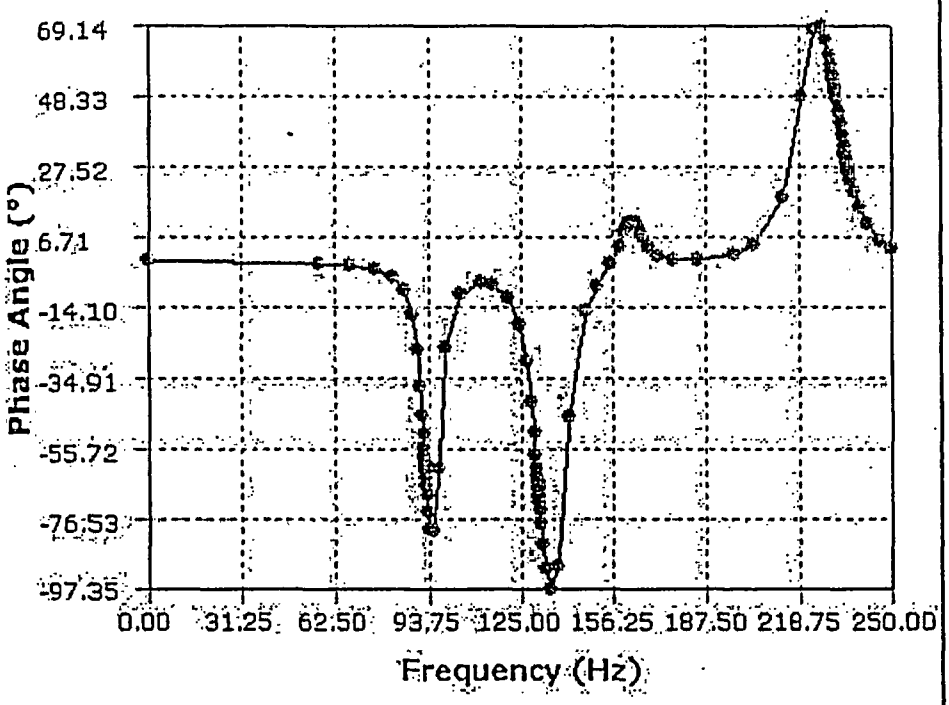


Table 3.3.1.11. base beam

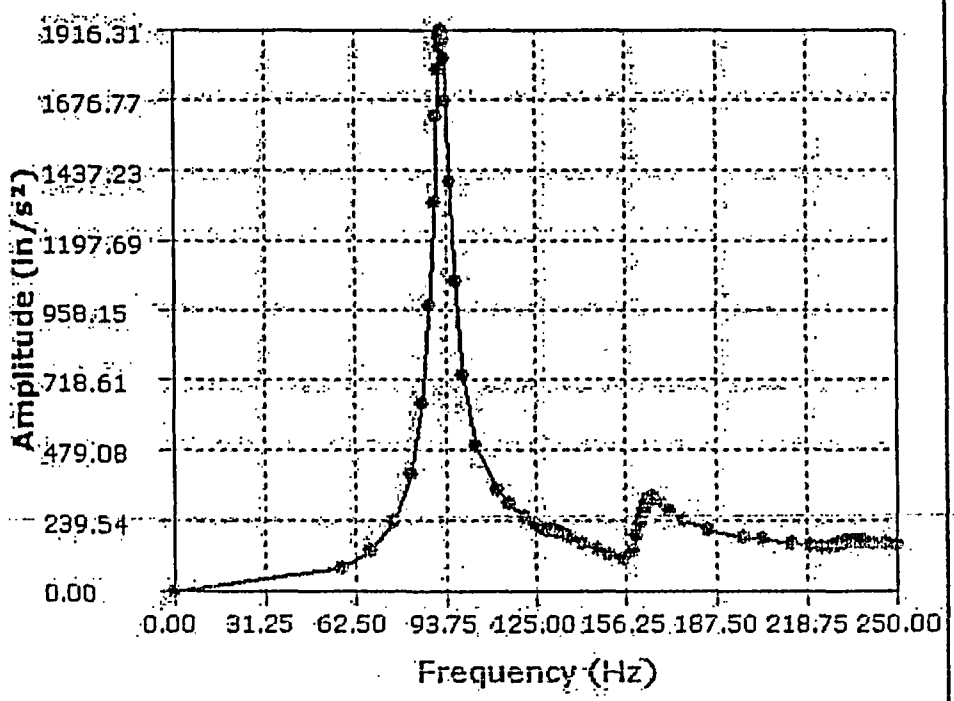


Table 3.3.1.12. base beam

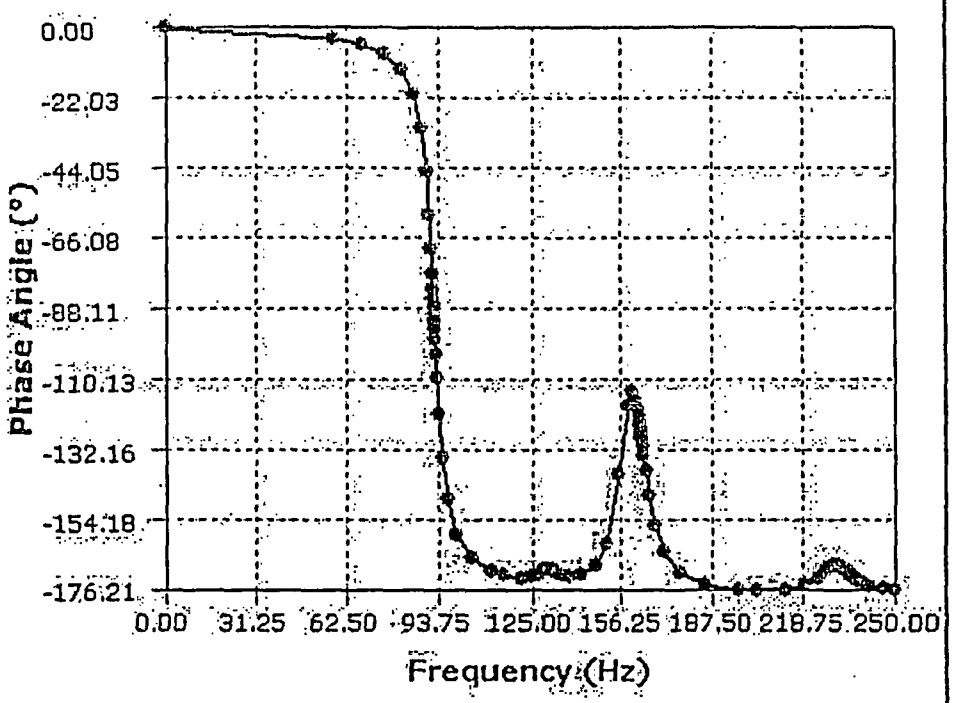


Table 3.3.1.13. base frame

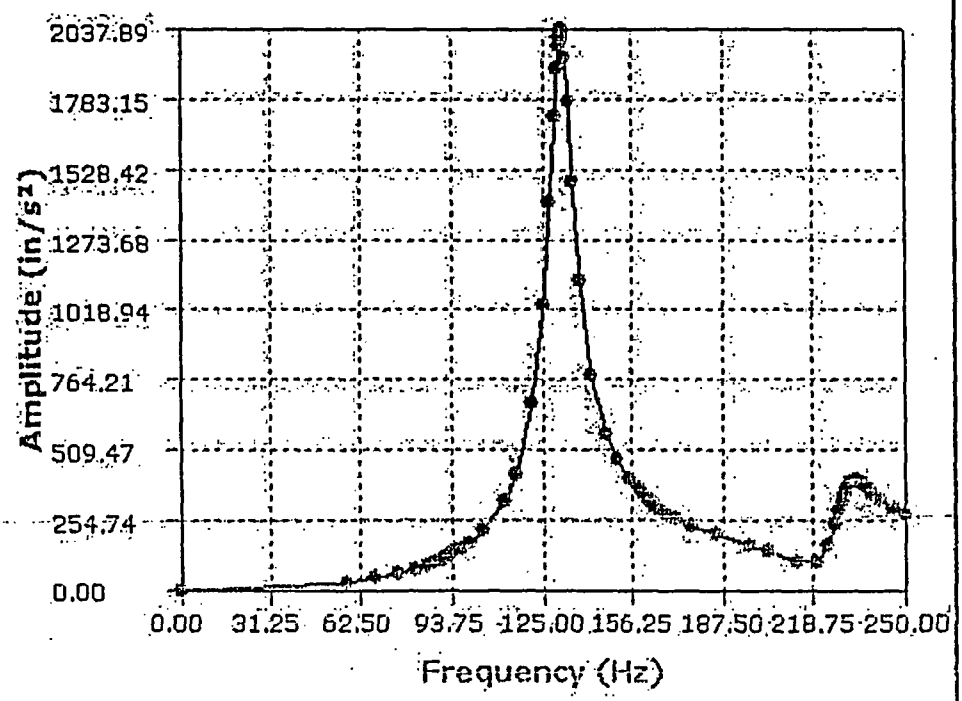


Table 3.3.1.14. base frame

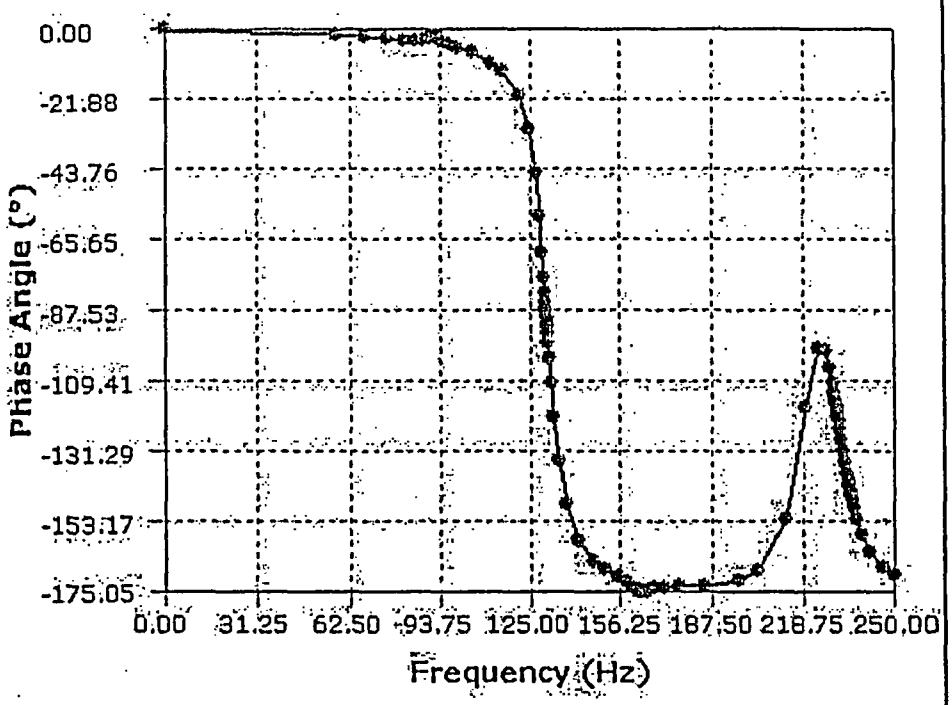


Table 3.3.1.15. finger frame

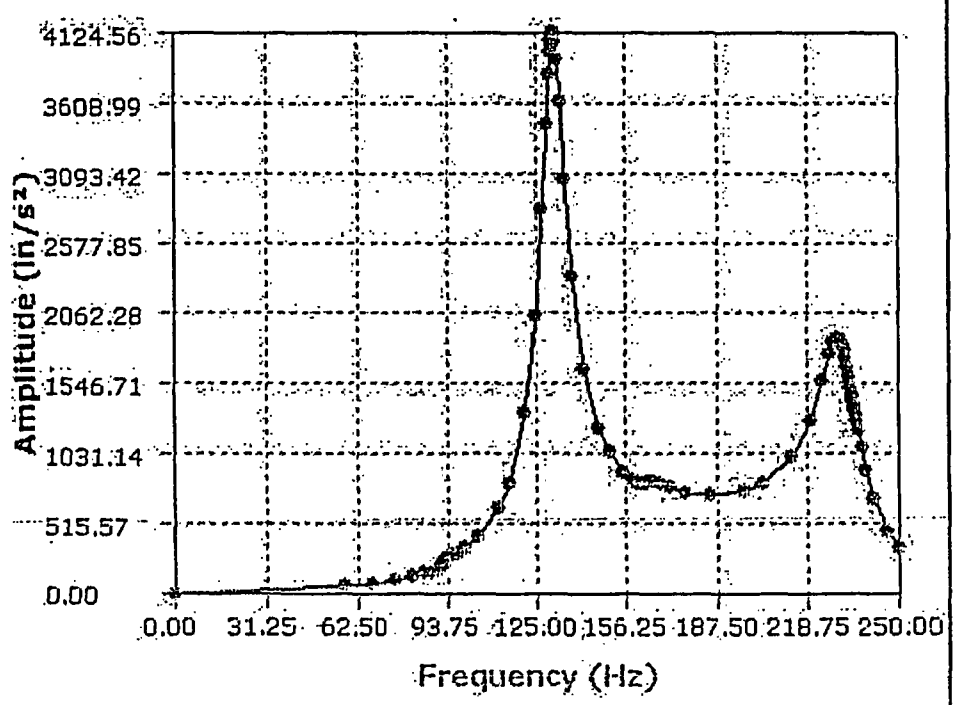
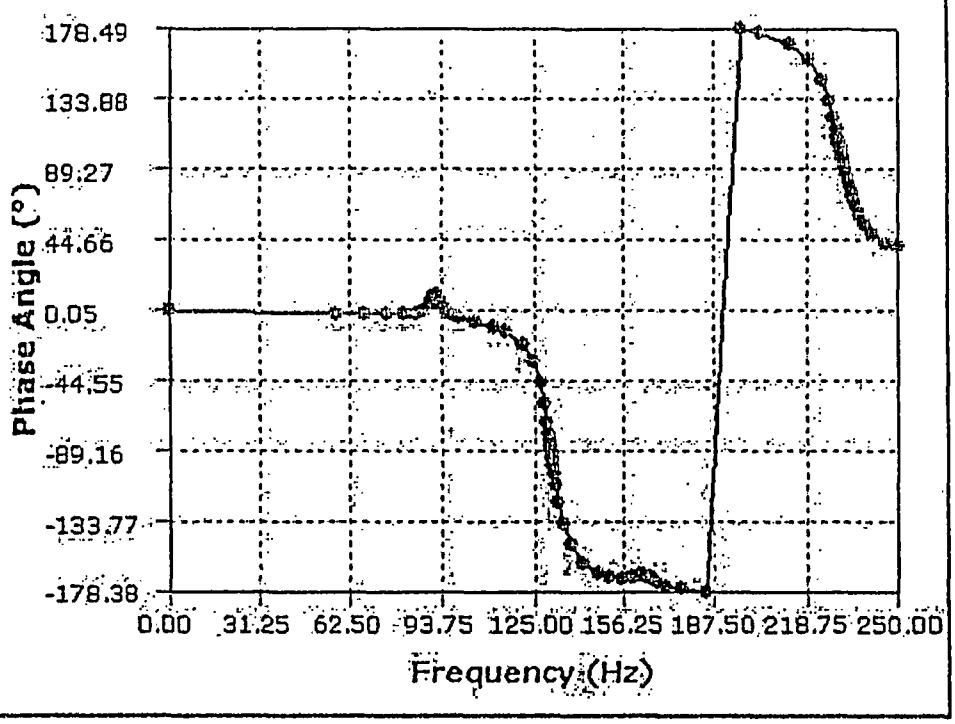


Table 3.3.1.16. finger frame



4. Scenario 3

4.1. "Supported"

"Supported" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 (12-900-FW)\ASM0001.ASM.10"*.

- *"HW[10]"* was suppressed. Suppressed parts do not effect the results in this scenario in any way.
- The bounding box for all positioned bodies in the model measures 67.06 by 23.51 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,384.89 lbm.
- The model has a total volume of 4,552.75 in³.

Table 4.1.1. Bodies

Name	Material	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements
"BODY[1]"	*"Structural Steel"*	17.0, 18.13, 18.13	428.3	1,509.01	4776	2446
"YOKE[2]"	*"Structural Steel"*	23.0, 18.13, 18.13	208.06	733.06	3334	1575
"GEARBOX[3]"	*"Structural Steel"*	5.94, 23.5, 26.29	82.06	289.13	4598	2241
"HWSTEM[4]"	*"Structural Steel"*	3.0, 3.0, 7.06	8.27	29.15	1138	658
"IMPACTOR[7]"	*"Structural Steel"*	6.25, 4.0, 2.0	4.93	17.36	680	316
"GEARBOXCOVER[13]"	*"cover"*	21.25, 23.51, 23.5	73.34	258.41	7201	3450
"BONNET_LUMP[23]"	*"bonnet lump"*	6.0, 13.5, 13.5	320.14	829.38	1431	260
"GEAR_LUMP[31]"	*"gear lump"*	1.5, 20.58, 20.58	147.53	491.78	904	117
"STEM[35]"	*"Structural Steel"*	50.5, 5.49, 6.35	61.96	218.29	981	446
"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 4.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements

4.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 4.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2"									
"Contact Region 3"	Bonded	*"GEARBOX[3]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	*"HWSTEM[4]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	*"GEARBOXCOVER[13]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	*"GEAR_LUMP[31]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	*"IMPACTOR[7]"* and *"HWSTEM[4]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	*"STEM[35]"* and *"GEARBOXCOVER[13]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	*"STEM[35]"* and *"BONNET_LUMP[23]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	*"STEM[35]"* and *"GEAR_LUMP[31]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	*"RHN017[46]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	*"RHN017[50]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	*"RHN002[51]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	*"CLAMP[171]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	*"CLAMP[175]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	*"CLAMP[171]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 20"	Bonded	*"CLAMP[175]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 21"	Bonded	*"CLAMP[175]"* and *"CLAMP[171]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

4.1.2. Mesh

- *"Mesh"*(Figure A1.3) , associated with *"Supported"* has an overall relevance of 0.
- *"Mesh"* contains 36553 nodes and 17929 elements.

No mesh controls specified.

4.2. "Stress Analysis"

"Stress Analysis" contains all loading conditions defined for *"Supported"* in this scenario.

- **acceleration - Constant Linear Acceleration**

  - Magnitude: 6,795.01 in/s²
  - Vector: [140.0 in/s² x, 4,250.0 in/s² y, 5,300.0 in/s² z] in the global coordinate system

The following tables list local loads and supports applied to specific geometry.

4.2.1. Structural Supports

Table 4.2.1.1. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	23,909.18 lbf (not updated)	[466.53 lbf x, 13,995.93 lbf y, 19,378.99 lbf z] (not updated)	558,742.2 lbf·in (not updated)	[-3,525.13 lbf·in x, 453,730.2 lbf·in y, -326,051.11 lbf·in z] (not updated)	*"BODY[1]"*

4.3. "Solution"

"Solution" contains the calculated response for *"Supported"* given loading conditions defined in *"Stress Analysis"*.

It was selected that the program would choose the solver used in this solution.

4.3.1. Structural Results

Table 4.3.1.1. Values

Name	Figure	Scope	Minimum	Maximum	Alert Criteria
" Equivalent Stress"	A3.1	All Bodies In *"Supported"*	0.65 psi (not updated)	8,911.19 psi (not updated)	None
"Total Deformation"	A3.2	All Bodies In *"Supported"*	0.0 in (not updated)	3.27×10^{-2} in (not updated)	None

- Convergence tracking not enabled.

5. Scenario 4

5.1. "Original"

"Original" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.

- The bounding box for all positioned bodies in the model measures 67.06 by 23.5 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,290.51 lbm.
- The model has a total volume of 4,546.8 in³.

Table 5.1.1. Bodies

Name	Material	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements
"BODY[1]"	*"Structural Steel"*	17.0, 18.13, 18.13	428.3	1,509.01	4763	2435
"YOKE[2]"	*"Structural Steel"*	23.0, 18.13, 18.13	208.06	733.06	3341	1580
"GEARBOX[3]"	*"Structural Steel"*	5.94, 23.5, 26.29	82.06	289.13	4615	2252
"HWSTEM[4]"	*"Structural Steel"*	3.0, 3.0, 7.06	8.27	29.15	1138	658
"IMPACTOR[7]"	*"Structural Steel"*	6.25, 4.0, 2.0	4.93	17.36	680	316
"HW[10]"	*"Structural Steel"*	12.0, 12.0, 1.05	6.98	24.59	8196	4369
"GEARBOXCOVER[13]"	*"Structural Steel"*	21.25, 23.5, 23.5	64.68	227.87	7266	3456
"BONNET_LUMP[23]"	*"Structural Steel"*	6.0, 13.5, 13.5	235.4	829.38	1431	260
"GEAR_LUMP[31]"	*"Structural Steel"*	1.5, 20.58, 20.58	139.58	491.78	904	117
"STEM[35]"	*"Structural Steel"*	50.5, 5.49, 6.35	61.96	218.29	964	433
"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 5.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements

5.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 5.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2"									
"Contact Region 3"	Bonded	"CLAMP[171]" and "BODY[1]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"CLAMP[175]" and "BODY[1]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"GEARBOX[3]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"CLAMP[171]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	"CLAMP[175]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 8"	Bonded	"HWSTEM[4]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	"GEARBOXCOVER[13]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	"GEAR_LUMP[31]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	"IMPACTOR[7]" and "HWSTEM[4]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	"HW[10]" and "IMPACTOR[7]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	"STEM[35]" and "GEARBOXCOVER[13]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	"STEM[35]" and "BONNET_LUMP[23]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 15"	Bonded	"STEM[35]" and "GEAR_LUMP[31]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 16"	Bonded	"RHN017[46]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	"RHN017[50]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	"RHN002[51]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	"CLAMP[175]" and "CLAMP[171]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

5.1.2. Mesh

- *"Mesh"*(Figure A4.3) , associated with *"Original"* has an overall relevance of 0.
- *"Mesh"* contains 44808 nodes and 22296 elements.

No mesh controls specified.

5.2. "Natural Frequency"

"Natural Frequency" contains all loading conditions defined for *"Original"* in this scenario.

The following tables list local loads and supports applied to specific geometry.

5.2.1. Structural Supports

Table 5.2.1.1. Structural Supports		
Name	**Type**	**Associated Bodies**
"Fixed Support"	Fixed Surface	*"BODY[1]"*

5.3. "Solution"

"Solution" contains the calculated response for *"Original"* given loading conditions defined in *"Natural Frequency"*.

It was selected that the program would choose the solver used in this solution.

5.3.1. Frequency Results

Frequency results apply to all active bodies in *"Original"*.

Table 5.3.1.1. First 6 Natural Frequencies				
Name	**Figure**	**Mode**	**Frequency**	**Alert Criteria**
"1st Frequency Mode In Range"	A4.4	1	60.49 Hz	none
"2nd Frequency Mode In Range"	A4.5	2	62.24 Hz	none
"3rd Frequency Mode In Range"	None	3	116.15 Hz	none
"4th Frequency Mode In Range"	None	4	133.57 Hz	none
"5th Frequency Mode In Range"	None	5	151.4 Hz	none
"6th Frequency Mode In Range"	None	6	182.39 Hz	none

- Convergence tracking not enabled.

6. Scenario 5

6.1. "Original"

"Original" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.

- The bounding box for all positioned bodies in the model measures 67.06 by 23.5 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,290.51 lbm.
- The model has a total volume of 4,546.8 in³.

Table 6.1.1. Bodies

Name	Material	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements
"BODY[1]"	*"Structural Steel"*	17.0, 18.13, 18.13	428.3	1,509.01	4763	2435
"YOKE[2]"	*"Structural Steel"*	23.0, 18.13, 18.13	208.06	733.06	3341	1580
"GEARBOX[3]"	*"Structural Steel"*	5.94, 23.5, 26.29	82.06	289.13	4615	2252
"HWSTEM[4]"	*"Structural Steel"*	3.0, 3.0, 7.06	8.27	29.15	1138	658
"IMPACTOR[7]"	*"Structural Steel"*	6.25, 4.0, 2.0	4.93	17.36	680	316
"HW[10]"	*"Structural Steel"*	12.0, 12.0, 1.05	6.98	24.59	8196	4369
"GEARBOXCOVER[13]"	*"Structural Steel"*	21.25, 23.5, 23.5	64.68	227.87	7266	3456
"BONNET_LUMP[23]"	*"Structural Steel"*	6.0, 13.5, 13.5	235.4	829.38	1431	260
"GEAR_LUMP[31]"	*"Structural Steel"*	1.5, 20.58, 20.58	139.58	491.78	904	117
"STEM[35]"	*"Structural Steel"*	50.5, 5.49, 6.35	61.96	218.29	964	433
"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 6.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements

6.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 6.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2"									
"Contact Region 3"	Bonded	"CLAMP[171]" and "BODY[1]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	"CLAMP[175]" and "BODY[1]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	"GEARBOX[3]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	"CLAMP[171]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	"CLAMP[175]" and "YOKE[2]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 8"	Bonded	"HWSTEM[4]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	"GEARBOXCOVER[13]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	"GEAR_LUMP[31]" and "GEARBOX[3]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	"IMPACTOR[7]" and "HWSTEM[4]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	"HW[10]" and "IMPACTOR[7]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	"STEM[35]" and "GEARBOXCOVER[13]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	"STEM[35]" and "BONNET_LUMP[23]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 15"	Bonded	"STEM[35]" and "GEAR_LUMP[31]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 16"	Bonded	"RHN017[46]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	"RHN017[50]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	"RHN002[51]" and "STEM[35]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	"CLAMP[175]" and "CLAMP[171]"	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

6.1.2. Mesh

- *"Mesh"*(Figure A4.3) , associated with *"Original"* has an overall relevance of 0.
- *"Mesh"* contains 44808 nodes and 22296 elements.

No mesh controls specified.

6.2. "Frequency Response"

"Frequency Response" contains all loading conditions defined for *"Original"* in this scenario.

Acceleration - Constant Linear Acceleration

- Magnitude: 200.92 in/s²
- Vector: [116.0 in/s² x, 116.0 in/s² y, 116.0 in/s² z] in the global coordinate system
- The time type is harmonic

The following tables list local loads and supports applied to specific geometry.

6.2.1. Structural Supports

Table 6.2.1.1. Structural Supports

Name	Type	Associated Bodies
"Fixed Support"	Fixed Surface	*"BODY[1]"*

6.3. "Solution"

"Solution" contains the calculated response for *"Original"* given loading conditions defined in *"Frequency Response"*.

It was selected that the program would choose the solver used in this solution.

6.3.1. Harmonic Results

Table 6.3.1.1. Definition

Range Minimum	Range Maximum	Solution Method	Cluster Number	Cluster Results	Damping Ratio	Beta Damping
0.0	250.0	Mode Superposition	15	Yes	0.03	0.0

Table 6.3.1.2. Frequency Response Values

Name	Type	Scope	Multiple Entities	Minimum Frequency	Maximum Frequency	Maximum Amplitude	Frequency at Max Amplitude	Phase Angle at Max Amplitude	Real at Max Amplitude	Imaginary at Max Amplitude
"top axial"	Directional Acceleration, X Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	4,596.64in/s²	182.12Hz	-81.93°	645.63in/s²	-4,551.07in/s²
"top beam"	Directional Acceleration, Y Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	4,565.35in/s²	60.58Hz	-92.22°	-176.57in/s²	-4,561.94in/s²
"top	Directional	Surface(s) on	Use	0.0Hz	250.0Hz	4,370.28in/s²	62.29Hz	-89.4°	45.49in/s²	-4,370.04in/s²

frame"	Acceleration, Z Axis	*"GEARBOXCOVER[13]"*	Average							
"base axial"	Directional Acceleration, X Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	1,300.51in/s²	182.12Hz	-82.29°	174.58in/s²	-1,288.73in/s²
"base beam"	Directional Acceleration, Y Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	2,134.85in/s²	116.32Hz	-93.56°	-432.41in/s²	-2,130.74in/s²
"base frame"	Directional Acceleration, Z Axis	Surface(s) on *"GEARBOXCOVER[13]"*	Use Average	0.0Hz	250.0Hz	1,527.96in/s²	151.27Hz	-84.12°	156.58in/s²	-1,519.92in/s²
"finger beam"	Directional Acceleration, Y Axis	Surface(s) on *"STEM[35]"*	Use Average	0.0Hz	250.0Hz	2,909.27in/s²	60.58Hz	-90.17°	-8.8in/s²	-2,909.26in/s²

Table 6.3.1.3. top axial

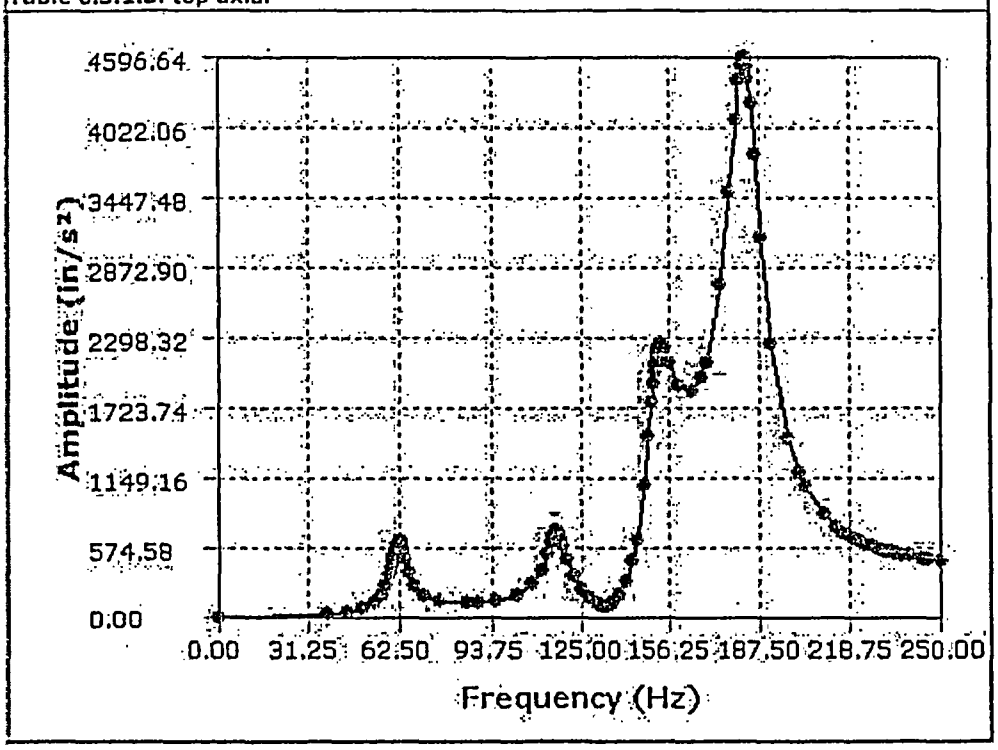


Table 6.3.1.4. top axial

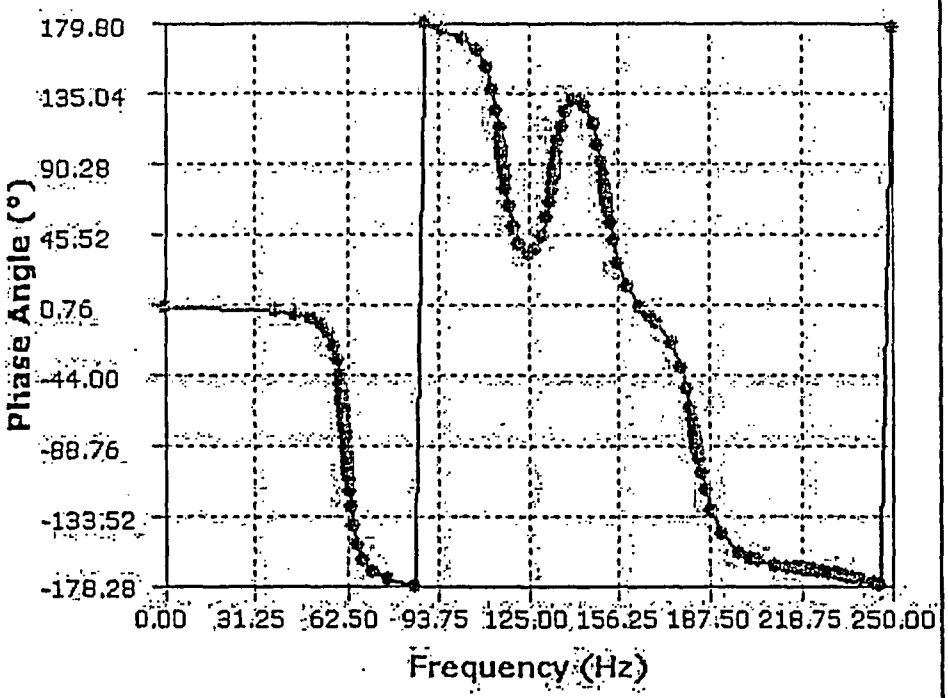


Table 6.3.1.5. top beam

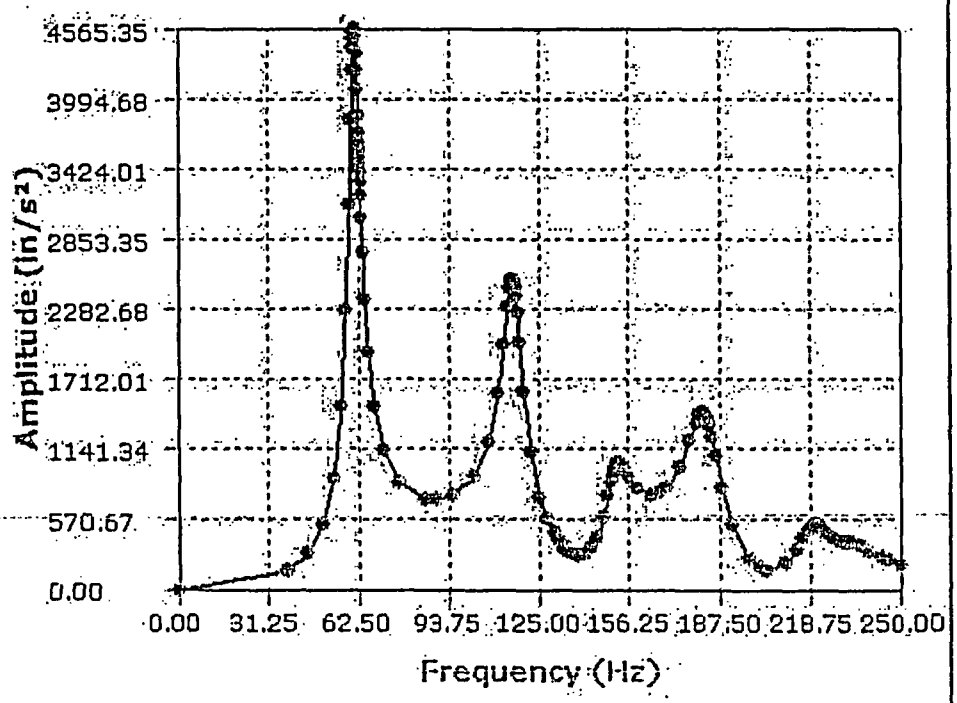


Table 6.3.1.6. top beam

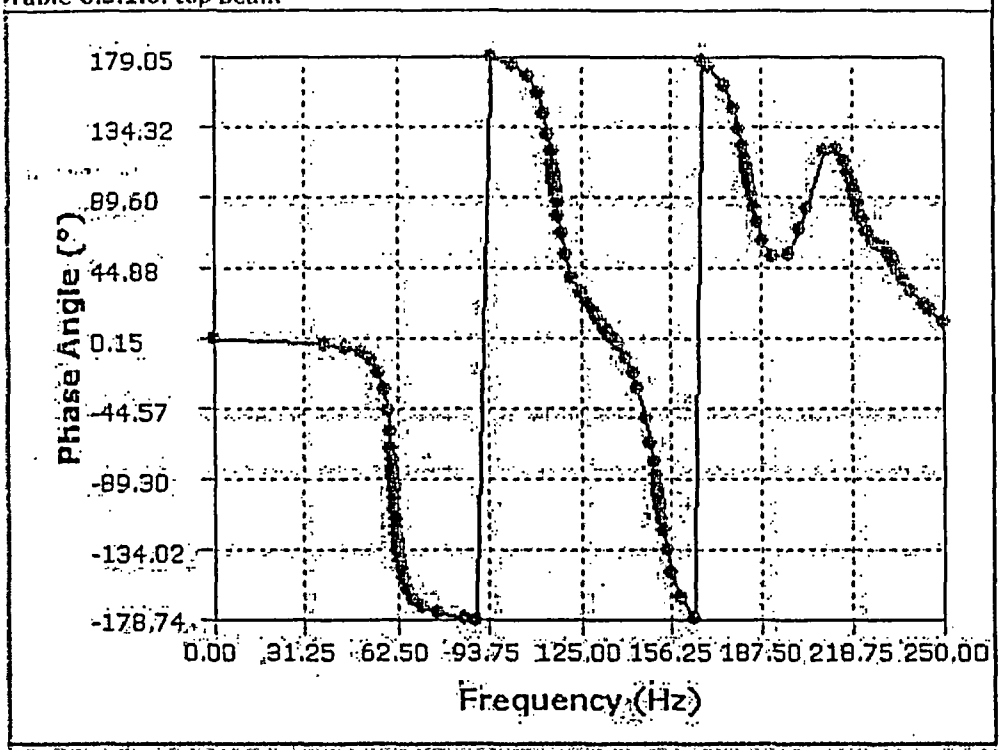


Table 6.3.1.7. top frame

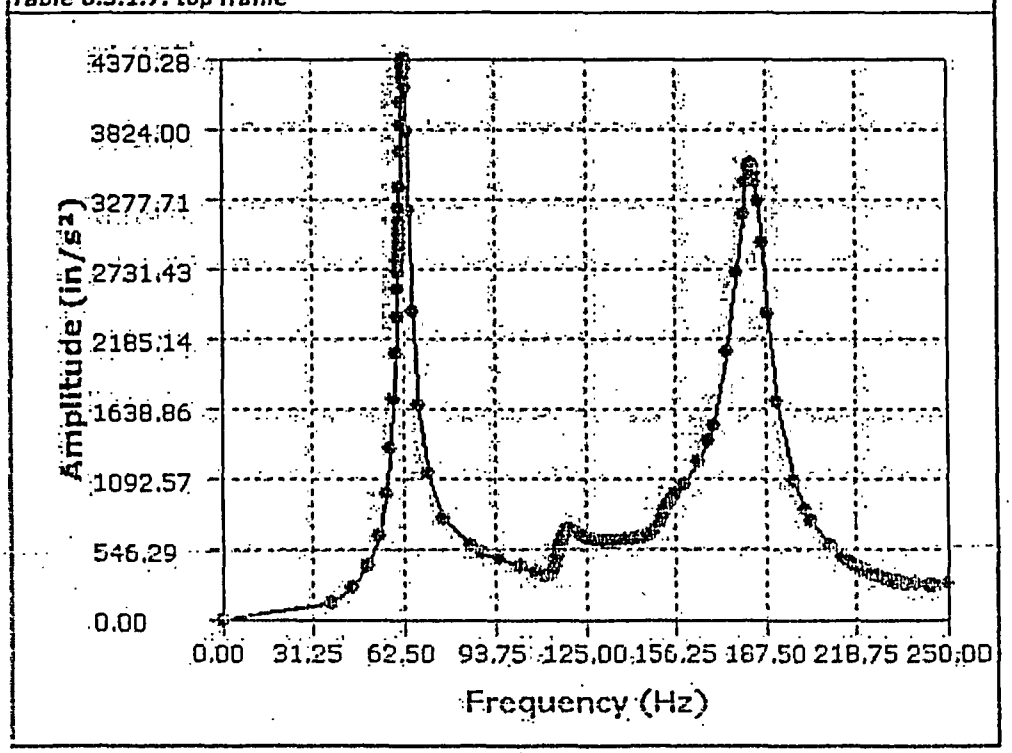


Table 6.3.1.8. top frame

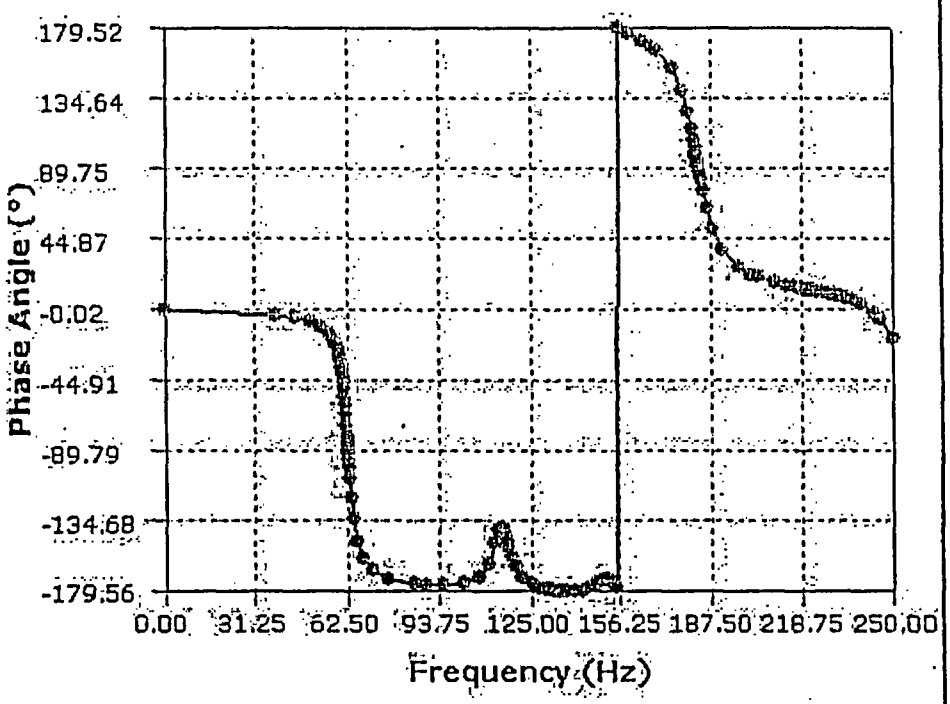


Table 6.3.1.9. base axial

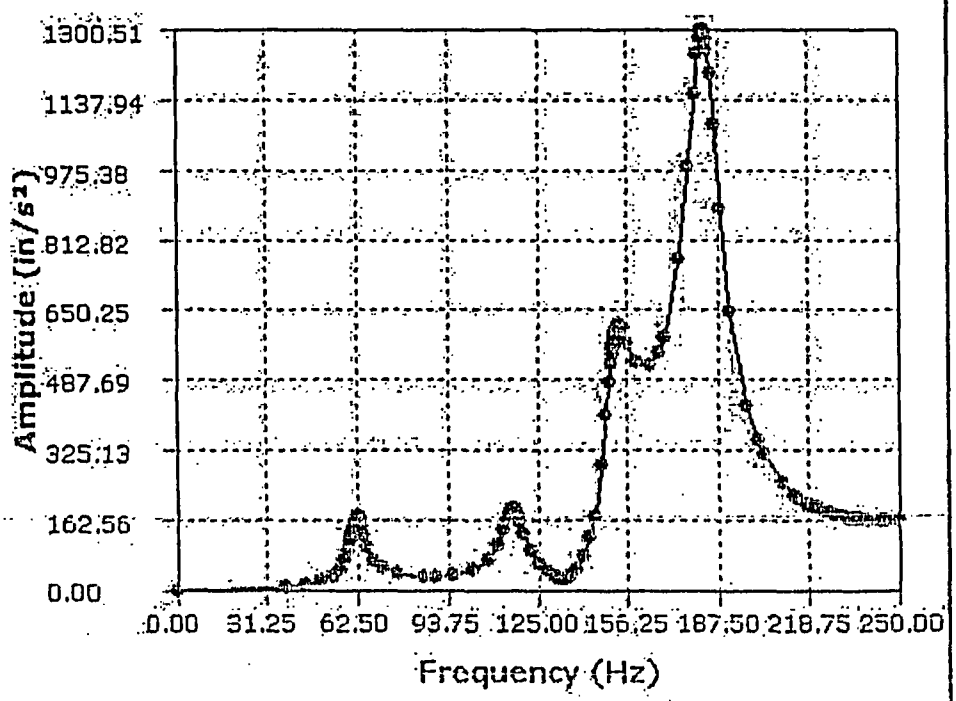


Table 6.3.1.10. base axial

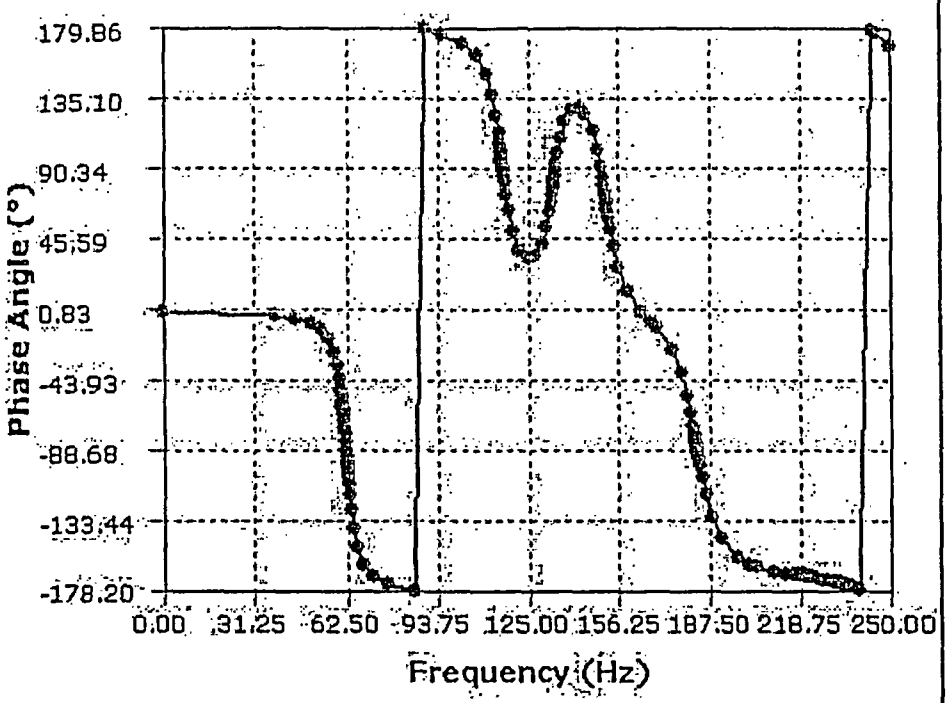


Table 6.3.1.11. base beam

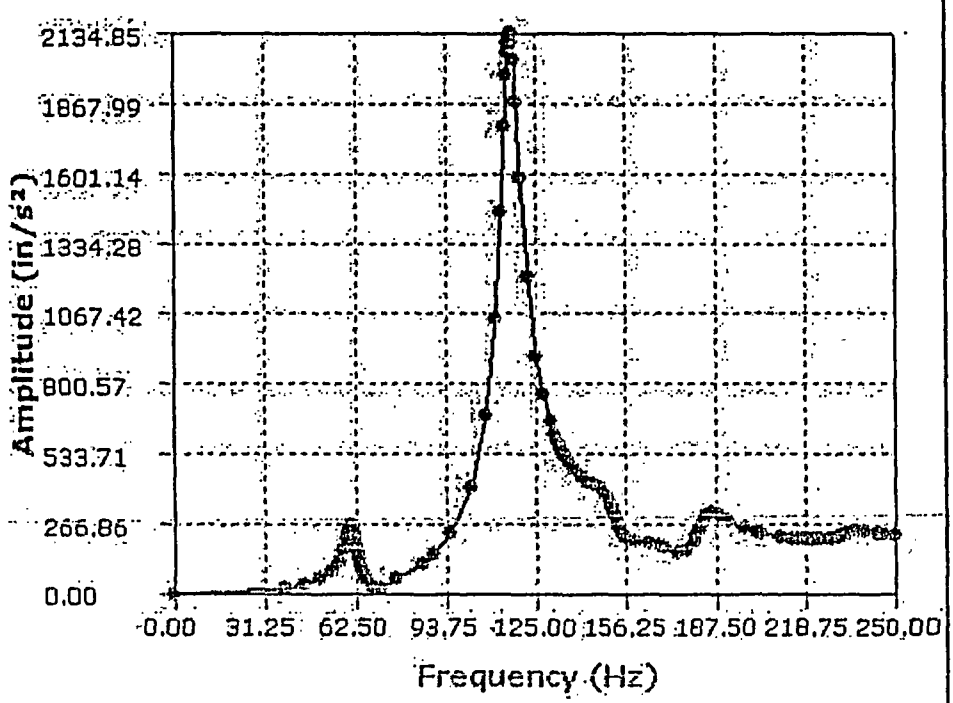


Table 6.3.1.12. base beam

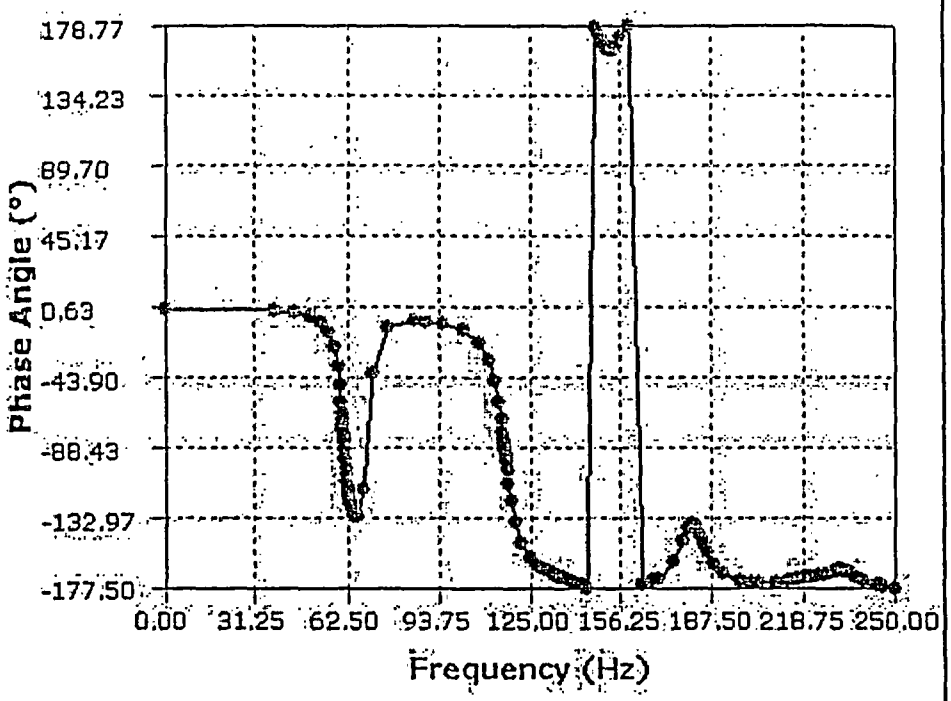


Table 6.3.1.13. base frame

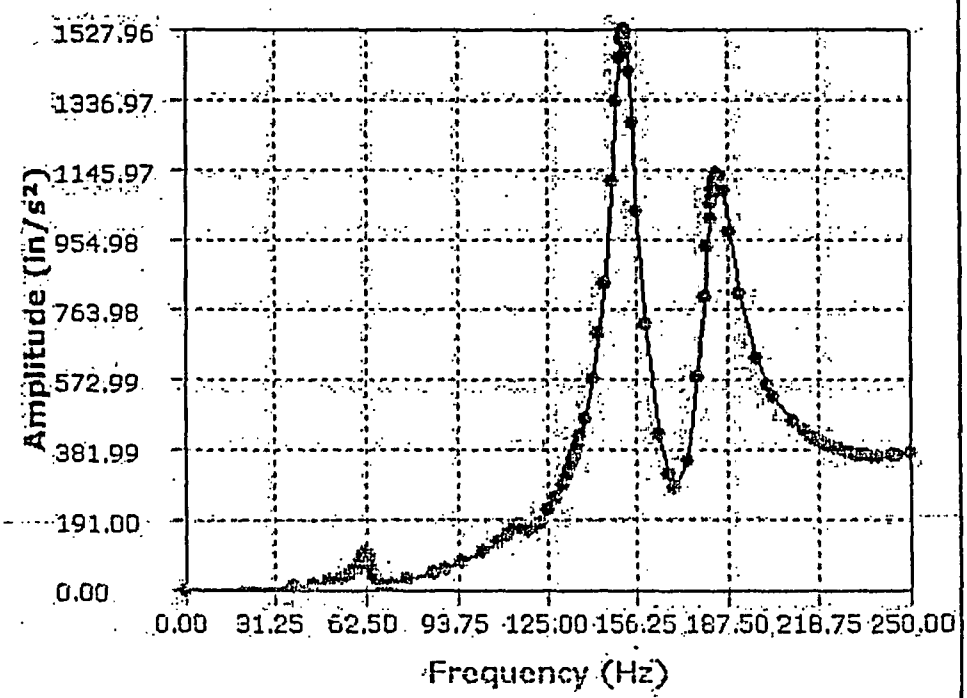


Table 6.3.1.14. base frame

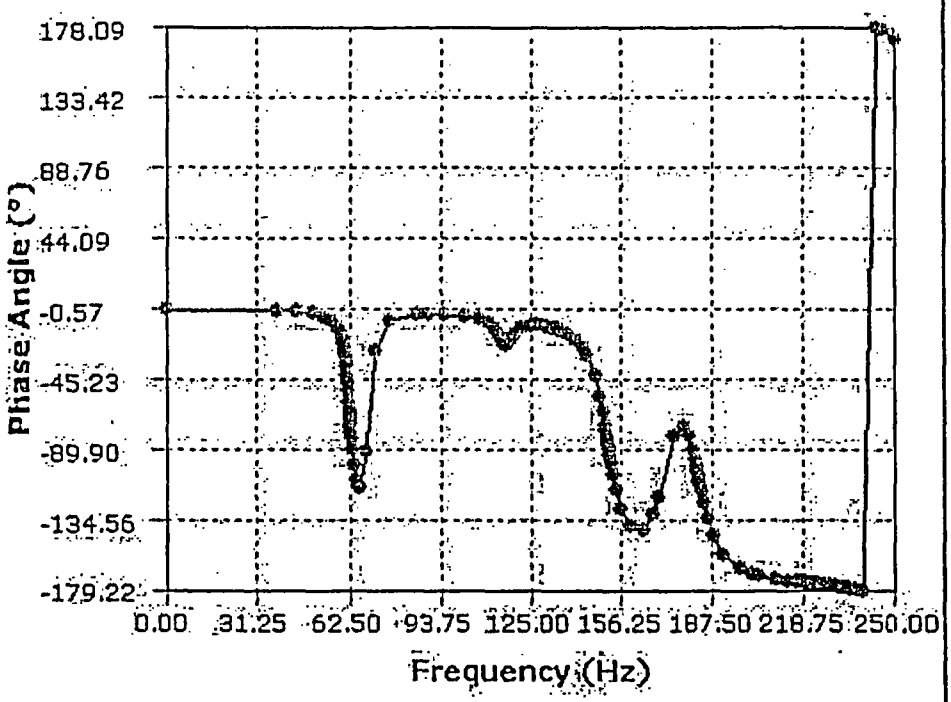


Table 6.3.1.15. finger beam

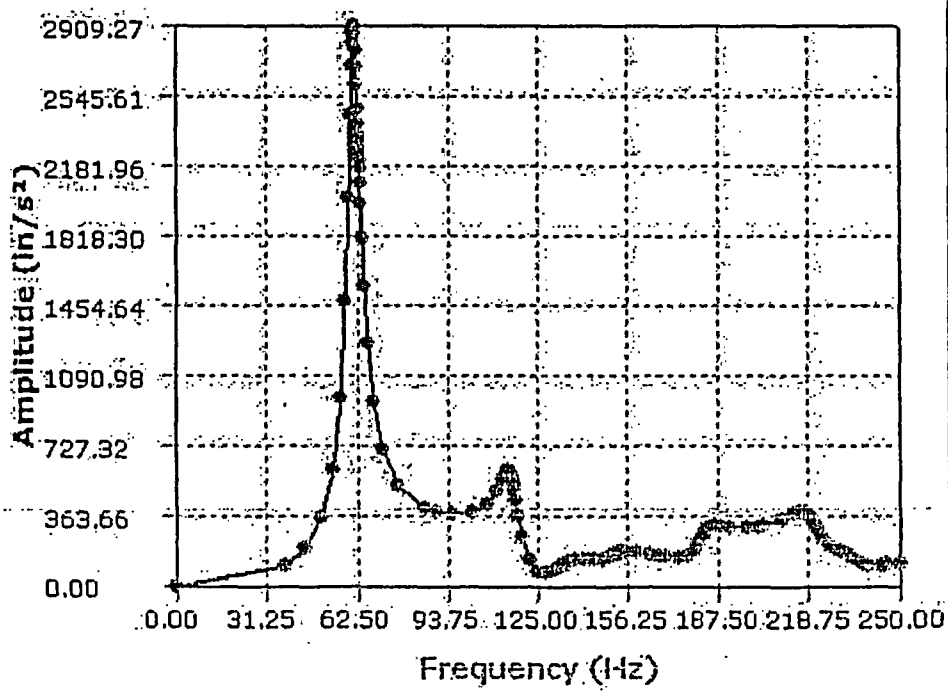
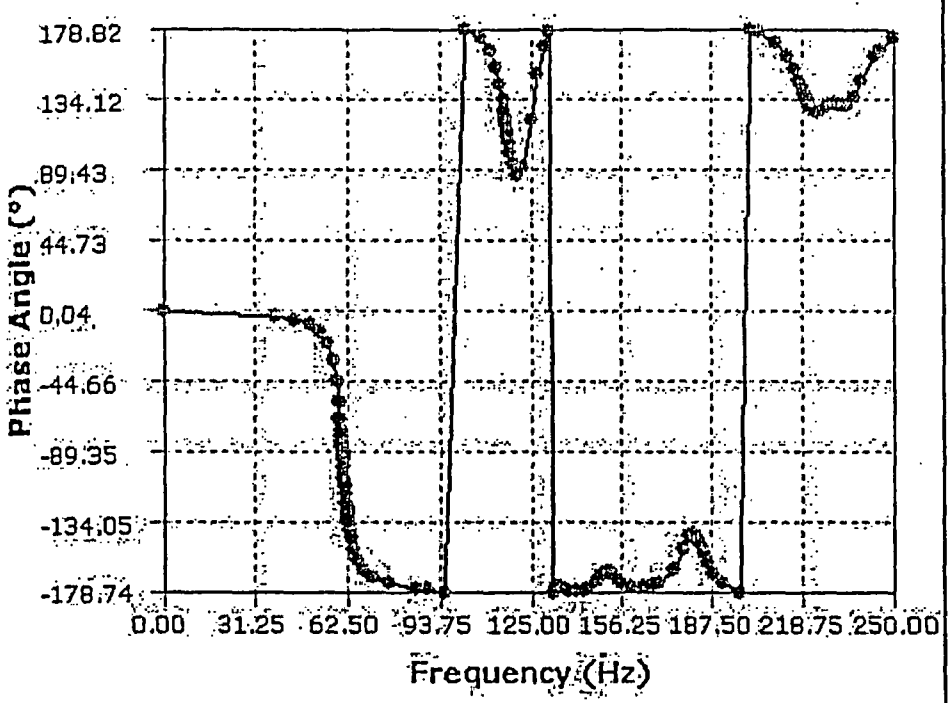


Table 6.3.1.16. finger beam



7. Scenario 6

7.1. "Original"

"Original" obtains geometry from the Pro/ENGINEER® assembly *"z:\home\rfarrell\31042 orig (12-900-FW)\ASM0001.ASM.10"*.

- The bounding box for all positioned bodies in the model measures 67.06 by 23.5 by 29.44 in along the global x, y and z axes, respectively.
- The model has a total mass of 1,290.51 lbm.
- The model has a total volume of 4,546.8 in³.

Table 7.1.1. Bodies

Name	Material	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements
"BODY[1]"	*"Structural Steel"*	17.0, 18.13, 18.13	428.3	1,509.01	4763	2435
"YOKE[2]"	*"Structural Steel"*	23.0, 18.13, 18.13	208.06	733.06	3341	1580
"GEARBOX[3]"	*"Structural Steel"*	5.94, 23.5, 26.29	82.06	289.13	4615	2252
"HWSTEM[4]"	*"Structural Steel"*	3.0, 3.0, 7.06	8.27	29.15	1138	658
"IMPACTOR[7]"	*"Structural Steel"*	6.25, 4.0, 2.0	4.93	17.36	680	316
"HW[10]"	*"Structural Steel"*	12.0, 12.0, 1.05	6.98	24.59	8196	4369
"GEARBOXCOVER[13]"	*"Structural Steel"*	21.25, 23.5, 23.5	64.68	227.87	7266	3456
"BONNET_LUMP[23]"	*"Structural Steel"*	6.0, 13.5, 13.5	235.4	829.38	1431	260
"GEAR_LUMP[31]"	*"Structural Steel"*	1.5, 20.58, 20.58	139.58	491.78	904	117
"STEM[35]"	*"Structural Steel"*	50.5, 5.49, 6.35	61.96	218.29	964	433
"RHN017[46]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN017[50]"	*"Structural Steel"*	0.64, 1.3, 1.3	0.12	0.42	2469	1407
"RHN002[51]"	*"Structural Steel"*	0.64, 1.69, 1.62	0.12	0.42	3920	2238
"CLAMP[171]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684
"CLAMP[175]"	*"Structural Steel"*	2.5, 9.69, 23.5	24.97	87.98	1326	684

Table 7.1.2. Body Groupings

Name	Body Names	Bounding Box (in)	Mass (lbm)	Volume (in³)	Nodes	Elements

7.1.1. Contact

- *"Contact"* uses a tolerance of 0.0 for automatic detection.

Table 7.1.1.1. Contact Conditions

Name	Type	Associated Bodies	Scope	Normal Stiffness	Scope Mode	Behavior	Formulation	Thermal Conductance	Pinball Region
"Contact Region"	Bonded	*"YOKE[2]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region	Bonded	*"BONNET_LUMP[23]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

2"									
"Contact Region 3"	Bonded	*"CLAMP[171]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 4"	Bonded	*"CLAMP[175]"* and *"BODY[1]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 5"	Bonded	*"GEARBOX[3]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 6"	Bonded	*"CLAMP[171]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 7"	Bonded	*"CLAMP[175]"* and *"YOKE[2]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 8"	Bonded	*"HWSTEM[4]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 9"	Bonded	*"GEARBOXCOVER[13]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 10"	Bonded	*"GEAR_LUMP[31]"* and *"GEARBOX[3]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 11"	Bonded	*"IMPACTOR[7]"* and *"HWSTEM[4]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 12"	Bonded	*"HW[10]"* and *"IMPACTOR[7]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 13"	Bonded	*"STEM[35]"* and *"GEARBOXCOVER[13]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 14"	Bonded	*"STEM[35]"* and *"BONNET_LUMP[23]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 15"	Bonded	*"STEM[35]"* and *"GEAR_LUMP[31]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 16"	Bonded	*"RHN017[46]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 17"	Bonded	*"RHN017[50]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 18"	Bonded	*"RHN002[51]"* and *"STEM[35]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled
"Contact Region 19"	Bonded	*"CLAMP[175]"* and *"CLAMP[171]"*	Face, Face	Program Controlled	Automatic	Symmetric	Pure Penalty	Program Controlled	Program Controlled

7.1.2. Mesh

- *"Mesh"*(Figure A4.3) , associated with *"Original"* has an overall relevance of 0.
- *"Mesh"* contains 44808 nodes and 22296 elements.

No mesh controls specified.

7.2. "Stress Analysis"

"Stress Analysis" contains all loading conditions defined for *"Original"* in this scenario.

acceleration - Constant Linear Acceleration

- Magnitude: 7,853.66 in/s²
- Vector: [4,600.0 in/s² x, 4,600.0 in/s² y, 4,400.0 in/s² z] in the global coordinate system

The following tables list local loads and supports applied to specific geometry.

7.2.1. Structural Supports

Table 7.2.1.1. Structural Supports

Name	Type	Reaction Force	Reaction Force Vector	Reaction Moment	Reaction Moment Vector	Associated Bodies
"Fixed Support"	Fixed Surface	26,265.22 lbf	[15,383.91 lbf x, 15,383.91 lbf y, 14,715.04 lbf z]	505,106.62 lbf·in	[-5,621.9 lbf·in x, 352,819.24 lbf·in y, -361,413.44 lbf·in z]	*"BODY[1]"*

7.3. "Solution"

"Solution" contains the calculated response for *"Original"* given loading conditions defined in *"Stress Analysis"*.

It was selected that the program would choose the solver used in this solution.

7.3.1. Structural Results

Table 7.3.1.1. Values

Name	Figure	Scope	Minimum	Maximum	Alert Criteria
"Equivalent Stress"	A6.1	All Bodies In *"Original"*	2.34 psi	65,153.61 psi	None
"Total Deformation"	A6.2	All Bodies In *"Original"*	0.0 in	9.51×10^{-2} in	None

- Convergence tracking not enabled.

Appendices

A1. Scenario 1 Figures

Figure A1.1. *"Geometry"* Geometry

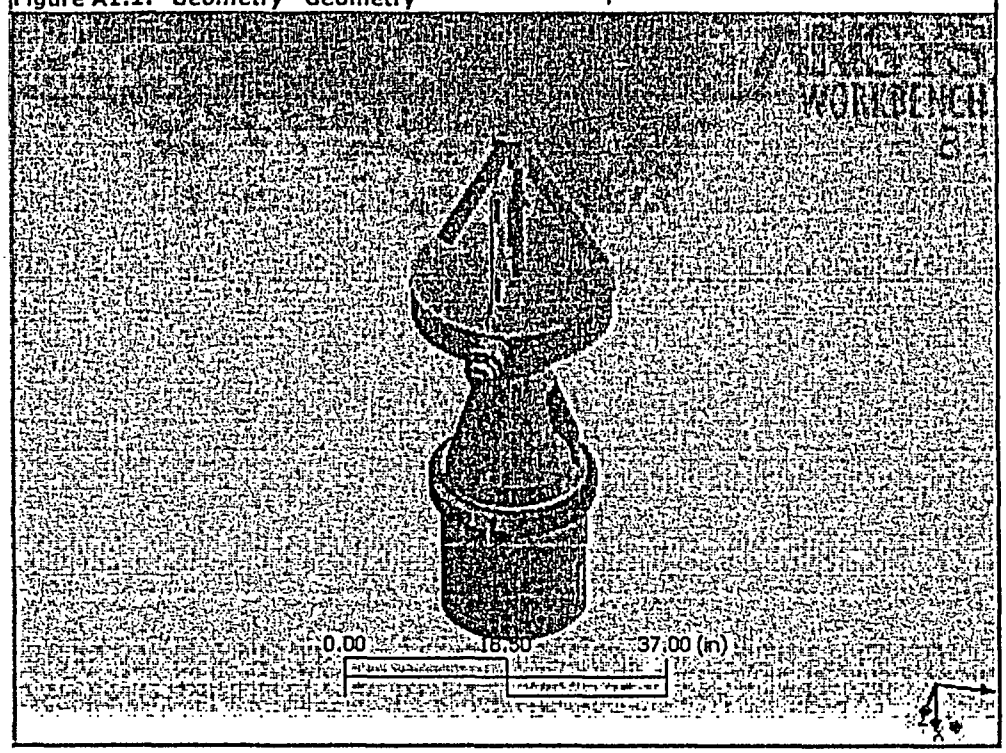


Figure A1.2. *"Geometry"* Geometry

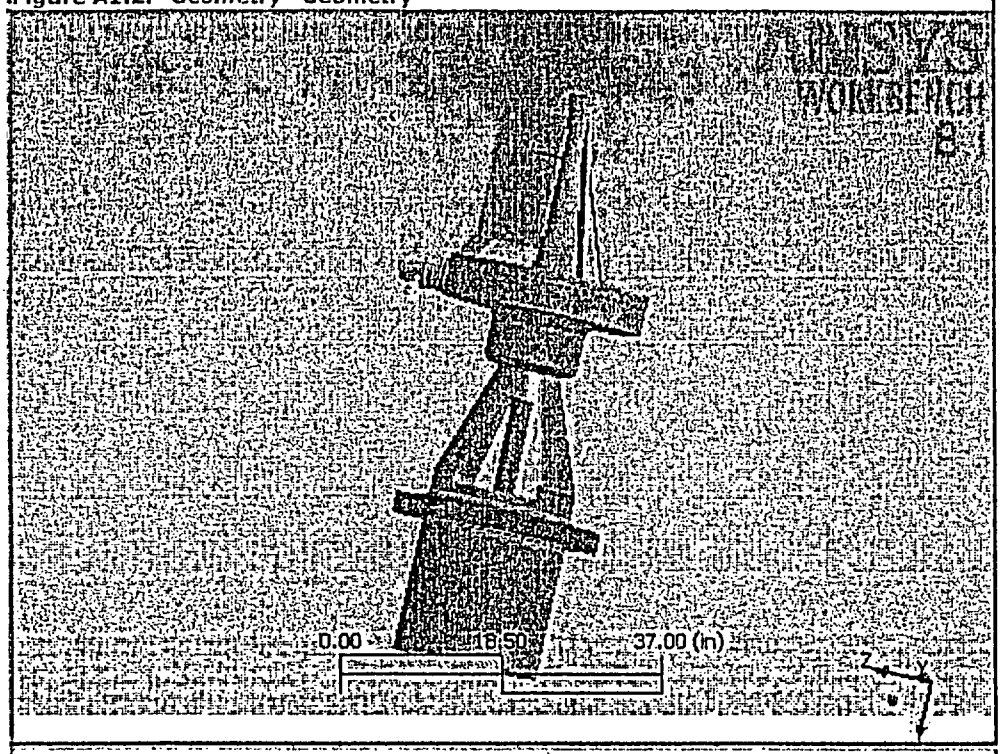


Figure A1.3. *"Mesh"* Geometry

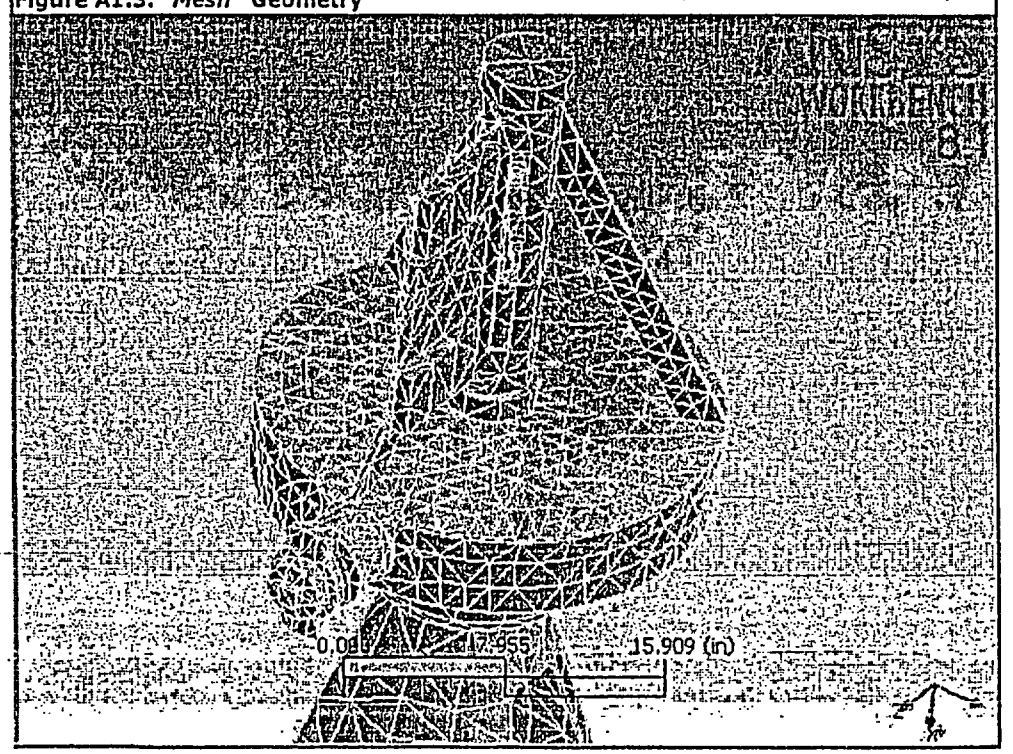


Figure A1.4. ***"1st Frequency Mode In Range"*** **Contours**

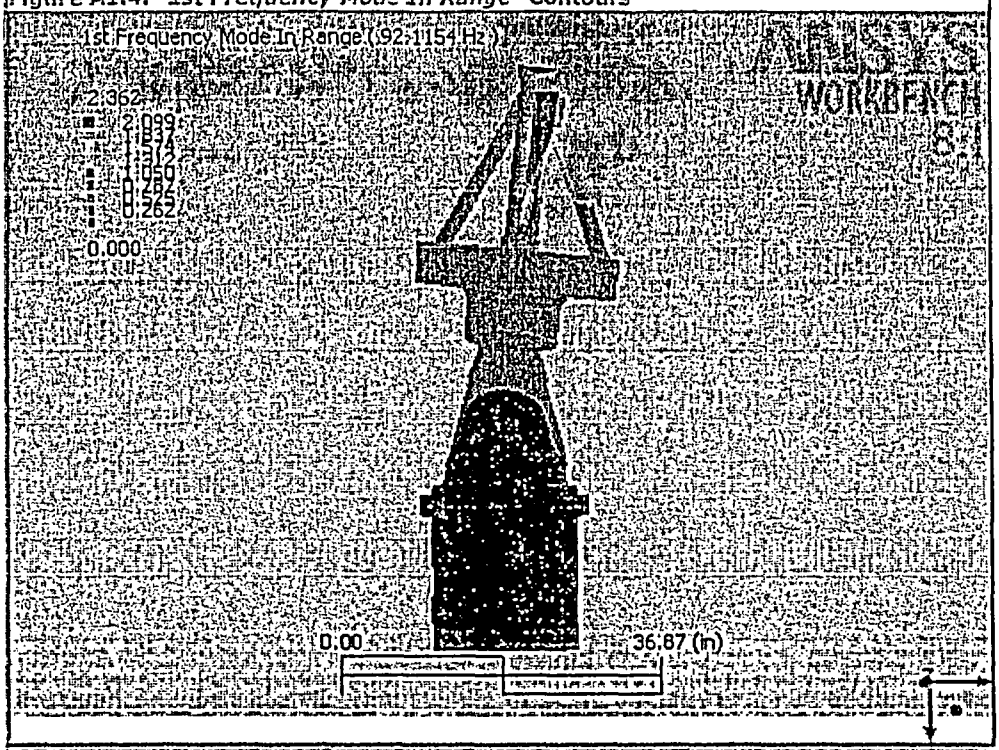
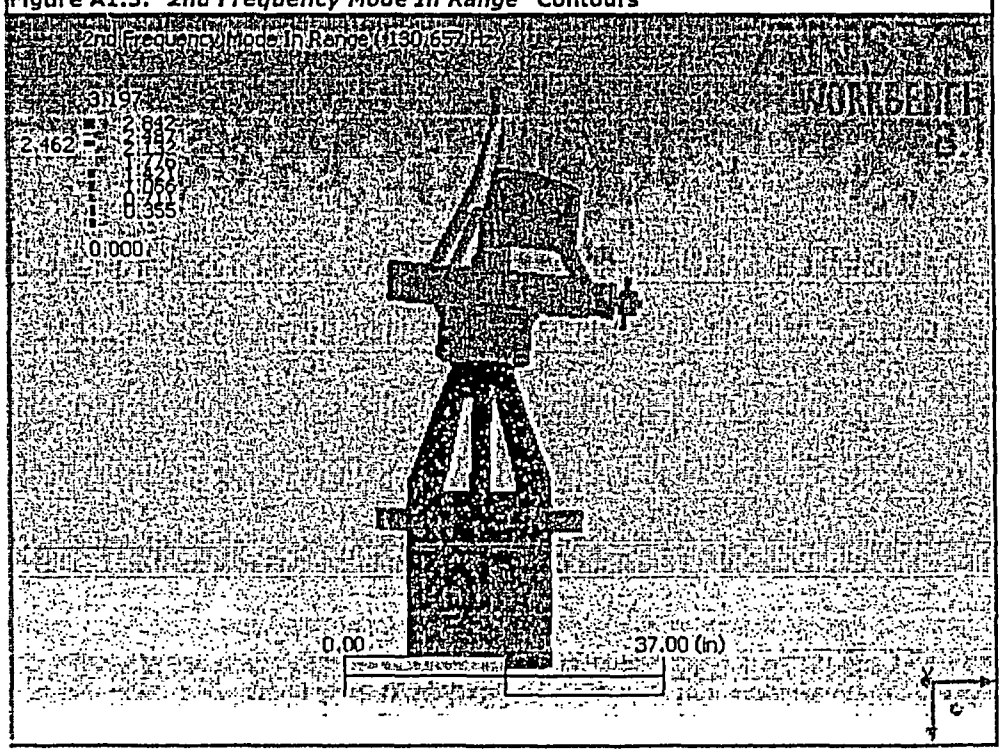


Figure A1.5. ***"2nd Frequency Mode In Range"*** **Contours**



A2. Scenario 2 Figures

No figures to display.

A3. Scenario 3 Figures

Figure A3.1. *" Equivalent Stress"* **Contours (not updated)**

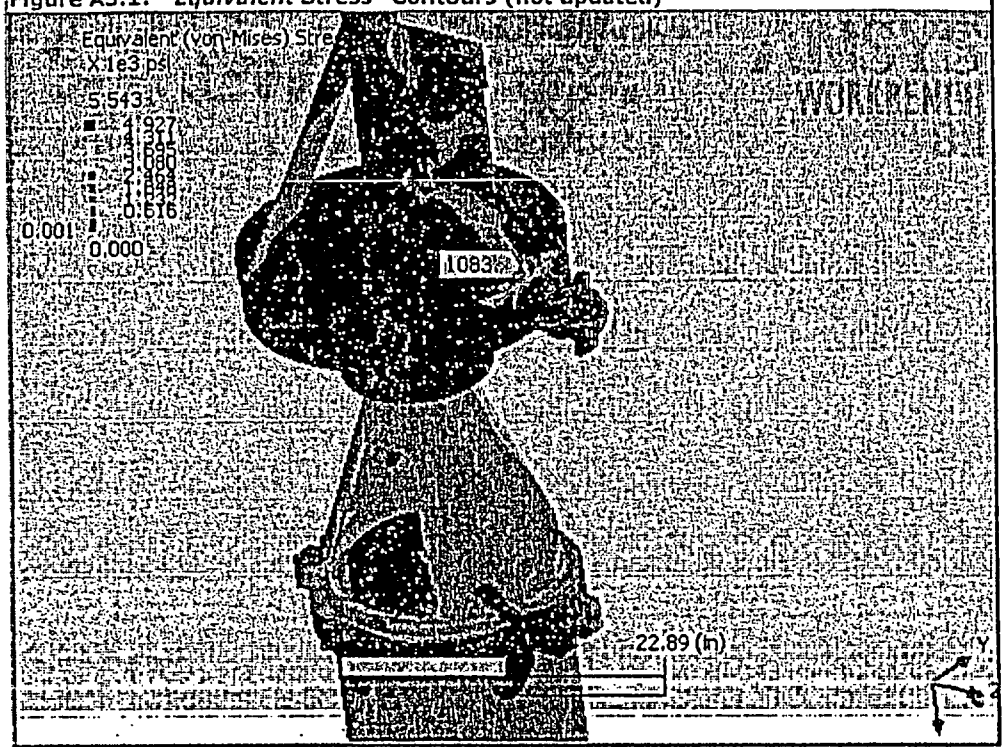
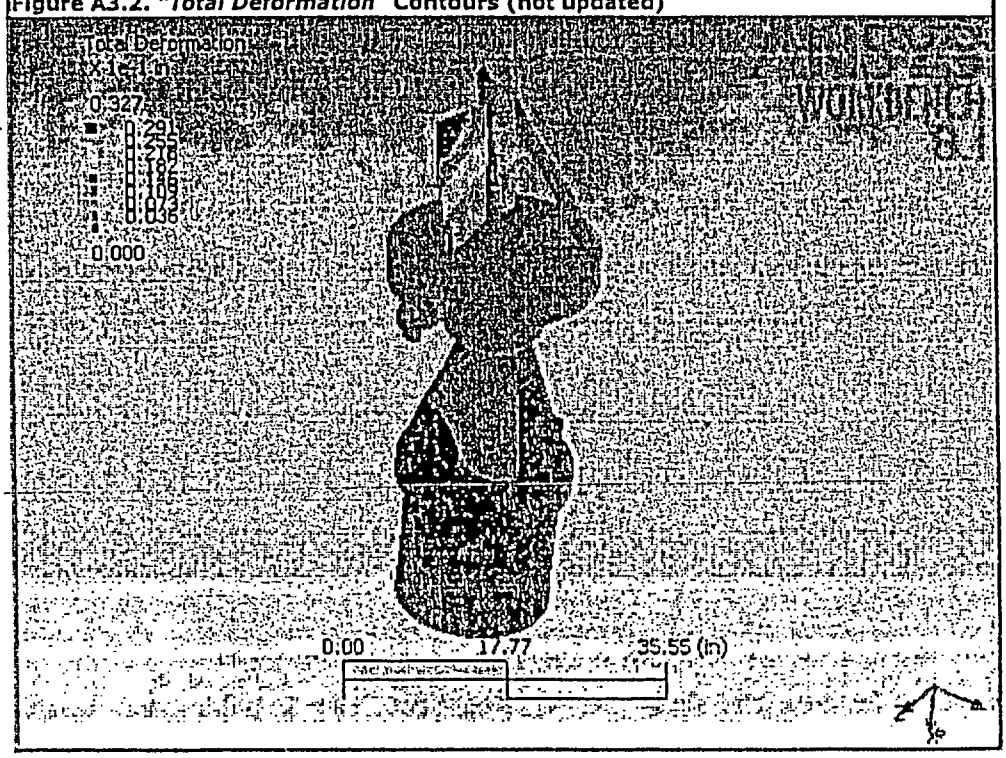


Figure A3.2. *"Total Deformation"* **Contours (not updated)**



A4. Scenario 4 Figures

Figure A4.1. *"Geometry"* Geometry

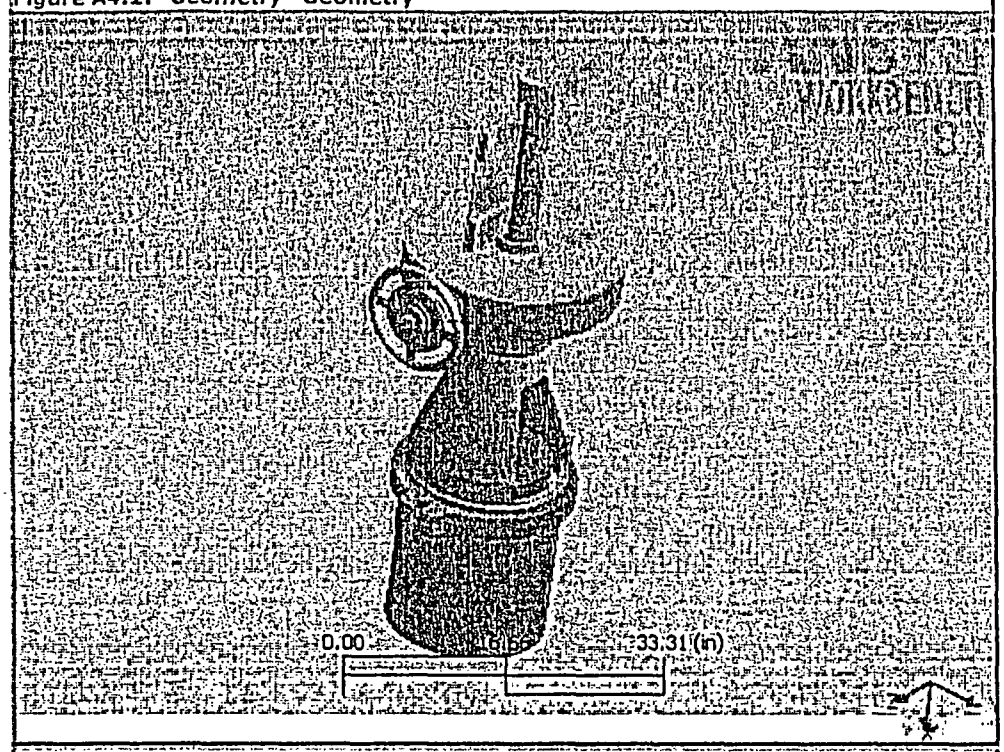


Figure A4.2. *"Geometry"* Geometry

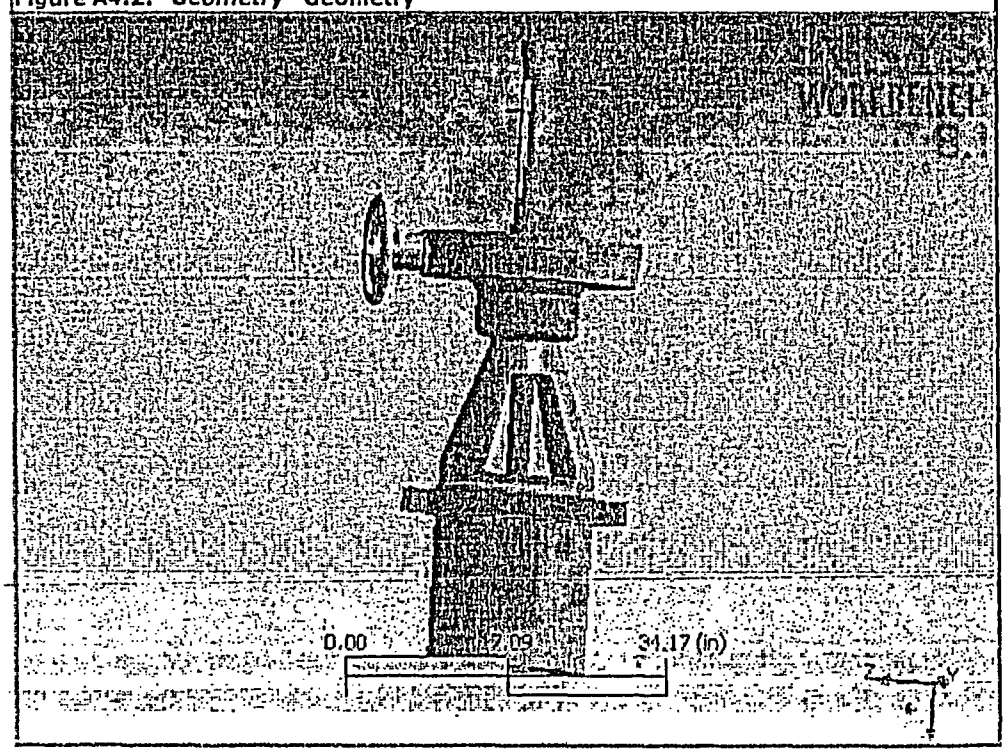


Figure A4.3. *"Mesh"* Geometry

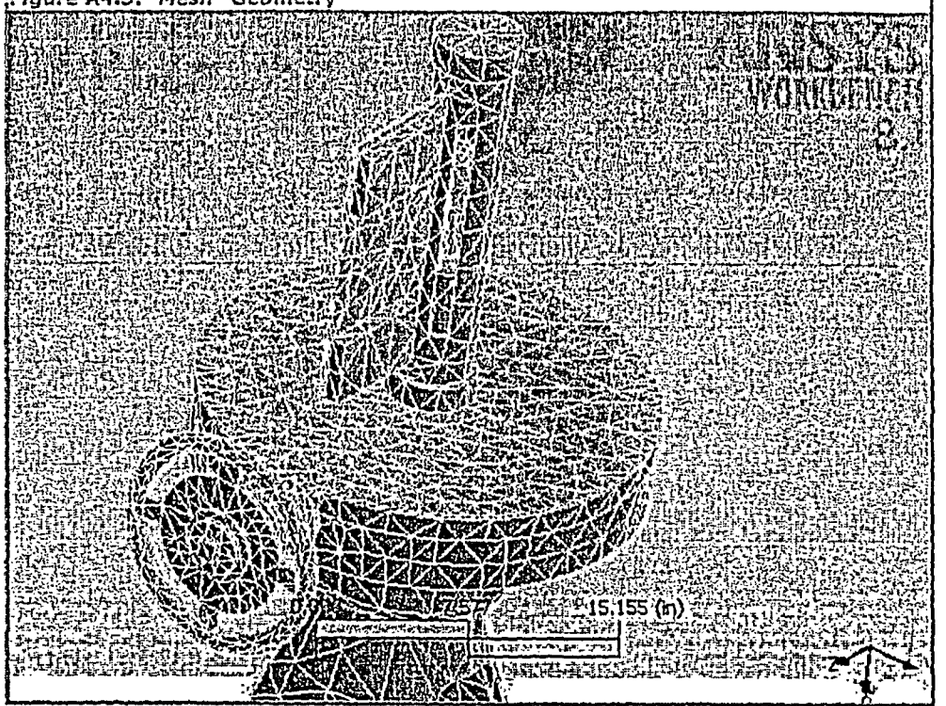


Figure A4.4. *"1st Frequency Mode In Range"* Contours

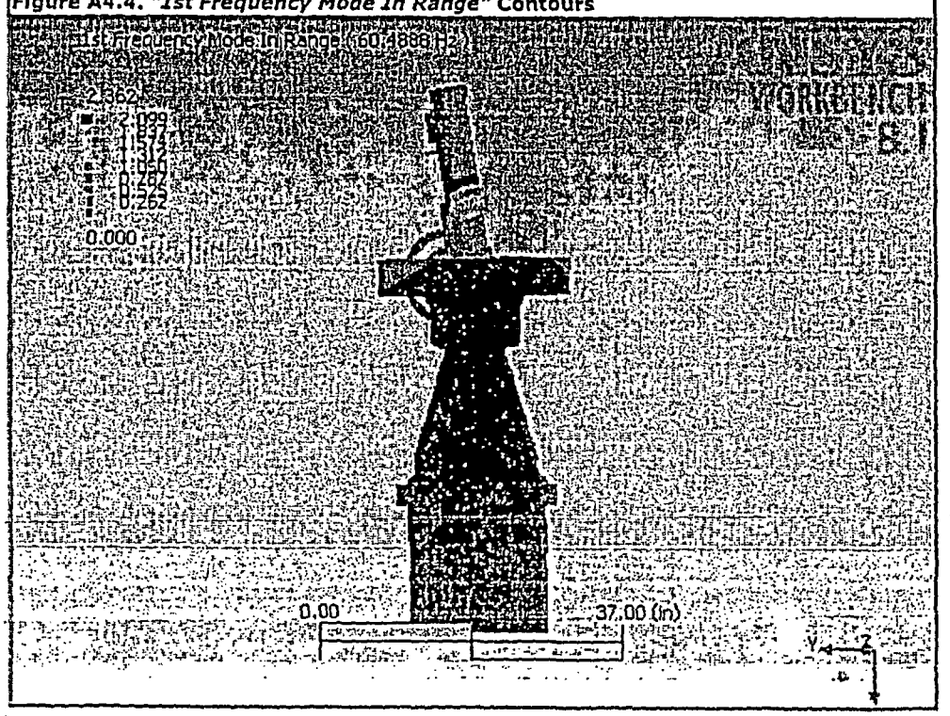
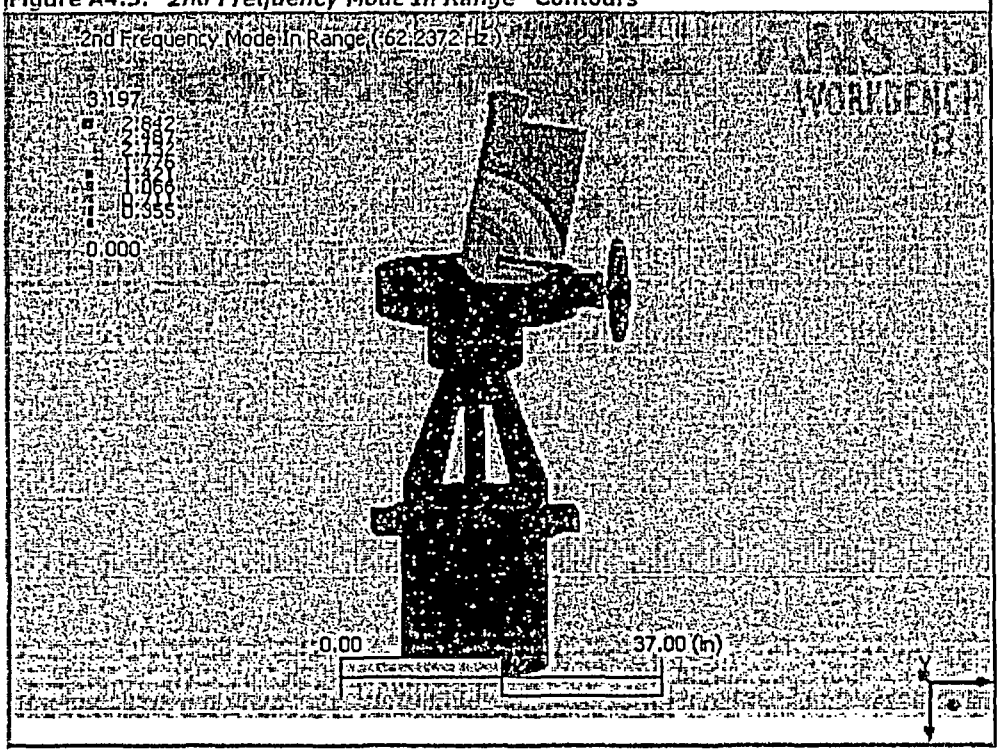


Figure A4.5. ***"2nd Frequency Mode In Range"*** **Contours**



A5. Scenario 5 Figures

No figures to display.

A6. Scenario 6 Figures

Figure A6.1. ***"Equivalent Stress"*** **Contours**

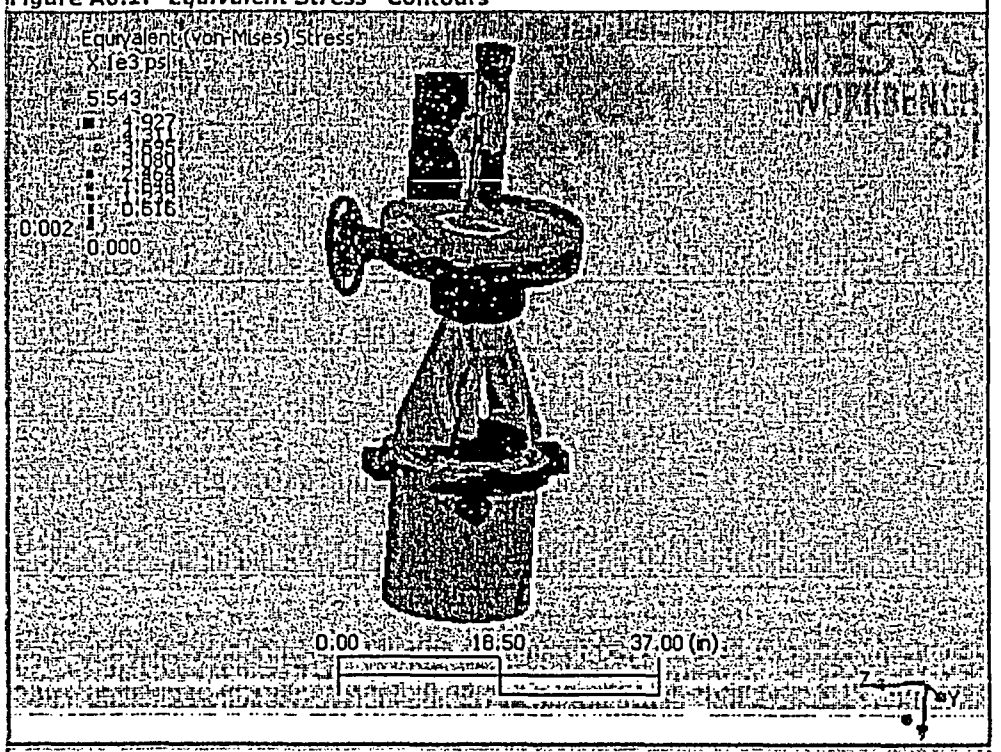
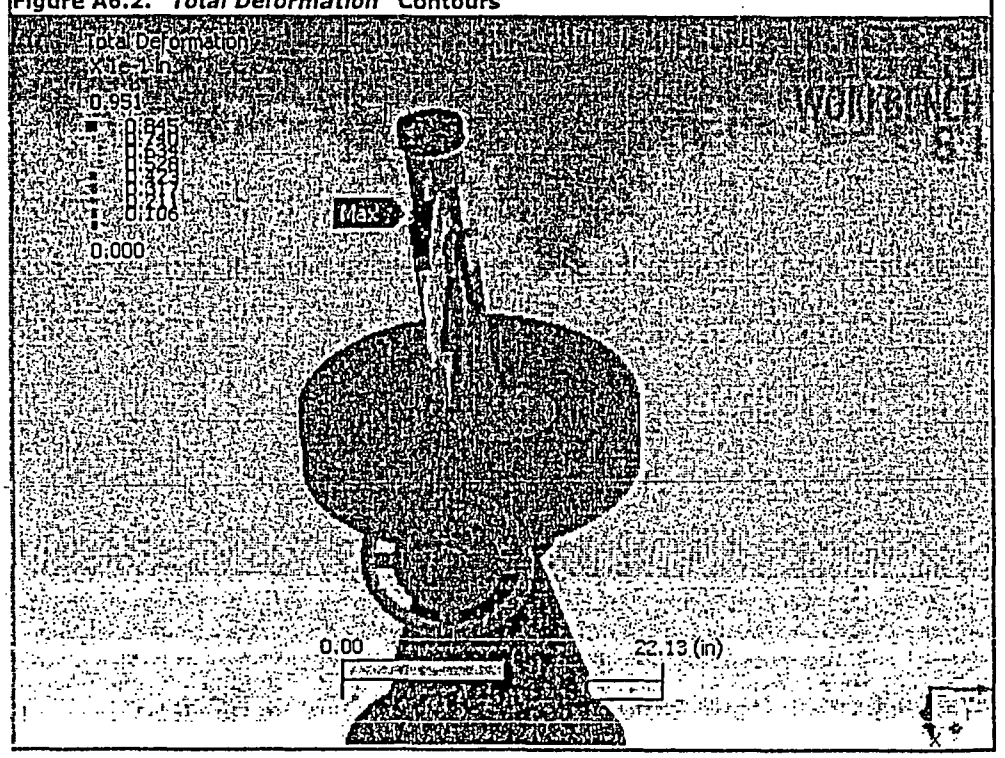


Figure A6.2. ***"Total Deformation"*** **Contours**



A7. Definition of "Structural Steel"

Table A7.1. *"Structural Steel"* Properties		
Name	**Type**	**Value**
Modulus of Elasticity	Temperature-Independent	2.9×10^{7} psi
Poisson's Ratio	Temperature-Independent	0.3
Mass Density	Temperature-Independent	0.28 lbm/in^3
Coefficient of Thermal Expansion	Temperature-Independent	6.67×10^{-6} 1/°F
Thermal Conductivity	Temperature-Independent	8.09×10^{-4} BTU/s·in·°F
Specific Heat	Temperature-Independent	0.1 BTU/lbm·°F

A8. Definition of "cover"

Table A8.1. *"cover"* Properties		
Name	**Type**	**Value**
Modulus of Elasticity	Temperature-Independent	2.9×10^{7} psi
Poisson's Ratio	Temperature-Independent	0.3
Mass Density	Temperature-Independent	0.28 lbm/in^3
Coefficient of Thermal Expansion	Temperature-Independent	6.67×10^{-6} 1/°F
Thermal Conductivity	Temperature-Independent	8.09×10^{-4} BTU/s·in·°F
Specific Heat	Temperature-Independent	0.1 BTU/lbm·°F

A9. Definition of "bonnet lump"

Table A9.1. *"bonnet lump"* Properties		
Name	**Type**	**Value**
Modulus of Elasticity	Temperature-Independent	2.9×10^{7} psi
Poisson's Ratio	Temperature-Independent	0.3
Mass Density	Temperature-Independent	0.39 lbm/in^3
Coefficient of Thermal Expansion	Temperature-Independent	6.67×10^{-6} 1/°F
Thermal Conductivity	Temperature-Independent	8.09×10^{-4} BTU/s·in·°F
Specific Heat	Temperature-Independent	0.1 BTU/lbm·°F

A10. Definition of "gear lump"

Table A10.1. *"gear lump"* Properties		
Name	**Type**	**Value**
Modulus of Elasticity	Temperature-Independent	2.9×10^{7} psi
Poisson's Ratio	Temperature-Independent	0.3
Mass Density	Temperature-Independent	0.3 lbm/in^3
Coefficient of Thermal Expansion	Temperature-Independent	6.67×10^{-6} 1/°F
Thermal Conductivity	Temperature-Independent	8.09×10^{-4} BTU/s·in·°F
Specific Heat	Temperature-Independent	0.1 BTU/lbm·°F