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ENGINEERING DATA TRANSMITTAL

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7. Abstract

The purpose of the Shot Loading Trainer is testing and training on loading lead or steel shot for shielding into the annulus spaces in cylindrical shipping containers. This document provides the structural analysis of the Shot Loading Trainer.

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SHOT LOADING TRAINER ANALYSIS

DECEMBER 1994

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CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed WHC-SD-W320-DA-006, Rev. 0

Author K. M. Jones

Yes No NA

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

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Reviewer - R. S. Marlow

2/3/95
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DESIGN VERIFICATION METHOD

The need for design verification has been reviewed with the method selected as indicated below: (ESR/Work Plan # WP-8D430-289).

<u> X </u>	Independent Review
<u> </u>	Alternative Calculations
<u> </u>	Qualification Testing
<u> </u>	Formal Design Review

R. B. Pan
Cognizant/~~P~~roject/Design Manger

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ENGINEERING ANALYSIS SOFTWARE REPORT FORM

SEPTEMBER 1994
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SOFTWARE LOG NUMBER

SOFTWARE APPLICATION:

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COMPONENT STRESS ANALYSIS

2/3/95
DATE

J. B. Truitt
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COMPONENT STRESS ANALYSIS

2/3/95
DATE

DESCRIPTION OF ANALYSIS:

A finite element model of the shot loading trainer (SLT) was developed in the ANSYS finite element program. This model then was used to determine the stresses and natural frequencies of the SLT under operating and gravity loads resulting from the vibrators and the weight of the components and steel shot, respectively.

R. S. Marlow
REVIEWER - R. S. Marlow

2/3/95
DATE

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SHOT LOADING TRAINER ANALYSIS

1.0 INTRODUCTION

This document presents the results from the analysis of the shot loading trainer (SLT). This device will be used to test the procedure for installing shot into the annulus of the Project W-320 shipping container. To ensure that the shot is installed uniformly around the container, vibrators will be used to settle the shot.

The SLT was analyzed to ensure that it would not jeopardize worker safety during operation. The results from the static analysis of the SLT under deadweight and vibrator operating loads show that the stresses in the SLT are below code allowables. The results from the modal analysis show that the natural frequencies of the SLT are far below the operating frequencies of the vibrators, provided the SLT is mounted on pneumatic tires. The SLT was also analyzed for wind, seismic, deadweight, and moving/transporting loads.

Analysis of the SLT is in accordance with SDC-4.1 for safety class (SC) 3 structures (DOE-RL 1993) and the American Institute of Steel Construction (AISC) Manual of Steel Construction (AISC 1989).

2.0 REQUIREMENTS

Because of the nature of the equipment involved, no personnel are allowed on or underneath the SLT during vibrator operation. Also, the SLT tires must be chocked to prevent lateral movement during testing (with or without the vibrators being used).

The results from the modal analysis show a need to use the pneumatic tires and a requirement that the vibrators be brought up to operational speed quickly to reduce the time during which the SLT is exposed to low-frequency vibrations. Because the SLT acts as a single-degree-of-freedom system, operating the SLT at low frequencies could lead to "bouncing" on the tires and the associated instability. With the normal procedure of bringing the vibrators up to operational speeds quickly, the SLT bouncing on the tires is not a concern.

3.0 DISCUSSION

3.1 DESCRIPTION

The SLT consists of a full-scale model of a section of the Project W-320 shipping container mounted on four legs of 3- by 3-in. steel tubing. Each leg rests on two, 18-in. pneumatic tires, which provide vibration isolation and allow the SLT to be easily moved. The vibrating force is applied by two vibrators, one mounted on each side of the SLT. The vibrators will be operated at three speeds. For testing purposes, steel shot is used in place of the lead shot.

The purpose of the SLT is to train personnel in loading shot into shipping containers and to gather data on the use of the vibrators. The configuration of the SLT is given in drawing H-2-83742 (WHC 1994a). The SLT is to be used in conjunction with two shot loading funnels shown on drawing H-2-83745 (WHC 1994b), the shot loading platform shown on drawing H-2-83738 (WHC 1994c), and three vendor-supplied items: 1) Garbro Shot Loading Hopper, 2) Garbro Shot Loading Bucket, and 3) Valley Craft Barrel Dumper (these three items are outlined in Certified Vendor Information no. 22641).

3.2 VIBRATOR OPERATING LOADS ANALYSIS

3.2.1 Static-Equivalent Analysis

The SLT was analyzed structurally for two vibrator operating load cases. Dynamic loading effects were taken into consideration by applying a dynamic magnification factor (DMF) to the vibrator operating loads and applying the loads to the structure as static-equivalent loads.

Load case 1 was the deadweight of the SLT and steel shot and an operating load of 1,533.3 lbf applied in the horizontal direction. Load case 2 was the deadweight of the SLT and steel shot and the operating load applied in the vertical direction. The static-equivalent operating load was derived by multiplying the full vibrator load of 4,600 lbf by a dynamic magnification factor of one-third. This DMF corresponds to a frequency ratio of 2.0 (Clough and Penzien 1975, graph 4-4), where the frequency ratio is defined as the ratio of the applied frequency to the natural frequency. Using a frequency ratio of at least 2.0 ensures that the operating frequency will not couple with a natural frequency of the SLT. The DMF of one-third for the vibrator load is conservative because the actual values obtained for the DMF are much lower than one-third (see Appendix B, pp. 10-13 for the actual values). The resulting stresses then were compared to AISC code allowables for combined compression and bending. Appendix B contains the details of the structural evaluation of the SLT for vibrator loads.

Tables 1 and 2 give the worst-case compressive and bending stresses at two locations on the SLT for load cases 1 and 2, respectively. The stresses for load case 1 were determined from the computer output in Appendix D. The stresses for load case 2 were determined from the computer output in Appendix E. The computer model input data is in Appendix G.

For analytical purposes the tires were modeled as linear springs. The spring constant was based on the geometry and an internal tire pressure of 50 lbf/in². Appendix A shows the derivation of this spring constant and also gives the required load-carrying capacity for each tire. This load is slightly higher than the load rating of the tires. However, the tires are designed with an extra load margin available to account for some dynamic loading as they roll. Because very little of the dynamic load from the vibrators will be transmitted to the tires, the extra static load on these tires is acceptable.

Table 1. Stresses in the SLT
Load Case 1.

Location (Element No.) (Figure 4)	Calculated Axial Stress (lbf)	AISC Allowable Axial Stress (lbf)	Calculated Bending Stress (lbf)	AISC Allowable Bending Stress (lbf)
Elements 19 & 20	1,347	8,843	4,571	21,600
Elements 23 & 24	1,318	19,753	5,281	21,600

Table 2. Stresses in the SLT
Load Case 2.

Location (Element No.) (Figure 4)	Calculated Axial Stress (lbf)	AISC Allowable Axial Stress (lbf)	Calculated Bending Stress (lbf)	AISC Allowable Bending Stress (lbf)
Elements 19 & 20	951	8,843	1,228	21,600
Element 15	903	21,114	1,644	21,600

3.2.2 Modal Analysis

A modal analysis of the SLT was performed to determine its natural frequencies. The computer output is in Appendix F; the computer model input data is in Appendix G. Of interest was whether one of the operating frequencies could cause harmonic excitation of the SLT at one of its natural frequencies. To ensure that this would not occur, the frequency ratio of the lowest operating frequency of the vibrators to the highest natural frequency of the SLT must be greater than 2.0. The lowest operating frequency of the vibrators would be the first frequency to couple with one of the natural frequencies of the SLT.

The modal analysis was performed for three cases. Case 1 considered the SLT mounted on springs to model the response of the pneumatic tires and included the mass of the steel shot. Case 2 considered the SLT on fixed supports and also included the mass of the steel shot. Case 3 was identical to case 1, but did not include the mass of the steel shot. Table 3 gives the operating frequencies of the SLT (from Appendix C vendor data). Tables 4 through 6 give the calculated natural frequencies and critical frequency ratios for cases 1 through 3.

Table 3. Operating Frequencies and Loads.

Operating Speed (r/min)	4,128	4,650	5,200
Operating Frequency (Hz)	68.8	77.5	86.7
Force (lbf)	1,450	1,840	2,300

Table 4. Natural Frequencies of the SLT
Case 1 -- Spring Supports.

Mode Number (Attachment 4)	Direction (Figures 1 and 2)	Natural Frequency (Hz)	Frequency Ratio*
1	z	0.75	92.0
2	x	1.94	35.5
4	y	4.91	14
6	x	8.32	8.3

Table 5. Natural Frequencies of the SLT
Case 2 -- Fixed Supports.

Mode Number (Attachment 4)	Direction (Figures 1 and 2)	Natural Frequency (Hz)	Frequency Ratio*
1	z	0.90	76.8
2	x	4.41	15.6
7	x and y	35.47	1.94
8	x	53.64	1.28

*Frequency ratio of the lowest operating frequency (68.8 Hz) and the natural frequency.

Table 6. Natural Frequencies of the SLT
Case 3 -- Spring Supports and No Shot Mass.

Mode Number (Attachment 4)	Direction (Figures 1 and 2)	Natural Frequency (Hz)	Frequency Ratio*
1	z	0.92	74.7
2	x	2.40	28.6
4	y	6.02	11.4
6	x	10.17	6.76

*Frequency ratio of the lowest operating frequency (68.8 Hz) and the natural frequency.

3.3 SEISMIC LOADS ANALYSIS

The SLT was evaluated for seismic loading in accordance with SDC-4.1 for SC 3 structures. The seismic loading for a SC 3 structure is a horizontal acceleration of 0.12 g's. Critical components (tube steel braces) were analyzed for buckling. The seismic loads cause low stresses in the SLT. See Appendix H for the seismic evaluation.

3.4 WIND LOADS ANALYSIS

The SLT was evaluated for wind loading in accordance with SDC-4.1 for SC 3 structures. The design wind velocity for a SC 3 structure is 70 mi/hr. The pressure loading resulting from the design wind velocity results in low stresses in the SLT. The structure was evaluated for overturning, which showed that overturning is not a concern. See Appendix H for the wind loading evaluation.

3.5 MOVING/TRANSPORTING SLT

The SLT can be moved by two methods; by lifting the entire structure or rolling on the tires (see Appendix H for analysis). For lifting, two lifting lugs are attached to the top of the SLT. The SLT weights 4000 lbf when empty. Use a two-point pick with 8 1/2-ton shackles, 1 1/8-in. pin diameter. For rolling on the tires, attach a cable or chain to one of the tube steel cross-members that span between the legs at either end of the SLT (the cross-members that are approximately 2 ft-3 in. off the ground). A single attachment point can be used.

Note: The SLT can be moved only if empty of the lead or steel shot.

4.0 CONCLUSIONS

The results from the static-equivalent analysis show that the stresses in the SLT for vibrator operating and deadweight loads remain below the AISC code allowables. The results from the modal analysis show that the minimum operating frequency is at least twice the natural frequencies of the SLT, provided the SLT is mounted on the pneumatic tires. The frequency ratio does drop below 2.0 for case 2 where the SLT is mounted on rigid supports; this result shows the necessity of using the pneumatic tires. The slowest safe operating speed for the SLT when mounted on the tires is 1,856 r/min; however, every effort should be made to operate the SLT above this speed to ensure that no harmonic excitation will occur.

The results from the structural evaluation for wind, seismic, deadweight, and moving/transporting loads show that all stresses are below AISC code allowables.

5.0 REFERENCES

- AISC, 1989, *Manual of Steel Construction, Allowable Strength Design*, Ninth Edition, American Institute of Steel Construction, Chicago, Illinois.
- Clough, R. W. and J. Penzien, 1975, *Dynamics of Structures*, McGraw-Hill, Inc., New York, New York.
- DOE-RL, 1993, *Standard Arch-Civil Design Criteria, Design Loads for Facilities*, SDC-4.1, Revision 12, Hanford Plant Standards, U.S. Department of Energy, Richland Field Office, Richland, Washington, 1993.
- WHC, 1994a, *Shot Loading Trainer*, drawing H-2-83742, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1994b, *Shot Loading Funnel*, drawing H-2-83745, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1994c, *Shot Loading Platform*, drawing H-2-83738, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

Pneumatic Tire Spring Constant Determination

ANALYTICAL CALCULATIONS

Page 1 of 2

Subject Determination of the Spring Constant for the Pneumatic Tires of the Shot Loading Trainer

Originator Kevin M. Jones *Kevin M. Jones* Date 9-21-94

Checker R. S. Marlow *R. S. Marlow* Date 9/21/94

Figure 1. Pneumatic Tire

Tire Footprint

The pneumatic tires of the shot loading trainer have an internal pressure of 50 lbf/in² and the following dimensions.

$$P_i = 50 \frac{\text{lbf}}{\text{in}^2} \quad \text{Internal pressure of the tire.}$$

$$D = 18 \text{ in} \quad \text{Tire diameter.}$$

$$w = 4.5 \text{ in} \quad \text{Tire width.}$$

$$F_{dw} = P_i \cdot w \cdot l_{dw}$$

$$F_{dw} = 728.75 \text{ lbf}$$

The deadweight load on the tire. The full deadweight load is 5830 lbf. This is carried by eight tires. The load for one tire is 5830 lbf / 8 = 728.75 lbf.

$$l_{dw} = \frac{F_{dw}}{P_i \cdot w}$$

$$l_{dw} = 3.24 \text{ in}$$

Length of the tire impression for the deadweight load.

$$x_{dw} = \frac{D}{2} \left(1 - \cos \left(\arcsin \left(\frac{l_{dw}}{D} \right) \right) \right)$$

$$x_{dw} = 0.147 \text{ in}$$

Tire deflection for the deadweight load.

$$i = 0.50$$

$$x_i = \frac{i}{10} \text{ in}$$

Define a range of x values.

$$l(x) = D \cdot \sin \left(\arccos \left(1 - \frac{2 \cdot x}{D} \right) \right)$$

$$F(x) = P_i \cdot w \cdot \left(D \cdot \sin \left(\arccos \left(1 - \frac{2 \cdot x}{D} \right) \right) \right)$$

ANALYTICAL CALCULATIONS

Page 2 of 2

Subject Determination of the Spring Constant for the Pneumatic Tires of the Shot Loading Trainer

Originator Kevin M. Jones *Kevin M. Jones* Date 9-21-94

Checker R. S. Marlow *R. S. Marlow* Date 9/21/94

$$k_t = \frac{d}{dx_{dw}} F(x_{dw})$$

$$k_t = 2460 \cdot \frac{\text{lbf}}{\text{in}}$$

Spring constant for the tire @ 50 lbf/in².

APPENDIX B

**Structural Evaluation - Vibrator Loads
(Finite-Element Model Results)**

ANALYTICAL CALCULATIONS

Page 1 of 19

Subject Evaluation of the FEM Analysis of the Shot Loading Trainer
Originator Kevin M. Jones *Kevin M. Jones* Date 9-21-94
Checker R. S. Marlow *R. S. Marlow* Date 9/21/94

ORIGIN=1

The shot loading trainer (SLT) will be used to test the procedure for loading lead shot into the annulus of the 241SY101 mixer pump disposal container. For testing purposes steel shot will be used in place of lead. Vibrators will be used to ensure that the steel shot is loaded uniformly around the container. The SLT will be mounted on tires to provide vibration isolation.

Both static and modal analyses were performed on the SLT. The static analysis looked at the stresses in the members of the structure and compared them to AISC code allowables. The reaction forces at the tires were calculated to determine whether the SLT would tip over. A modal analysis was performed to determine whether the operation of the vibrators would cause excitation of the SLT at one of its natural frequencies.

An ANSYS model was developed to analyze the SLT (See Attachments 9 - 10 for the model input). The support structure of the SLT was modeled with BEAM4 elements with the cross section and material properties of the 3- by 3-in. A36 structural steel. The barrel section of the SLT was modeled with BEAM4 elements with the mass and cross section of the 52-in. round inner pipe. To accurately account for the mass of the stiffeners and the outer pipe, MASS21 elements were used at nodes 36 and 37 (Figures 1 and 3). To account for the mass of the steel shot, a MASS21 element was placed at node 41 (Figures 1 and 3). To translate the displacements and loads from the barrel section of the model to the structure, constraint equations were generated between nodes 12, 14, and 38, and 26, 28, and 35 (Figures 1 and 3). Two sets of boundary conditions (BC) were used for the structure supports. The first set of BCs modeled the tires as linear springs in the vertical direction, where the spring constant was based on the tire geometry and internal pressure (Figures 1-2). The second set of BCs assumed fixed supports in the vertical direction (Figures 3-4). Both sets of BCs fixed the SLT at two supports in the horizontal direction, and at one support in the longitudinal direction (Figures 5 and 6).

Static Analysis of the SLT

The SLT was analyzed structurally under operating and gravity loads. The magnitude of the operating load from the two vibrators mounted on both sides of the barrel section of the SLT was provided by the vendor. The vibrator will be operated at three speeds. At the highest speed, the load from one vibrator is 2,300 lbf. To ensure that the vibrators will not excite a harmonic of the SLT, the vibrator frequency must remain twice the natural frequency of the SLT. A frequency ratio of 2.0 corresponds to a dynamic load factor of 1/3 (Ref. 2, pp. 57-58). Therefore, the vibrator load used in the static analysis is $4,600/3 \text{ lbf} = 1533.3 \text{ lbf}$. Using this reduced load is conservative because the actual frequency ratios obtained are greater than 2.0 and therefore the load magnification factors are much less than 1/3. The SLT was analyzed for two load cases with the supports fixed in the vertical direction.

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The load cases are as follows:

Load Case 1 - Considered the weight of the SLT and steel shot and the load from the vibrators (1533.3 lbf) acting in the horizontal (x) direction (Figure 5).

Load Case 2 - Considered the weight of the SLT and steel shot and the load from the vibrators (1533.3 lbf) acting in the downward (-y) direction (Figure 6).

The calculated stresses and reaction loads from both load cases are given in Attachments 4 and 5, respectively. The stresses at critical locations are compared to AISC allowables for combined axial compression and bending (Ref. 3).

AISC Code Allowables (Ref. 3)

Notation: A = cross-sectional area

I = second moment of area about a given axis

E = elastic modulus

l = length of tubular member

k = effective length factor

r = "radius of gyration" associated with the second moment of area

F_y = yield stress of material

F_a = allowable axial stress based on axial compression only

F_b = allowable stress based on bending only

F_t = allowable stress based on axial tension only

f_a = calculated axial compressive stress

f_b = calculated bending stress

f_t = calculated axial tensile stress

Input Data (Geometry and Material Properties (Ref. 1))

$$A := (3\text{-in})^2 - (2.5\text{-in})^2$$

$$A = 2.75\text{-in}^2$$

Cross-sectional area of structural beams.

$$I := \frac{(3\text{-in})^4 - (2.5\text{-in})^4}{12}$$

$$I = 3.49\text{-in}^4$$

Moment of inertia of structural beams.

$$E = 30 \cdot 10^6 \frac{\text{lbf}}{\text{in}^2}$$

Modulus of elasticity of A36 steel.

$$F_y = 36000 \frac{\text{lbf}}{\text{in}^2}$$

Yield strength of A36 steel.

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$k = 2$ Effective length factor for fixed-free end conditions (Conservatively assume for all beams).

$\beta = 2$ Minimum frequency ratio for an operating frequency twice the natural frequency.

$$DMF = \left[\frac{1}{1 - \beta^2} \right]^{\frac{1}{2}} \quad \text{Dynamic magnification factor (Ref. 2, pp. 57).}$$

$$r = \sqrt{\frac{I}{A}} \quad r = 1.13 \text{ in}$$

Allowable Axial Compression Strength (Ref. 3, Section 1.5.1.3)

To determine the value for F_a , the value of kL/r is compared to C_c .

$$\frac{kL}{r} \quad C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{F_y}} \quad C_c = 128.255$$

If the value of kL/r is greater than C_c , the value of F_a is calculated using the following equation:

$$F_{a1}(L) = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{kL}{r} \right)^2} \quad (1)$$

If the value of kL/r is less than C_c , the value of F_a is calculated using the following equation:

$$F_{a2}(L) = \frac{F_y \left[1 - \frac{\left(\frac{kL}{r} \right)^2}{2 \cdot C_c^2} \right]}{\left(\frac{5}{3} \right) + \frac{3 \cdot \left(\frac{kL}{r} \right)}{8 \cdot C_c} - \frac{\left(\frac{kL}{r} \right)^3}{8 \cdot C_c^3}} \quad (2)$$

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Allowable Axial Tensile Strength (Ref. 3, Section 1.5.1.1)

$$F_t = 0.60 \cdot F_y \quad F_t = 21600 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2} \quad \text{Allowable axial tension.}$$

Allowable Bending Strength (Ref. 3, Section 1.5.1.4)

As a measure of conservatism, the minimum value of bending strength shall be used.

$$F_b = 0.60 \cdot F_y \quad F_b = 21600 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2} \quad \text{Allowable bending strength.}$$

Combined effects of axial compression and bending (Ref. 3, Section 1.6.1)

$$\frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_a}{F_{ey}}\right) \cdot F_{by}} \leq 1.0$$

Because we have bending in only one direction, this reduces to

$$\frac{f_a}{F_a} + \frac{C_m \cdot f_b}{\left(1 - \frac{f_a}{F_e}\right) \cdot F_b} \leq 1.0$$

Where,

C_m

Coefficient whose value is taken from Ref. 3, Section 1.6.1.

$r_b = r$

Radius of gyration in the plane of bending.

L_b

Actual unbraced length in the plane of bending.

$$F_e(L_b) = \frac{12 \cdot \pi^2 \cdot E}{23 \cdot \left(\frac{k L_b}{r_b}\right)^2}$$

Euler stress divided by a factor of safety.

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Combined effects of axial tension and bending (Ref. 3, Section 1.6.2)

Members subject to both axial tension and bending must satisfy the following inequality, provided the computed bending stress shall not exceed the allowable bending strength.

$$\frac{f_a}{0.60 \cdot F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$$

Because we have bending in only one direction and $0.60 \cdot F_y = F_a$, this reduces to

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} \leq 1.0$$

Load Case 1 (Load in x direction equal to 1533.3 lbf, Figure 5)

The stresses in elements 19 and 20 represent the worst-case combined compression and bending in the long unbraced section of the front legs of the structure (See Figure 4).

$$L = 74.5 \text{ in}$$

Length of the long section of the front legs of the structure.

$$f_a = 1162 \cdot \frac{\text{lbf}}{\text{in}^2} \quad f_b = 4363 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Axial compression and bending in the member.

$$\frac{kL}{r} = 132.173 \quad C_c = 128.255$$

kL/r is greater than C_c ; therefore F_a is based on equation (1)

$$F_{al}(L) = 8843 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$F_b = 21600 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Allowable stresses for the member.

$$C_m = 1.0$$

Conservative assumption for C_m .

$$L_b = 74.5 \text{ in}$$

$$\frac{f_a}{F_{al}(L)} + \frac{C_m \cdot f_b}{\left(1 - \frac{f_a}{F_{e}(L_b)}\right) \cdot F_b} = 0.364$$

The value 0.36 is less than 1.0; therefore the member is OK.

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The stresses in elements 23 and 24 represent the highest combined compression and bending stress in the structure (Figure 4).

$$L = 18.7\text{-in}$$

Length of the top section of the front legs of the structure.

$$f_a = 1131 \cdot \frac{\text{lb}}{\text{in}^2} \quad f_b = 5253 \cdot \frac{\text{lb}}{\text{in}^2}$$

Axial compression and bending in the member.

$$\frac{kL}{r} = 33.176$$

$$C_c = 128.255$$

kL/r is less than C_c ; therefore F_a is based on equation (2)

$$F_{a2}(L) = 19753 \cdot \frac{\text{lb}}{\text{in}^2}$$

$$F_b = 21600 \cdot \frac{\text{lb}}{\text{in}^2}$$

Allowable stresses for the member.

$$L_b = 18.7\text{-in}$$

$$C_m = 1.0$$

Conservative assumption for C_m .

$$\frac{f_a}{F_{a2}(L)} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F_{a2}(L)}\right) \cdot F_b} = 0.302$$

The value 0.3 is less than 1.0; therefore the member is OK.

Load Case 2 (Load in y direction equal to -1533.3 lbf, Figure 6)

The stresses in elements 19 and 20 represent the worst-case combined compression and bending in the long unbraced section of the front legs of the structure (Figure 4).

$$L = 74.5\text{-in}$$

Length of the long section of the front legs of the structure.

$$f_a = 766 \cdot \frac{\text{lb}}{\text{in}^2} \quad f_b = 1017 \cdot \frac{\text{lb}}{\text{in}^2}$$

Axial compression and bending in the member.

$$\frac{kL}{r} = 132.173$$

$$C_c = 128.255$$

kL/r is greater than C_c ; therefore F_a is based on equation (1).

$$F_{a1}(L) = 3843 \cdot \frac{\text{lb}}{\text{in}^2}$$

$$F_b = 21600 \cdot \frac{\text{lb}}{\text{in}^2}$$

Allowable stresses for the member.

$$C_m = 1.0$$

Conservative assumption for C_m .

$$L_b = 74.5\text{-in}$$

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$$\frac{f_a}{F_{a1}(L)} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F_e(L_b)}\right) F_b} = 0.138 \quad \text{The value 0.14 is less than 1.0; therefore the member is OK.}$$

The stresses in element 15 represent the highest bending stress in the structure (Figure 4).

$$L = 6.2 \text{ in}$$

Length of the bottom section of the back legs of the structure.

$$f_a = 730 \frac{\text{lb}}{\text{in}^2}$$

$$f_b = 1323 \frac{\text{lb}}{\text{in}^2}$$

Axial compression and bending in the member.

$$\frac{kL}{r} = 11$$

$$C_c = 128.255$$

kL/r is less than C_c ; therefore F_a is based on equation (2).

$$F_{a2}(L) = 21114 \frac{\text{lb}}{\text{in}^2}$$

$$F_b = 21600 \frac{\text{lb}}{\text{in}^2}$$

Allowable stresses for the member.

$$C_m = 1.0$$

Conservative assumption for C_m .

$$L_b = 6.2 \text{ in}$$

$$\frac{f_a}{F_{a2}(L)} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F_e(L_b)}\right) F_b} = 0.096 \quad \text{The value 0.1 is less than 1.0; therefore the member is OK.}$$

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Modal Analysis of the SLT

The response to harmonic loading was evaluated by performing a modal analysis of the shot loading trainer. The results of this analysis then were evaluated by using information from Chapter 4 of Reference 2. Of interest is whether the operating frequencies will excite any of the natural frequencies of the SLT. The damping ratio for this analysis was assumed close to zero on the basis of the behavior of the steel members.

For each calculated natural frequency (corresponding to a significant mode) and each vibrator frequency, the frequency ratio is calculated (The frequency ratio is defined as the ratio of the applied load frequency to the natural free-vibration frequency).

The shot loading trainer was evaluated for the three cases as follows:

Case One – Mass of the structure and steel shot included. The boundary conditions are as follows: the vertical direction (y) is modeled as having spring supports (to represent the pneumatic tires, where the spring constant is based on the geometry and internal pressure of the tires), the horizontal direction (x) is modeled as being fixed at two supports, and the longitudinal direction (z) is modeled as being fixed at one support.

Case Two – Mass of the structure and steel shot is included. The boundary conditions are the same as Case One except the y-direction is fixed at all four supports.

Case Three – Same as Case One, except the mass of the steel shot is not included.

Case one gives the results for operating the vibrators with the steel shot in the SLT. Case two gives the results of not using the pneumatic tires and fixing the SLT on a rigid surface. Case three gives the results of running the vibrators before the steel shot is placed in the SLT. The fixed BCs in the x and z directions represent the SLT's being tethered to prevent "walking."

Note: x, y and z directions are given on Figures 5 and 6.

$i = 1..3$

Simple Calculation of Natural Frequency

$W = 5830 \text{ lbf}$ Weight of the shot loading trainer including shot (Provided by cognizant engineer).

$g = 386.4 \frac{\text{in}}{\text{sec}^2}$ Gravitational constant.

$m = \frac{W}{g}$ $m = 15.1 \frac{\text{lbf} \cdot \text{sec}^2}{\text{in}}$ Mass of the SLT and steel shot.

$k = 8 \cdot 2460 \frac{\text{lbf}}{\text{in}}$ Spring constant for eight tires.

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$$\omega_s = \sqrt{\frac{k}{m}} \quad \omega_s = 36.1 \frac{\text{rad}}{\text{sec}}$$

Natural frequency of the system in the vertical (y) direction.

$$f_s = \frac{\omega_s}{2\pi} \quad f_s = 5.75 \text{ Hz}$$

This value for the natural frequency was calculated to provide a "ballpark" frequency for comparison with the modal analysis results of case 1.

Applied Load Frequencies

$$f_o = \begin{bmatrix} 68.8 \\ 77.5 \\ 86.7 \end{bmatrix} \text{ Hz}$$

Operating speeds provided from vendor (Attachment 3).

$$\omega_o = 2\pi f_o \quad \omega_o = \begin{bmatrix} 432.3 \\ 486.9 \\ 544.8 \end{bmatrix} \frac{\text{rad}}{\text{sec}}$$

Dynamic Magnification Factor

β is defined as the frequency ratio of the applied frequency to the natural frequency.

$$\text{DMF}(\beta) = \left[(1 - \beta^2)^2 \right]^{-\frac{1}{2}} \quad \text{Dynamic magnification factor (Ref. 2, pp. 57).}$$

For each of the significant modes given below, the largest DMF is calculated for the smallest beta.

Case One - Model with Full Mass and Spring Supports (Attachment 6)

The frequencies for the first 10 modes of the structure are calculated to be as follows:

$$f_{cl} = \begin{bmatrix} 0.87 \\ 2.27 \\ 4.57 \\ 5.67 \\ 7.58 \\ 12.78 \\ 15.37 \\ 15.47 \\ 18.56 \\ 51.44 \end{bmatrix} \text{ Hz}$$

The significant modes are 1, 2, 4, and 8. With these modes, 98% of the mass is accounted for.

In the x - direction the natural frequency is given by modes 2 and 8.

In the y - direction the natural frequency is given by mode 4.

In the z - direction the natural frequency is given by mode 1.

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x - Direction, Mode 2

$$\beta_i = \frac{f_{o_i}}{f_{cl_2}} \quad \beta = \begin{pmatrix} 30.3 \\ 34.1 \\ 38.2 \end{pmatrix} \quad DMF(\beta_1) = 0.0011$$

x - Direction, Mode 8

$$\beta_i = \frac{f_{o_i}}{f_{cl_8}} \quad \beta = \begin{pmatrix} 4.45 \\ 5.01 \\ 5.6 \end{pmatrix} \quad DMF(\beta_1) = 0.053$$

y - Direction, Mode 4

$$\beta_i = \frac{f_{o_i}}{f_{cl_4}} \quad \beta = \begin{pmatrix} 12.1 \\ 13.7 \\ 15.3 \end{pmatrix} \quad DMF(\beta_1) = 0.0068$$

z - Direction, Mode 1

$$\beta_i = \frac{f_{o_i}}{f_{cl_1}} \quad \beta = \begin{pmatrix} 79 \\ 89 \\ 100 \end{pmatrix} \quad DMF(\beta_1) = 0.00016$$

For the frequencies calculated in case one, the frequency ratio remains above 2.0, which shows that the shot loading trainer will operate safely above the range in which a harmonic frequency could be excited. The highest DMF is 0.053 which shows the conservatism of using a value of 1/3.

The natural frequency corresponding to mode 4 is 5.67 Hz which is very close to 5.75 Hz, which shows that these results are close to what was expected.

Case Two -- Model with Full Mass and Fixed Supports (Attachment 7)

The frequencies for the first 10 modes of the structure are calculated to be as follows:

$$f_{c2} = \begin{pmatrix} 1.04 \\ 5.31 \\ 10.42 \\ 13.60 \\ 17.79 \\ 27.09 \\ 44.66 \\ 56.42 \\ 57.82 \\ 62.69 \end{pmatrix} \text{ Hz}$$

The significant modes are 1, 2, and 7. With these modes, 98% of the mass is accounted for.

In the x - direction the natural frequency is given by modes 2.

In the y - direction the natural frequency is given by modes 7.

In the z - direction the natural frequency is given by mode 1.

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x - Direction, Mode 2

$$\beta_i = \frac{f_{o_i}}{f_{c2_2}}$$

$$\beta = \begin{pmatrix} 13 \\ 14.6 \\ 16.3 \end{pmatrix}$$

$$DMF(\beta_1) = 0.006$$

y - Direction, Mode 7

$$\beta_i = \frac{f_{o_i}}{f_{c2_7}}$$

$$\beta = \begin{pmatrix} 1.54 \\ 1.74 \\ 1.94 \end{pmatrix}$$

$$DMF(\beta_1) = 0.73$$

z - Direction, Mode 1

$$\beta_i = \frac{f_{o_i}}{f_{c2_1}}$$

$$\beta = \begin{pmatrix} 66.2 \\ 74.5 \\ 83.4 \end{pmatrix}$$

$$DMF(\beta_1) = 0.00023$$

For the frequencies calculated for case two, the frequency ratio remains above 2.0 for the frequencies corresponding to modes 1 and 2. For mode 7 the frequency ratio is below 2.0 for all three operating speeds. The possibility exists to excite a harmonic frequency during vibrator operation at these speeds. Because the vibrators will not be operated with fixed BCs, the DMF of 0.728 will never be reached and the value of 1/3 is still conservative.

Case Three - Model with No Shot Mass and Spring Supports (Attachment 8)

The frequencies for the first 10 modes of the structure are calculated to be as follows:

$$f_{c3} = \begin{pmatrix} 1.12 \\ 2.97 \\ 4.62 \\ 7.25 \\ 7.65 \\ 12.80 \\ 15.43 \\ 15.47 \\ 18.57 \\ 51.79 \end{pmatrix} \text{ Hz}$$

The significant modes are 1,2,4,5 and 8. With these modes, 98% of the mass is accounted for.

In the x - direction the natural frequency is given by modes 2 and 8.

In the y - direction the natural frequency is given by modes 4 and 5.

In the z - direction the natural frequency is given by mode 1.

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x - Direction, Mode 2

$$\beta_i = \frac{f_{o_i}}{f_{c3_2}} \quad \beta = \begin{pmatrix} 23.2 \\ 26.1 \\ 29.2 \end{pmatrix} \quad DMF(\beta_1) = 0.0019$$

x - Direction, Mode 8

$$\beta_i = \frac{f_{o_i}}{f_{c3_3}} \quad \beta = \begin{pmatrix} 4.45 \\ 5.01 \\ 5.6 \end{pmatrix} \quad DMF(\beta_1) = 0.053$$

y - Direction, Mode 4

$$\beta_i = \frac{f_{o_i}}{f_{c3_4}} \quad \beta = \begin{pmatrix} 9.49 \\ 10.69 \\ 11.96 \end{pmatrix} \quad DMF(\beta_1) = 0.011$$

y - Direction, Mode 5

$$\beta_i = \frac{f_{o_i}}{f_{c3_5}} \quad \beta = \begin{pmatrix} 8.99 \\ 10.13 \\ 11.33 \end{pmatrix} \quad DMF(\beta_1) = 0.013$$

z - Direction, Mode 1

$$\beta_i = \frac{f_{o_i}}{f_{c3_1}} \quad \beta = \begin{pmatrix} 61.43 \\ 69.2 \\ 77.41 \end{pmatrix} \quad DMF(\beta_1) = 0.00027$$

For the frequencies calculated in case three, the frequency ratio remains above 2.0, which shows that the shot loading trainer will operate above the range in which a harmonic frequency could be excited. The highest DMF is 0.053, which shows the conservatism of using a value of 1/3.

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Minimum Operating Speed

SLT Loaded with Steel Shot

Based on the highest natural frequency of case one results, the slowest speed at which the vibrators can be operated safely to maintain a frequency ratio above 2.0 is calculated as follows:

$$f_{c1g} = 15.47 \cdot \text{Hz}$$

Highest natural frequency of a significant mode for case one.

$$\beta = 2.0$$

Minimum frequency ratio.

$$f_{los} = \beta \cdot f_{c1g}$$

$$f_{los} = 30.94 \cdot \text{Hz}$$

Frequency of the lowest operating speed for case one.

$$60 \cdot \text{sec} \cdot f_{los} = 1856 \frac{\text{rev}}{\text{min}}$$

Slowest safe operating speed when loaded with steel shot.

SLT Not Loaded with Steel Shot

Based on the highest natural frequency of case three results, the slowest speed at which the vibrators can be operated safely to maintain a frequency ratio above 2.0 is calculated as follows:

$$f_{c3g} = 15.47 \cdot \text{Hz}$$

Highest natural frequency of a significant mode for case three.

$$\beta = 2.0$$

Minimum frequency ratio.

$$f_{los} = \beta \cdot f_{c3g}$$

$$f_{los} = 30.94 \cdot \text{Hz}$$

Frequency of the lowest operating speed for case three.

$$60 \cdot \text{sec} \cdot f_{los} = 1856 \frac{\text{rev}}{\text{min}}$$

Slowest safe operating speed when not loaded with steel shot.

ANSYS 5.0 A
 SEP 19 1994
 15:54:08
 PLOT NO. 1
 ELEMENTS
 TYPE NUM

XV =1
 YV =1
 ZV =1
 DIST=92.509
 XF =47
 YF =55.5
 ZF =40.5
 CENTROID HIDDEN

FIGURE 1.
 Node Plot -- Spring Supports

ANSYS 5.0 A
 SEP 19 1994
 15:53:10
 PLOT NO. 1
 ELEMENTS
 ELEM NUM

XV =1
 YV =1
 ZV =1
 DIST=92.509
 XF =47
 YF =55.5
 ZF =40.5
 CENTROID HIDDEN

FIGURE 2.
 Element Plot -- Spring Supports

ANSYS 5.0 A
SEP 19 1994
16:02:34
PLOT NO. 1
ELEMENTS
TYPE .NUM

XV =1
YV =1
ZV =1
DIST=92.509
XF =47
YF =55.5
ZF =40.5
CENTROID HIDDEN

FIGURE 3.
Node Plot -- Fixed Supports

ANSYS 5.0 A
SEP 19 1994
16:01:42
PLOT NO. 1
ELEMENTS
ELEM NUM

XV =1
YV =1
ZV =1
DIST=92.509
XF =47
YF =55.5
ZF =40.5
CENTROID HIDDEN

FIGURE 4.
Element Plot -- Fixed Supports

WHC--SD-W320-DA--006
Rev. 0.

FIGURE 5.
Load Case 1 -- 1533.3 lbf in +X Direction

ANSYS 5.0 A
SEP 19 1994
16:10:05
PLOT NO. 1
ELEMENTS
TYPE NUM

U F CE
ACEL

XV =1
YV =1
ZV =1

DIST=92.509

XF =47
YF =55.5
ZF =40.5

CENTROID HIDDEN

FIGURE 6.
Load Case 2 -- 1533.3 lbf in -Y Direction

APPENDIX C

**Pneumatic Vibrator Performance Data
(Vendor Information)**

GLOBAL[®] MANUFACTURING, INC.

PNEUMATIC VIBRATOR PERFORMANCE DATA

MODEL	UNBAL LB-IN (N-M)	START PSI (BAR)	40 PSI (2.8 BAR)			50 PSI (3.5 BAR)			30 PSI (2.1 BAR)		
			SPEED RPM	FLOW SCFM (LPS)	FORCE LB (KN)	SPEED RPM	FLOW SCFM (LPS)	FORCE LB (KN)	SPEED RPM	FLOW SCFM (LPS)	FORCE LB (KN)
CS-6A-6AC	1.5 (0.17)	3 (0.35)	4400	41 (19)	320 (3.3)	3150	35 (26)	1130 (5.3)	3650	74 (35)	1360 (6.3)
	2.3 (0.23)	3 (0.35)	4310	40 (19)	1050 (4.7)	4980	34 (25)	1410 (6.3)	3500	73 (34)	1720 (7.6)
	2.5 (0.25)	3 (0.35)	4220	39 (18)	1260 (5.6)	4820	33 (25)	1450 (7.3)	3350	72 (34)	2030 (9.3)
	3.3 (0.34)	3 (0.35)	4130	38 (18)	1450 (6.5)	4650	32 (25)	1840 (8.2)	3200	71 (34)	2300 (10.3)
	4.3 (0.43)	3 (0.35)	4050	37 (17)	1860 (8.3)	4540	31 (24)	2340 (10.6)	3170	70 (33)	3040 (13.5)
	5.3 (0.57)	3 (0.35)	3980	36 (17)	2250 (10.3)	4440	31 (24)	2800 (12.5)	3130	70 (33)	3740 (16.6)
	6.3 (0.63)	3 (0.35)	3900	35 (16)	2590 (11.5)	4330	30 (24)	3220 (14.2)	3100	69 (33)	4430 (19.7)
24.3-6-6AC 204.3-6-6AC	6.3 (0.7)	3 (0.35)	3950	35 (16)	2660 (11.8)	4250	30 (24)	3080 (13.7)	4500	68 (31)	3450 (15.3)
24.3-8-6AC 204.3-8-6AC	8.3 (0.7)	3 (0.35)	3600	30 (14)	2940 (13.1)	3900	28 (22)	3460 (15.4)	4300	64 (30)	4200 (18.7)
24.3-10-6AC 204.3-10-6AC	10.3 (1.1)	3 (0.35)	3350	32 (15)	3190 (14.2)	3700	27 (22)	3890 (17.3)	3900	62 (29)	4320 (19.2)
37-12-6AC 227-12-6AC	12.3 (1.4)	3 (0.35)	4000	35 (26)	3450 (24.2)	3250	35 (26)	7390 (41.3)	OPERATION NOT RECOMMENDED AT PRESSURES ABOVE 50 PSI		
37-18-6AC 227-18-6AC	18.3 (2.0)	3 (0.35)	3550	34 (25)	5440 (28.4)	4650	32 (29)	11050 (49.2)	5400	114 (54)	16910 (66.3)
37-25-6AC 227-25-6AC	25.3 (2.3)	3 (0.35)	3300	32 (24)	7730 (34.4)	4400	31 (28)	13750 (61.2)	5050	109 (51)	18110 (80.6)
37-50-6AC 227-50-6AC	50.3 (5.7)	3 (0.35)	3700	48 (22)	10350 (46.3)	3750	57 (32)	19970 (88.3)	4350	93 (44)	26870 (120)

The table above represents the vibrator's performance at various speeds. It is important to note that with any rotary vibrator the load on the bearings increases as the speed increases; therefore, the life of the bearings is very sensitive to the speed. Increasing the speed by just 10% will cut the bearing life in half. Likewise, reducing the speed 10% will double the bearing life. Please remember that the speed is controlled by the hydraulic flow (SCFM), not the pressure (PSI). The pressure across the motor will vary according to the rigidity of the vibrator mount and the type of material being resonated.

Metric:

N-M - Newton-Meter
LPM - Liters per minute
BAR - Unit of measure
RPM - Revolutions per minute
GN - Gilonewtons
KG - Kilograms

American:

LB-IN - Pounds-Inch
SCFM - Standard cubic feet per minute
PSI - Pounds per square inch
RPM - Revolutions per minute
LB - Pounds

Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
MSIN S2-03
Fax: 509-373-7302
Phone: 509-373-1117
February 13, 1995

Global Manufacturing Inc.
PO Box 3824
Little Rock, AR 72203
Fax: 501-376-7147

Dear Sirs:

I am writing to request permission to a cut sheet of your pneumatic vibrator performance data for an analysis document on a piece of equipment your vibrators are used on. The material, I am requesting to use has a copyright date of 1992 on it.

The document is WHC-SD-W320-DA-006, Rev. 0, "Shot Loading Trainer Analysis." The analysis addresses the structural integrity of the equipment for its design loads with and without using a Global C3-5A-4AC pneumatic vibrator. The release of this document allows Westinghouse Hanford Company to use the Shot Loading Trainer with your pneumatic vibrator to test the efficiency of using your vibrators on other equipment currently on site and in the design process.

Your permission is required to release this document with your copyrighted material in the document as reference material. The document is being produced for Westinghouse Hanford Company and Department of Energy, Richland Office records. The document is to be released with public access.

I would appreciate a faxed letter of your consent at your earliest convenience. My fax number is 509-373-7302. With your consent to allow your copyrighted materials to be published, the estimated date for publication of the document is February 17, 1995.

Sincerely,

Theresa Peterson

Theresa Peterson

PERMISSION GRANTED

Catherine Janosky
CATHERINE JANOSKY
PRESIDENT

GLOBAL MANUFACTURING, INC. - LITTLE ROCK, ARKANSAS

APPENDIX D

**Computer Output - Load Case 1
Vibrator Load Applied in Horizontal Direction**

Static Analysis -- Fixed Supports Load Cases 1 and 2

RESUME ANSYS DATA FROM FILE NAME=file.db

*** ANSYS GLOBAL STATUS ***

ANALYSIS TYPE = MODAL

NUMBER OF ELEMENT TYPES = 3

41 ELEMENTS CURRENTLY SELECTED. MAX ELEMENT NUMBER = 45

37 NODES CURRENTLY SELECTED. MAX NODE NUMBER = 41

MAXIMUM LINEAR PROPERTY NUMBER = 1

MAXIMUM REAL CONSTANT SET NUMBER = 8

ACTIVE COORDINATE SYSTEM = 0 (CARTESIAN)

MAXIMUM CONSTRAINT EQUATION NUMBER = 48

NUMBER OF SPECIFIED CONSTRAINTS = 7

NUMBER OF MODAL LOADS = 1

INITIAL JOBNAM = file

CURRENT JOBNAM = file

*** NOTE ***

CP= 1.140 TIME= 13:29:03

The element set contains elements that have only one structural degree of freedom per node. Viewing nodal displacements or forces in other than the nodal coordinate system may be invalid.

PERFORM A STATIC ANALYSIS

THIS WILL BE A NEW ANALYSIS

PRINT BASIC ITEMS WITH A FREQUENCY OF ALL

FOR ALL APPLICABLE ENTITIES

ANSYS REVISION 5.0 A 15:16:43 09/08/1994

Load step file number 1. Begin solution ...

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.3-D

DEGREES OF FREEDOM.UX UY UZ ROTX ROTY ROTZ

ANALYSIS TYPESTATIC (STEADY-STATE)

*** NOTE ***

CP= 1.930 TIME= 13:32:17

Real constant set 3 is not used by any element types that require real constants.

*** NOTE ***

CP= 1.940 TIME= 13:32:21

Real constant set 8 is not used by any element types that require real constants.

*** NOTE ***

CP= 1.950 TIME= 13:32:25

Present time 0 is less than or equal to the previous time.

Time will default to 1.

Static Analysis -- Fixed Supports

LOAD STEP OPTIONS

LOAD STEP NUMBER. 1
 TIME AT END OF THE LOAD STEP. 1.0000
 NUMBER OF SUBSTEPS. 1
 STEP CHANGE BOUNDARY CONDITIONS NO
 INERTIA LOADS X Y Z
 ACCEL 0.00000E+00 386.40 0.00000E+00
 PRINT OUTPUT CONTROLS
 ITEM FREQUENCY COMPONENT
 BASE ALL
 DATABASE OUTPUT CONTROLS. ALL DATA WRITTEN
 FOR THE LAST SUBSTEP

***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS = 15.357

CENTROID	MOM. OF INERTIA ABOUT ORIGIN	MOM. OF INERTIA ABOUT CENTROID
XC = 47.000	Ixx = 0.2067E+06	Ixx = 0.1532E+05
YC = 104.35	Iyy = 0.6737E+05	Iyy = 9274.
ZC = 39.679	Izz = 0.2100E+06	Izz = 8895.
	Ixy = -0.7531E+05	Ixy = 0.0000E+00
	Iyz = -0.6350E+05	Iyz = 83.93
	Izx = -0.2864E+05	Izx = -0.3638E-11

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	5.93684
2	9.42000

Range of element maximum matrix coefficients in global coordinates
 Maximum= 3.24208E+11 at element 39.
 Minimum= 9230769.23 at element 17.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.090	0.002
2	3	MASS21	0.000	0.000

Time at end of element matrix formulation CP= 2.089999991.

Estimated number of active DOF= 215.

Maximum wavefront= 48.

Time at end of matrix triangularization CP= 2.230000002.

Equation solver maximum pivot= 8.770113063E+10 at node 35 ROTX.

Equation solver minimum pivot= 640.445489 at node 39 UZ.

Analysis of the Shot Loading Trainer -- Fixed Supports

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.000000E+00	0.000000E+00	-0.255312E-02	0.278451E-04	0.145923E-03	-0.158946E-02
2	0.927536E-02	-0.242319E-02	-0.260494E-02	0.278451E-04	0.145923E-03	-0.147106E-02
3	0.959169E-02	-0.152807E-01	-0.907708E-02	0.272150E-04	0.138861E-03	0.497127E-03
4	0.813829E-02	0.000000E+00	-0.156279E-01	0.265850E-04	0.133563E-03	-0.267477E-03
5	0.990803E-02	0.325895E-03	-0.152680E-01	0.265850E-04	0.133563E-03	-0.336187E-03
6	0.571020E-01	0.120977E-01	-0.130738E-01	0.258768E-04	0.128816E-03	-0.181970E-02
7	0.717028E-01	-0.196323E-01	-0.300519E-02	0.293017E-04	0.154126E-03	-0.170866E-02
8	0.111029	-0.307321E-01	-0.340893E-02	0.319008E-04	0.162027E-03	-0.203742E-03
9	0.107796	0.248063E-01	-0.109721E-01	0.240263E-04	0.123766E-03	-0.514580E-03
10	0.109084	0.250129E-01	-0.105416E-01	0.344905E-05	0.130110E-03	0.265689E-03
11	0.110002	-0.306127E-01	-0.366294E-02	0.824088E-05	0.156934E-03	0.442285E-03
12	0.102605	-0.286568E-01	-0.399073E-02	0.104240E-04	0.144394E-03	0.121147E-02
13	0.102605	-0.290100E-02	-0.706812E-02	0.104240E-04	0.144394E-03	0.121147E-02
14	0.102605	0.229822E-01	-0.101455E-01	0.104240E-04	0.144394E-03	0.121147E-02
15	0.000000E+00	0.000000E+00	0.000000E+00	-0.719315E-05	0.139890E-03	-0.214544E-02
16	0.124766E-01	-0.307239E-02	-0.252994E-03	-0.719315E-05	0.139890E-03	-0.194195E-02
17	0.130570E-01	-0.248018E-01	-0.663702E-02	-0.747119E-05	0.140879E-03	0.537557E-03
18	0.139853E-01	0.000000E+00	-0.132547E-01	-0.774922E-05	0.142788E-03	0.114854E-03
19	0.136374E-01	-0.328233E-03	-0.130870E-01	-0.774922E-05	0.142788E-03	-0.273489E-04
20	0.603777E-01	0.105216E-01	-0.120072E-01	-0.836883E-05	0.145205E-03	-0.200077E-02
21	0.843802E-01	-0.219291E-01	-0.183188E-02	-0.674905E-05	0.139270E-03	-0.179243E-02
22	0.123555	-0.321359E-01	-0.337742E-02	-0.570952E-05	0.138493E-03	-0.139735E-03
23	0.118366	0.243526E-01	-0.109383E-01	-0.958387E-05	0.147464E-03	-0.636144E-03
24	0.120519	0.246057E-01	-0.105216E-01	0.116811E-04	0.149263E-03	0.207022E-03
25	0.121997	-0.316481E-01	-0.368265E-02	0.126545E-04	0.137084E-03	0.500799E-03
26	0.114335	-0.294001E-01	-0.394437E-02	0.528465E-05	0.143090E-03	0.121660E-02
27	0.114335	-0.353514E-02	-0.699399E-02	0.528465E-05	0.143090E-03	0.121660E-02
28	0.114335	0.224572E-01	-0.100436E-01	0.528465E-05	0.143090E-03	0.121660E-02
29	0.117530	-0.326452E-01	-0.339318E-02	0.194474E-04	0.156823E-03	-0.171738E-03
30	0.112841	0.234087E-01	-0.109552E-01	0.479063E-05	0.127920E-03	-0.575362E-03
35	0.960864E-01	-0.347146E-02	-0.691472E-02	0.528465E-05	0.143090E-03	0.121660E-02
36	0.937956E-01	-0.338463E-02	-0.691413E-02	0.573156E-05	0.143348E-03	0.121558E-02
37	0.861652E-01	-0.296143E-02	-0.691220E-02	0.101645E-04	0.144359E-03	0.121223E-02
38	0.844326E-01	-0.283732E-02	-0.691176E-02	0.104240E-04	0.144394E-03	0.121147E-02
39	0.971596E-01	-0.351111E-02	-0.691472E-02	0.528664E-05	0.143090E-03	0.121660E-02
40	0.833496E-01	-0.275915E-02	-0.691176E-02	0.104220E-04	0.144394E-03	0.121147E-02
41	0.896990E-01	-0.318972E-02	-0.691309E-02	0.820200E-05	0.144066E-03	0.121378E-02

MAXIMUMS

NODE	22	29	4	8	8	15
VALUE	0.123555	-0.326452E-01	-0.156279E-01	0.319008E-04	0.162027E-03	-0.214544E-02

Analysis of the Shot Loading Trainer -- Fixed Supports

***** ELEMENT SOLUTION ***** TIME = 1.0000
 LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

EL= 1 NODES= 1 2 MAT= 1
 BEAM4
 LOCATION SDIR SBYT SBYB SBZT SBZB
 1 (I) -491.92 0.23115E-11-0.23115E-11-0.32379E-11 0.32379E-11
 2 (J) -490.23 -1722.4 1722.4 0.22689E-11-0.22689E-11
 LOCATION SMAX SMIN
 1 (I) -491.92 -491.92
 2 (J) 1232.2 -2212.6
 LOCATION EPELDIR EPELBYT EPELBYB EPELBTZT EPELBZB
 1 (I) -0.000016 0.000000 0.000000 0.000000 0.000000
 2 (J) -0.000016 -0.000057 0.000057 0.000000 0.000000

EL= 4 NODES= 5 4 MAT= 1
 BEAM4
 LOCATION SDIR SBYT SBYB SBZT SBZB
 1 (I) -547.57 -999.37 999.37 -0.68066E-11 0.68066E-11
 2 (J) -549.27 -0.13280E-10 0.13280E-10-0.68066E-11 0.68066E-11
 LOCATION SMAX SMIN
 1 (I) 451.80 -1546.9
 2 (J) -549.27 -549.27
 LOCATION EPELDIR EPELBYT EPELBYB EPELBTZT EPELBZB
 1 (I) -0.000018 -0.000033 0.000033 0.000000 0.000000
 2 (J) -0.000018 0.000000 0.000000 0.000000 0.000000

EL= 15 NODES= 15 16 MAT= 1
 BEAM4
 LOCATION SDIR SBYT SBYB SBZT SBZB
 1 (I) 219.24 -0.39251E-11 0.39251E-11-0.30724E-12 0.30724E-12
 2 (J) 220.93 -2960.7 2960.7 0.15357E-08-0.15357E-08
 LOCATION SMAX SMIN
 1 (I) 219.24 219.24
 2 (J) 3181.7 -2739.3
 LOCATION EPELDIR EPELBYT EPELBYB EPELBTZT EPELBZB
 1 (I) 0.000007 0.000000 0.000000 0.000000 0.000000
 2 (J) 0.000007 -0.000099 0.000099 0.000000 0.000000

EL= 18 NODES= 19 18 MAT= 1
 BEAM4
 LOCATION SDIR SBYT SBYB SBZT SBZB
 1 (I) -1134.5 -2068.8 2068.8 -0.13330E-10 0.13330E-10
 2 (J) -1136.2 -0.89922E-11 0.89922E-11 0.14700E-10-0.14700E-10
 LOCATION SMAX SMIN
 1 (I) 934.38 -3203.3
 2 (J) -1136.2 -1136.2
 LOCATION EPELDIR EPELBYT EPELBYB EPELBTZT EPELBZB
 1 (I) -0.000038 -0.000069 0.000069 0.000000 0.000000
 2 (J) -0.000038 0.000000 0.000000 0.000000 0.000000

```

EL=      2  NODES=      2      3  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  208.57    -3101.9    3101.9    -7.8570    7.8570
  2 (J)  208.57    -676.22     676.22    -6.1119    6.1119
LOCATION  SMAX      SMIN
  1 (I)  3318.3    -2901.2
  2 (J)  890.91    -473.76
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000007  -0.000103  0.000103  0.000000  0.000000
  2 (J)  0.000007  -0.000023  0.000023  0.000000  0.000000

```

```

EL=      3  NODES=      3      5  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  208.57    -676.22     676.22    -6.1119    6.1119
  2 (J)  208.57    2439.6    -2439.6    -4.3668    4.3668
LOCATION  SMAX      SMIN
  1 (I)  890.91    -473.76
  2 (J)  2652.5    -2235.3
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000007  -0.000023  0.000023  0.000000  0.000000
  2 (J)  0.000007  0.000081  -0.000081  0.000000  0.000000

```

```

EL=     16  NODES=     16     17  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  382.68    -3727.7    3727.7    0.52345   -0.52345
  2 (J)  382.68   -1061.8    1061.8    1.4330    -1.4330
LOCATION  SMAX      SMIN
  1 (I)  4110.9    -3345.5
  2 (J)  1445.9    -680.55
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000013  -0.000124  0.000124  0.000000  0.000000
  2 (J)  0.000013  -0.000035  0.000035  0.000000  0.000000

```

```

EL=     17  NODES=     17     19  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  382.68   -1061.8    1061.8    1.4330    -1.4330
  2 (J)  382.68   2294.2   -2294.2    2.3426    -2.3426
LOCATION  SMAX      SMIN
  1 (I)  1445.9    -680.55
  2 (J)  2679.2   -1913.9
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000013  -0.000035  0.000035  0.000000  0.000000
  2 (J)  0.000013  0.000076  -0.000076  0.000000  0.000000

```

```

EL=       7  NODES=       2      7  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -577.84    1379.5   -1379.5    1.5413   -1.5413
  2 (J)  -567.66   -785.51    785.51    0.11327  -0.11327
LOCATION  SMAX      SMIN
  1 (I)  803.20    -1958.9
  2 (J)  217.96   -1353.3
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  -0.000019  0.000046  -0.000046  0.000000  0.000000
  2 (J)  -0.000019  -0.000026  0.000026  0.000000  0.000000

```

```

EL=      5  NODES=      5      6  MAT=  1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -536.56    3438.9    -3438.9    1.5777    -1.5777
  2 (J) -526.38    127.46    -127.46    3.0057    -3.0057
LOCATION  SMAX      SMIN
  1 (I)  2903.9    -3977.1
  2 (J) -395.91    -656.84
LOCATION  EPBLDIR  EPBLBYT  EPBLBYB  EPBLBZT  EPBLBZB
  1 (I) -0.000018  0.000115  -0.000115  0.000000  0.000000
  2 (J) -0.000018  0.000004  -0.000004  0.000000  0.000000

```

```

EL=     21  NODES=     16     21  MAT=  1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  86.713    766.97    -766.97    -0.33808  0.33808
  2 (J)  96.896    -1108.8    1108.8     -1.0824   1.0824
LOCATION  SMAX      SMIN
  1 (I)  354.02    -680.60
  2 (J) 1206.7     -1012.9
LOCATION  EPBLDIR  EPBLBYT  EPBLBYB  EPBLBZT  EPBLBZB
  1 (I)  0.000003  0.000026  -0.000026  0.000000  0.000000
  2 (J)  0.000003 -0.000037  0.000037  0.000000  0.000000

```

```

EL=     19  NODES=     19     20  MAT=  1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -1161.6    4363.1    -4363.1    -0.39320  0.39320
  2 (J) -1151.4    387.55    -387.55     0.35110  -0.35110
LOCATION  SMAX      SMIN
  1 (I)  3201.9    -5525.0
  2 (J) -763.49    -1539.3
LOCATION  EPBLDIR  EPBLBYT  EPBLBYB  EPBLBZT  EPBLBZB
  1 (I) -0.000039  0.000145  -0.000145  0.000000  0.000000
  2 (J) -0.000038  0.000013  -0.000013  0.000000  0.000000

```

```

EL=       8  NODES=       7      8  MAT=  1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -567.66    -785.51    785.51     0.11327  -0.11327
  2 (J) -557.48    -2832.6    2832.6     -1.3148   1.3148
LOCATION  SMAX      SMIN
  1 (I)  217.96    -1353.3
  2 (J)  2276.4    -3391.4
LOCATION  EPBLDIR  EPBLBYT  EPBLBYB  EPBLBZT  EPBLBZB
  1 (I) -0.000019  -0.000026  0.000026  0.000000  0.000000
  2 (J) -0.000019  -0.000094  0.000094  0.000000  0.000000

```

```

EL=       6  NODES=       6      9  MAT=  1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -526.38    127.46    -127.46     3.0057    -3.0057
  2 (J) -516.19    -3301.9    3301.9     4.4337    -4.4337
LOCATION  SMAX      SMIN
  1 (I) -395.91    -656.84
  2 (J)  2790.2    -3822.5
LOCATION  EPBLDIR  EPBLBYT  EPBLBYB  EPBLBZT  EPBLBZB
  1 (I) -0.000018  0.000004  -0.000004  0.000000  0.000000
  2 (J) -0.000017 -0.000110  0.000110  0.000000  0.000000

```

EL- 22 NODES- 21 22 MAT- 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	96.896	-1108.8	1108.8	-1.0824	1.0824
2 (J)	107.08	-2866.6	2866.6	-1.8267	1.8267
LOCATION	SMAX	SMIN			
1 (I)	1206.7	-1012.9			
2 (J)	2975.5	-2761.3			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000003	-0.000037	0.000037	0.000000	0.000000
2 (J)	0.000004	-0.000096	0.000096	0.000000	0.000000

EL- 20 NODES- 20 23 MAT- 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1151.4	387.55	-387.55	0.35110	-0.35110
2 (J)	-1141.2	-3705.9	3705.9	1.0954	-1.0954
LOCATION	SMAX	SMIN			
1 (I)	-763.49	-1539.3			
2 (J)	2565.7	-4848.2			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000038	0.000013	-0.000013	0.000000	0.000000
2 (J)	-0.000038	-0.000124	0.000124	0.000000	0.000000

EL- 29 NODES- 8 29 MAT- 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	11.673	175.48	-175.48	1.5100	-1.5100
2 (J)	11.673	-112.02	112.02	-13.074	13.074
LOCATION	SMAX	SMIN			
1 (I)	188.66	-165.32			
2 (J)	136.77	-113.43			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000006	-0.000006	0.000000	0.000000
2 (J)	0.000000	-0.000004	0.000004	0.000000	0.000000

EL- 31 NODES- 9 30 MAT- 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	12.512	158.19	-158.19	-3.9339	3.9339
2 (J)	12.512	-109.80	109.80	13.165	-13.165
LOCATION	SMAX	SMIN			
1 (I)	174.63	-149.61			
2 (J)	135.48	-110.46			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000005	-0.000005	0.000000	0.000000
2 (J)	0.000000	-0.000004	0.000004	0.000000	0.000000

EL- 30 NODES- 29 22 MAT- 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	11.673	-112.02	112.02	-13.074	13.074
2 (J)	11.673	147.25	-147.25	-27.659	27.659
LOCATION	SMAX	SMIN			
1 (I)	136.77	-113.43			
2 (J)	186.58	-163.24			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	-0.000004	0.000004	0.000000	0.000000
2 (J)	0.000000	0.000005	-0.000005	-0.000001	0.000001

```

EL= 32  NODES= 30  23  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  12.512    -109.80    109.80    13.165    -13.165
  2 (J)  12.512    168.99    -168.99    30.264    -30.264
LOCATION  SMAX      SMIN
  1 (I)  135.48    -110.46
  2 (J)  211.77    -186.74
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000000  -0.000004  0.000004  0.000000  0.000000
  2 (J)  0.000000  0.000006  -0.000006  0.000001  -0.000001

```

```

EL= 11  NODES= 8  11  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -545.10   -2805.2    2805.2    167.06    -167.06
  2 (J)  -542.56   -3401.0    3401.0    37.845    -37.845
LOCATION  SMAX      SMIN
  1 (I)  2427.2    -3517.4
  2 (J)  2896.3    -3981.4
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  -0.000018  -0.000094  0.000094  0.000006  -0.000006
  2 (J)  -0.000018  -0.000113  0.000113  0.000001  -0.000001

```

```

EL= 9  NODES= 9  10  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -507.06   -3353.9    3353.9    155.44    -155.44
  2 (J)  -504.51   -4145.0    4145.0    17.676    -17.676
LOCATION  SMAX      SMIN
  1 (I)  3002.2    -4016.4
  2 (J)  3658.2    -4667.2
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  -0.000017  -0.000112  0.000112  0.000005  -0.000005
  2 (J)  -0.000017  -0.000138  0.000138  0.000001  -0.000001

```

```

EL= 25  NODES= 22  25  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  118.73    -2893.9    2893.9    -150.99    150.99
  2 (J)  121.28    -3259.6    3259.6    -22.319    22.319
LOCATION  SMAX      SMIN
  1 (I)  3163.6    -2926.2
  2 (J)  3403.2    -3160.6
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  0.000004  -0.000096  0.000096  -0.000005  0.000005
  2 (J)  0.000004  -0.000109  0.000109  -0.000001  0.000001

```

```

EL= 23  NODES= 23  24  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -1131.8   -3653.9    3653.9    -169.72    169.72
  2 (J)  -1129.3   -4449.4    4449.4    -31.412    31.412
LOCATION  SMAX      SMIN
  1 (I)  2691.8    -4955.5
  2 (J)  3351.5    -5610.1
LOCATION  EPELDIR   EPELBYT   EPELBYB   EPELBZT   EPELBZB
  1 (I)  -0.000038  -0.000122  0.000122  -0.000006  0.000006
  2 (J)  -0.000038  -0.000148  0.000148  -0.000001  0.000001

```


EL- 12 NODES- 11 12 MAT- 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-542.56	-3401.0	3401.0	37.845	-37.845
2 (J)	-540.01	-3988.7	3988.7	-91.371	91.371
LOCATION	SMAX	SMIN			
1 (I)	2896.3	-3981.4			
2 (J)	3540.1	-4620.1			
LOCATION	EPELDIB	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000018	-0.000113	0.000113	0.000001	-0.000001
2 (J)	-0.000018	-0.000133	0.000133	-0.000003	0.000003

EL- 10 NODES- 10 14 MAT- 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-504.51	-4145.0	4145.0	17.676	-17.676
2 (J)	-501.97	-4944.3	4944.3	-120.09	120.09
LOCATION	SMAX	SMIN			
1 (I)	3658.2	-4667.2			
2 (J)	4562.4	-5566.3			
LOCATION	EPELDIB	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000017	-0.000138	0.000138	0.000001	-0.000001
2 (J)	-0.000017	-0.000165	0.000165	-0.000004	0.000004

EL- 26 NODES- 25 26 MAT- 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	121.28	-3259.6	3259.6	-22.319	22.319
2 (J)	123.82	-3617.1	3617.1	106.35	-106.35
LOCATION	SMAX	SMIN			
1 (I)	3403.2	-3160.6			
2 (J)	3847.3	-3599.6			
LOCATION	EPELDIB	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000004	-0.000109	0.000109	-0.000001	0.000001
2 (J)	0.000004	-0.000121	0.000121	0.000004	-0.000004

EL- 24 NODES- 24 28 MAT- 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1129.3	-4449.4	4449.4	-31.412	31.412
2 (J)	-1126.3	-5252.9	5252.9	106.90	-106.90
LOCATION	SMAX	SMIN			
1 (I)	3351.5	-5610.1			
2 (J)	4233.0	-6486.6			
LOCATION	EPELDIB	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000038	-0.000148	0.000148	-0.000001	0.000001
2 (J)	-0.000038	-0.000175	0.000175	0.000004	-0.000004

EL- 13 NODES- 12 13 MAT- 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-0.21166E-10	50.472	-50.472	0.38978E-12	-0.38978E-12
2 (J)	-0.21166E-10	-25.236	25.236	0.00000E+00	0.00000E+00
LOCATION	SMAX	SMIN			
1 (I)	50.472	-50.472			
2 (J)	25.236	-25.236			
LOCATION	EPELDIB	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000002	-0.000002	0.000000	0.000000
2 (J)	0.000000	-0.000001	0.000001	0.000000	0.000000

EL-14	NODES-13	14	NAT-1	EL-27	NODES-26	27	NAT-1	EL-28	NODES-27	28	NAT-1	EL-40	NODES-38	40	NAT-1	EL-34	NODES-37	38	NAT-1	EL-34	NODES-37	38	NAT-1
LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB	LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB	LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB	LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	0.21166E-10	-25.236	25.236	-0.97446E-13	0.97446E-12	1 (I)	0.21166E-10	-25.236	25.236	-0.87701E-12	0.87701E-12	1 (I)	0.21166E-10	-25.236	25.236	-0.97446E-12	0.97446E-12	1 (I)	0.21166E-10	-25.236	25.236	-0.87701E-12	0.87701E-12
2 (J)	0.21166E-10	50.472	-50.472	-0.97446E-13	0.97446E-12	2 (J)	0.21166E-10	50.472	-50.472	-0.97446E-12	0.97446E-12	2 (J)	0.21166E-10	50.472	-50.472	-0.97446E-12	0.97446E-12	2 (J)	0.21166E-10	50.472	-50.472	-0.85730E-01	0.85730E-01
LOCATION	SMAX	SMIN	SMAX	SMIN	SMAX	LOCATION	SMAX	SMIN	SMAX	SMIN	SMAX	LOCATION	SMAX	SMIN	SMAX	SMIN	SMAX	LOCATION	SMAX	SMIN	SMAX	SMIN	SMAX
1 (I)	25.236	-25.236	25.236	-25.236	25.236	1 (I)	25.236	-25.236	25.236	-25.236	25.236	1 (I)	25.236	-25.236	25.236	-25.236	25.236	1 (I)	25.236	-25.236	25.236	-25.236	25.236
2 (J)	50.472	-50.472	50.472	-50.472	50.472	2 (J)	50.472	-50.472	50.472	-50.472	50.472	2 (J)	50.472	-50.472	50.472	-50.472	50.472	2 (J)	50.472	-50.472	50.472	-50.472	50.472
LOCATION	EPRLDIR	EPRLBYT	EPRLBYB	EPRLBZT	EPRLBZB	LOCATION	EPRLDIR	EPRLBYT	EPRLBYB	EPRLBZT	EPRLBZB	LOCATION	EPRLDIR	EPRLBYT	EPRLBYB	EPRLBZT	EPRLBZB	LOCATION	EPRLDIR	EPRLBYT	EPRLBYB	EPRLBZT	EPRLBZB
1 (I)	0.000000	-0.000002	0.000002	-0.000002	0.000000	1 (I)	0.000000	-0.000002	0.000002	-0.000002	0.000000	1 (I)	0.000000	-0.000002	0.000002	-0.000002	0.000000	1 (I)	0.000000	-0.000002	0.000002	-0.000002	0.000000
2 (J)	0.000000	-0.000001	0.000001	-0.000001	0.000000	2 (J)	0.000000	-0.000001	0.000001	-0.000001	0.000000	2 (J)	0.000000	-0.000001	0.000001	-0.000001	0.000000	2 (J)	0.000000	-0.000001	0.000001	-0.000001	0.000000
EL-14	NODES-13	13	NAT-1	EL-27	NODES-26	26	NAT-1	EL-28	NODES-27	27	NAT-1	EL-40	NODES-38	38	NAT-1	EL-34	NODES-37	37	NAT-1	EL-34	NODES-37	38	NAT-1

EL- 42 NODES= 41 37 MAT= 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.0939	-87.114	87.114	14.106	-14.106
2 (J)	-1.0939	-35.639	35.639	4.5801	-4.5801
LOCATION	SMAx	SMin			
1 (I)	100.13	-102.31			
2 (J)	39.125	-41.313			
LOCATION	EPeLDIR	EPeLBYT	EPeLBYB	EPeLBZT	EPeLBZB
1 (I)	0.000000	-0.000003	0.000003	0.000000	0.000000
2 (J)	0.000000	-0.000001	0.000001	0.000000	0.000000

EL- 41 NODES= 36 41 MAT= 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.0939	-45.123	45.123	25.188	-25.188
2 (J)	-1.0939	-87.114	87.114	14.106	-14.106
LOCATION	SMAx	SMin			
1 (I)	69.216	-71.404			
2 (J)	100.13	-102.31			
LOCATION	EPeLDIR	EPeLBYT	EPeLBYB	EPeLBZT	EPeLBZB
1 (I)	0.000000	-0.000002	0.000002	0.000001	-0.000001
2 (J)	0.000000	-0.000003	0.000003	0.000000	0.000000

EL- 33 NODES= 35 36 MAT= 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.0939	2.4900	-2.4900	-0.70672E-01	0.70672E-01
2 (J)	-1.0939	-45.123	45.123	25.188	-25.188
LOCATION	SMAx	SMin			
1 (I)	1.4668	-3.6546			
2 (J)	69.216	-71.404			
LOCATION	EPeLDIR	EPeLBYT	EPeLBYB	EPeLBZT	EPeLBZB
1 (I)	0.000000	0.000000	0.000000	0.000000	0.000000
2 (J)	0.000000	-0.000002	0.000002	0.000001	-0.000001

EL- 39 NODES= 35 39 MAT= 1

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	0.00000E+00	0.62060	-0.62060	-0.62140E-09	0.62140E-09
2 (J)	0.00000E+00	0.55401E-10	-0.55401E-10	-0.12046E-08	0.12046E-08
LOCATION	SMAx	SMin			
1 (I)	0.62060	-0.62060			
2 (J)	0.12600E-08	-0.12600E-08			
LOCATION	EPeLDIR	EPeLBYT	EPeLBYB	EPeLBZT	EPeLBZB
1 (I)	0.000000	0.000000	0.000000	0.000000	0.000000
2 (J)	0.000000	0.000000	0.000000	0.000000	0.000000

*** ELEMENT RESULT CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.170	0.004
2	3	MASS21	0.000	0.000

*** NODAL LOAD CALCULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.000	0.000
2	3	MASS21	0.000	0.000

Analysis of the Shot Loading Trainer -- Fixed Supports

***** REACTION SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY	FZ	MX	MY	MZ
1	-302.881	1470.14				
4		1556.98				
15	-1230.45	-313.838	-0.579575E-09			
18		3220.60				
TOTAL	-1533.33	5933.88	-0.579575E-09	0.000000E+00	0.000000E+00	0.000000E+00

*** NOTE *** CP= 2.490 TIME= 13:32:30
Totals may not be correct if any reaction nodes are in a rotated nodal coordinate system.

***** CONSTRAINT EQN. REACTION SOLUTION ***** TIME = 1.0000
LOAD STEP= 1 SUBSTEP = 1 CUM. ITER.= 1

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY	FZ	MX	MY	MZ
12	-271.536	-1450.65	-32.1901	177.529	-153.877	9424.72
14	574.561	-1254.43	-34.3190	241.077	175.319	11418.9
26	178.917	319.389	32.0540	-229.535	99.6355	8557.70
28	1051.39	-2905.11	34.4551	-229.735	-103.540	12139.0
35	-1230.31	2585.72	-66.5091	1456.91	55.0781	29570.8
38	-303.026	2705.07	66.5091	-1416.24	-66.8132	-29570.8
TOTAL	0.517128E-06	-0.226182E-07	0.289901E-11	-0.502223E-08	5.80290	41540.3

*** NOTE *** CP= 2.510 TIME= 13:32:34
Totals may not be correct if any reaction nodes are in a rotated nodal coordinate system.

*** LOAD STEP 1 SUBSTEP 1 COMPLETED. CUM ITER = 1
*** TIME = 1.00000 TIME INC = 1.00000 NEW TRIANG MATRIX

*** PROBLEM STATISTICS

ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 215
R.M.S. WAVEFRONT SIZE = 32.2

APPENDIX E

Computer Output - Load Case 2
Vibrator Load Applied in Vertical Direction

Static Analysis -- Fixed Supports Load Cases 1 and 2

Load step file number 2. Begin solution ...

***** ANSYS SOLVE COMMAND *****

*** NOTE *** CP= 2.640 TIME= 13:32:39
Real constant set 3 is not used by any element types that require real constants.

*** NOTE *** CP= 2.650 TIME= 13:32:43
Real constant set 8 is not used by any element types that require real constants.

*** NOTE *** CP= 2.660 TIME= 13:32:47
Present time 0 is less than or equal to the previous time.
Time will default to 2.

LOAD STEP OPTIONS

LOAD STEP NUMBER. 2
TIME AT END OF THE LOAD STEP. 2.0000
NUMBER OF SUBSTEPS. 1
STEP CHANGE BOUNDARY CONDITIONS NO
INERTIA LOADS X Y Z
ACEL 0.00000E+00 386.40 0.00000E+00

PRINT OUTPUT CONTROLS

ITEM FREQUENCY COMPONENT
BASE ALL

DATABASE OUTPUT CONTROLS. ALL DATA WRITTEN
FOR THE LAST SUBSTEP

Element Formation Element= 1 Cum. Iter.= 2 CP= 2.670

Time= 2.0000 Load Step= 2 Substep= 1 Equilibrium Iteration= 1.

Static Analysis -- Fixed Supports

***** DEGREE OF FREEDOM SOLUTION ***** TIME = 2.0000
LOAD STEP= 2 SUBSTEP = 1 CUM. ITER.= 2

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
1	0.000000E+00	0.000000E+00	-0.231818E-02	0.243428E-04	0.121497E-04	-0.535564E-03
2	0.303706E-02	-0.383901E-03	-0.219035E-02	0.243428E-04	0.121497E-04	-0.462081E-03
3	0.328829E-02	-0.127191E-01	-0.264647E-02	0.243428E-04	0.789947E-05	0.714565E-14
4	0.657658E-02	0.000000E+00	-0.306073E-02	0.243428E-04	0.364924E-05	0.535564E-03
5	0.353953E-02	-0.383901E-03	-0.290920E-02	0.243428E-04	0.364924E-05	0.462081E-03
6	-0.256187E-02	-0.327498E-02	-0.201471E-02	0.246002E-04	-0.804157E-06	-0.473250E-04
7	0.913845E-02	-0.327498E-02	-0.144595E-02	0.246002E-04	0.166031E-04	0.473250E-04
8	0.451904E-02	-0.282389E-02	-0.734594E-03	0.248576E-04	0.210565E-04	0.117439E-03
9	0.205754E-02	-0.282389E-02	-0.115327E-02	0.248576E-04	-0.525755E-05	-0.117439E-03
10	0.293663E-02	-0.275936E-02	-0.105461E-02	0.434251E-05	-0.266463E-05	-0.648472E-04
11	0.363995E-02	-0.275936E-02	-0.676913E-03	0.434251E-05	0.184636E-04	0.648472E-04
12	0.328829E-02	-0.284600E-02	-0.562339E-03	0.114864E-04	0.789947E-05	0.182619E-13
13	0.328829E-02	-0.290968E-02	-0.330697E-03	0.114864E-04	0.789947E-05	0.182619E-13
14	0.328829E-02	-0.284600E-02	-0.999054E-03	0.114864E-04	0.789947E-05	0.182619E-13
15	0.000000E+00	0.000000E+00	0.000000E+00	-0.356890E-05	0.430573E-05	-0.538862E-03
16	0.361406E-02	-0.105841E-02	-0.578720E-04	-0.356890E-05	0.430573E-05	-0.547549E-03
17	0.392815E-02	-0.148381E-01	-0.335540E-03	-0.356890E-05	0.789947E-05	0.849166E-14
18	0.785630E-02	0.000000E+00	-0.742550E-03	-0.356890E-05	0.114932E-04	0.638862E-03
19	0.424223E-02	-0.105841E-02	-0.776724E-03	-0.356890E-05	0.114932E-04	0.547549E-03
20	-0.285306E-02	-0.390749E-02	-0.962050E-03	-0.378655E-05	0.152587E-04	-0.590434E-04
21	0.107094E-01	-0.390749E-02	-0.393288E-03	-0.378655E-05	0.540219E-06	0.590434E-04
22	0.529698E-02	-0.344287E-02	-0.700768E-03	-0.900420E-05	-0.322530E-05	0.131241E-03
23	0.255931E-02	-0.344287E-02	-0.111944E-02	-0.900420E-05	0.190242E-04	-0.131241E-03
24	0.353850E-02	-0.339901E-02	-0.103687E-02	0.118501E-04	0.174474E-04	-0.707075E-04
25	0.431780E-02	-0.339901E-02	-0.659174E-03	0.118501E-04	-0.164851E-05	0.707075E-04
26	0.392815E-02	-0.352424E-02	-0.568784E-03	0.504535E-05	0.789947E-05	0.184325E-13
27	0.392815E-02	-0.358792E-02	-0.737141E-03	0.504535E-05	0.789947E-05	0.184325E-13
28	0.392815E-02	-0.352424E-02	-0.905498E-03	0.504535E-05	0.789947E-05	0.184325E-13
29	0.515386E-02	-0.430666E-02	-0.717681E-03	0.749913E-05	0.994859E-05	0.124340E-03
30	0.206258E-02	-0.430666E-02	-0.113635E-02	0.749913E-05	0.585035E-05	-0.124340E-03
35	0.392815E-02	-0.352424E-02	-0.661461E-03	0.504535E-05	0.789947E-05	0.184325E-13
36	0.380176E-02	-0.343987E-02	-0.660856E-03	0.574992E-05	0.789947E-05	0.183988E-13
37	0.338309E-02	-0.298273E-02	-0.658854E-03	0.111930E-04	0.789947E-05	0.182871E-13
38	0.328829E-02	-0.284600E-02	-0.658401E-03	0.114864E-04	0.789947E-05	0.182619E-13
39	0.398739E-02	-0.356209E-02	-0.661461E-03	0.504734E-05	0.789947E-05	0.184325E-13
40	0.322905E-02	-0.275986E-02	-0.658401E-03	0.114844E-04	0.789947E-05	0.182619E-13
41	0.357662E-02	-0.323325E-02	-0.659780E-03	0.393781E-05	0.789947E-05	0.183388E-13
MAXIMUMS						
NODE	21	17	4	8	8	15
VALUE	0.107094E-01	-0.148381E-01	-0.306073E-02	0.248576E-04	0.210565E-04	-0.638862E-03

Analysis of the Shot Loading Trainer -- Fixed Supports

***** ELEMENT SOLUTION *****

TIME = 2.0000

LOAD STEP= 2 SUBSTEP = 1 CUM. ITER.= 2

EL= 1 NODES= 1 2 MAT= 1
BEAM4
LOCATION SDIR SBYT SBYB SBZT SBZB
1 (I) -587.38 -0.15864E-11 0.15864E-11 -0.47165E-11 0.47165E-11
2 (J) -585.68 -1068.8 1068.8 0.48834E-11 -0.48834E-11
LOCATION SMAX SMIN
1 (I) -587.38 -587.38
2 (J) 483.13 -1654.5
LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB
1 (I) -0.000020 0.000000 0.000000 0.000000 0.000000
2 (J) -0.000020 -0.000036 0.000036 0.000000 0.000000

EL= 4 NODES= 5 4 MAT= 1
BEAM4
LOCATION SDIR SBYT SBYB SBZT SBZB
1 (I) -585.68 -1068.8 1068.8 -0.18959E-11 0.18959E-11
2 (J) -587.38 -0.70433E-11 0.70433E-11 0.20259E-11 -0.20259E-11
LOCATION SMAX SMIN
1 (I) 483.13 -1654.5
2 (J) -587.38 -587.38
LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB
1 (I) -0.000020 -0.000036 0.000036 0.000000 0.000000
2 (J) -0.000020 0.000000 0.000000 0.000000 0.000000

EL= 15 NODES= 15 16 MAT= 1
BEAM4
LOCATION SDIR SBYT SBYB SBZT SBZB
1 (I) -729.76 -0.39251E-11 0.39251E-11 0.68687E-13 -0.68687E-13
2 (J) -728.06 -1328.3 1328.3 0.14583E-09 -0.14583E-09
LOCATION SMAX SMIN
1 (I) -729.76 -729.76
2 (J) 600.21 -2056.3
LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB
1 (I) -0.000024 0.000000 0.000000 0.000000 0.000000
2 (J) -0.000024 -0.000044 0.000044 0.000000 0.000000

EL= 18 NODES= 19 18 MAT= 1
BEAM4
LOCATION SDIR SBYT SBYB SBZT SBZB
1 (I) -728.06 -1328.3 1328.3 -0.95866E-12 0.95866E-12
2 (J) -729.76 -0.39251E-11 0.39251E-11 0.14121E-11 -0.14121E-11
LOCATION SMAX SMIN
1 (I) 600.21 -2056.3
2 (J) -729.76 -729.76
LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB
1 (I) -0.000024 -0.000044 0.000044 0.000000 0.000000
2 (J) -0.000024 0.000000 0.000000 0.000000 0.000000


```

EL=      2  NODES=      2      3  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)   165.65    -226.96    226.96    -4.2035    4.2035
  2 (J)   165.65    -572.02    572.02    -4.2035    4.2035
LOCATION  SMAX      SMIN
  1 (I)   396.82    -65.516
  2 (J)   741.88    -410.58
LOCATION  EPELDIB  EPELBYT  EPELBYB  EPELBZT  EPELBZB
  1 (I)   0.000006  -0.000008  0.000008  0.000000  0.000000
  2 (J)   0.000006  -0.000019  0.000019  0.000000  0.000000

```

```

EL=      3  NODES=      3      5  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)   165.65    -572.02    572.02    -4.2035    4.2035
  2 (J)   165.65    -226.96    226.96    -4.2035    4.2035
LOCATION  SMAX      SMIN
  1 (I)   741.88    -410.58
  2 (J)   396.82    -65.516
LOCATION  EPELDIB  EPELBYT  EPELBYB  EPELBZT  EPELBZB
  1 (I)   0.000006  -0.000019  0.000019  0.000000  0.000000
  2 (J)   0.000006  -0.000008  0.000008  0.000000  0.000000

```

```

EL=     16  NODES=     16     17  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)   207.09    -311.49    311.49     3.5542    -3.5542
  2 (J)   207.09    -656.55    656.55     3.5542    -3.5542
LOCATION  SMAX      SMIN
  1 (I)   522.13    -107.96
  2 (J)   867.20    -453.02
LOCATION  EPELDIB  EPELBYT  EPELBYB  EPELBZT  EPELBZB
  1 (I)   0.000007  -0.000010  0.000010  0.000000  0.000000
  2 (J)   0.000007  -0.000022  0.000022  0.000000  0.000000

```

```

EL=     17  NODES=     17     19  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)   207.09    -656.55    656.55     3.5542    -3.5542
  2 (J)   207.09    -311.49    311.49     3.5542    -3.5542
LOCATION  SMAX      SMIN
  1 (I)   867.20    -453.02
  2 (J)   522.13    -107.96
LOCATION  EPELDIB  EPELBYT  EPELBYB  EPELBZT  EPELBZB
  1 (I)   0.000007  -0.000022  0.000022  0.000000  0.000000
  2 (J)   0.000007  -0.000010  0.000010  0.000000  0.000000

```

```

EL=      7  NODES=      2      7  MAT=  1
        BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -613.55    -841.85    841.85     1.0725    -1.0725
  2 (J)  -603.36    -369.86    369.86     1.0725    -1.0725
LOCATION  SMAX      SMIN
  1 (I)   229.38    -1456.5
  2 (J)  -232.43    -974.30
LOCATION  EPELDIB  EPELBYT  EPELBYB  EPELBZT  EPELBZB
  1 (I)  -0.000020  -0.000028  0.000028  0.000000  0.000000
  2 (J)  -0.000020  -0.000012  0.000012  0.000000  0.000000

```

EL- 5 NODES- 5 6 MAT- 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-613.55	841.85	-841.85	1.0725	-1.0725
2 (J)	-603.36	369.86	-369.86	1.0725	-1.0725
LOCATION	SMAX	SMIN			
1 (I)	229.38	-1456.5			
2 (J)	-232.43	-974.30			
LOCATION	EPFLDIR	EPFLBYT	EPFLBYB	EPFLBZT	EPFLBZB
1 (I)	-0.000020	0.000028	-0.000028	0.000000	0.000000
2 (J)	-0.000020	0.000012	-0.000012	0.000000	0.000000

EL- 21 NODES- 16 21 MAT- 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-766.03	-1016.8	1016.8	-0.90688	0.90688
2 (J)	-755.85	-429.85	429.85	-0.90688	0.90688
LOCATION	SMAX	SMIN			
1 (I)	251.66	-1783.7			
2 (J)	-325.09	-1186.6			
LOCATION	EPFLDIR	EPFLBYT	EPFLBYB	EPFLBZT	EPFLBZB
1 (I)	-0.000026	-0.000034	0.000034	0.000000	0.000000
2 (J)	-0.000025	-0.000014	0.000014	0.000000	0.000000

EL- 19 NODES- 19 20 MAT- 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-766.03	1016.8	-1016.8	-0.90688	0.90688
2 (J)	-755.85	429.85	-429.85	-0.90688	0.90688
LOCATION	SMAX	SMIN			
1 (I)	251.66	-1783.7			
2 (J)	-325.09	-1186.6			
LOCATION	EPFLDIR	EPFLBYT	EPFLBYB	EPFLBZT	EPFLBZB
1 (I)	-0.000026	0.000034	-0.000034	0.000000	0.000000
2 (J)	-0.000025	0.000014	-0.000014	0.000000	0.000000

EL- 8 NODES- 7 8 MAT- 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-603.36	-369.86	369.86	1.0725	-1.0725
2 (J)	-593.18	220.03	-220.03	1.0725	-1.0725
LOCATION	SMAX	SMIN			
1 (I)	-232.43	-974.30			
2 (J)	-372.08	-814.29			
LOCATION	EPFLDIR	EPFLBYT	EPFLBYB	EPFLBZT	EPFLBZB
1 (I)	-0.000020	-0.000012	0.000012	0.000000	0.000000
2 (J)	-0.000020	0.000007	-0.000007	0.000000	0.000000

EL- 6 NODES- 6 9 MAT- 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-603.36	369.86	-369.86	1.0725	-1.0725
2 (J)	-593.18	-220.03	220.03	1.0725	-1.0725
LOCATION	SMAX	SMIN			
1 (I)	-232.43	-974.30			
2 (J)	-372.08	-814.29			
LOCATION	EPFLDIR	EPFLBYT	EPFLBYB	EPFLBZT	EPFLBZB
1 (I)	-0.000020	0.000012	-0.000012	0.000000	0.000000
2 (J)	-0.000020	-0.000007	0.000007	0.000000	0.000000

EL- 22 NODES= 21 22 MAT= 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-755.85	-429.85	429.85	-0.90688	0.90688
2 (J)	-745.66	274.99	-274.99	-0.90688	0.90688

LOCATION SMAX SMIN

1 (I)	-325.09	-1186.6
2 (J)	-469.77	-1021.6

LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB

1 (I)	-0.000025	-0.000014	0.000014	0.000000	0.000000
2 (J)	-0.000025	0.000009	-0.000009	0.000000	0.000000

EL- 20 NODES= 20 23 MAT= 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-755.85	429.85	-429.85	-0.90688	0.90688
2 (J)	-745.66	-274.99	274.99	-0.90688	0.90688

LOCATION SMAX SMIN

1 (I)	-325.09	-1186.6
2 (J)	-469.77	-1021.6

LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB

1 (I)	-0.000025	0.000014	-0.000014	0.000000	0.000000
2 (J)	-0.000025	-0.000009	0.000009	0.000000	0.000000

EL- 29 NODES= 8 29 MAT= 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	12.528	162.50	-162.50	-11.194	11.194
2 (J)	12.528	-109.94	109.94	-13.490	13.490

LOCATION SMAX SMIN

1 (I)	186.22	-161.16
2 (J)	135.96	-110.90

LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB

1 (I)	0.000000	0.000005	-0.000005	0.000000	0.000000
2 (J)	0.000000	-0.000004	0.000004	0.000000	0.000000

EL- 31 NODES= 9 30 MAT= 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	12.528	162.50	-162.50	11.194	-11.194
2 (J)	12.528	-109.94	109.94	13.490	-13.490

LOCATION SMAX SMIN

1 (I)	186.22	-161.16
2 (J)	135.96	-110.90

LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB

1 (I)	0.000000	0.000005	-0.000005	0.000000	0.000000
2 (J)	0.000000	-0.000004	0.000004	0.000000	0.000000

EL- 30 NODES= 29 22 MAT= 1
BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	12.528	-109.94	109.94	-13.490	13.490
2 (J)	12.528	164.40	-164.40	-15.785	15.785

LOCATION SMAX SMIN

1 (I)	135.96	-110.90
2 (J)	192.71	-167.66

LOCATION EPELDIR EPELBYT EPELBYB EPELBZT EPELBZB

1 (I)	0.000000	-0.000004	0.000004	0.000000	0.000000
2 (J)	0.000000	0.000005	-0.000005	-0.000001	0.000001

```

EL= 32  NODES= 30  23  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  12.528    -109.94    109.94    13.490    -13.490
  2 (J)  12.528    164.40    -164.40    15.785    -15.785
LOCATION  SMAX      SMIN
  1 (I)  135.96    -110.90
  2 (J)  192.71    -167.66
LOCATION  EPBLDIR    EPBLBYT    EPBLBYB    EPBLBZT    EPBLBZB
  1 (I)  0.000000    -0.000004    0.000004    0.000000    0.000000
  2 (J)  0.000000    0.000005    -0.000005    0.000001    -0.000001

```

```

EL= 11  NODES= 8  11  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -582.39    225.93    -225.93    160.41    -160.41
  2 (J) -579.84    280.76    -280.76    22.112    -22.112
LOCATION  SMAX      SMIN
  1 (I) -196.05    -968.73
  2 (J) -276.97    -882.72
LOCATION  EPBLDIR    EPBLBYT    EPBLBYB    EPBLBZT    EPBLBZB
  1 (I) -0.000019    0.000008    -0.000008    0.000005    -0.000005
  2 (J) -0.000019    0.000009    -0.000009    0.000001    -0.000001

```

```

EL= 9  NODES= 9  10  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -582.39    -225.93    225.93    160.41    -160.41
  2 (J) -579.84    -280.76    280.76    22.112    -22.112
LOCATION  SMAX      SMIN
  1 (I) -196.05    -968.73
  2 (J) -276.97    -882.72
LOCATION  EPBLDIR    EPBLBYT    EPBLBYB    EPBLBZT    EPBLBZB
  1 (I) -0.000019    -0.000008    0.000008    0.000005    -0.000005
  2 (J) -0.000019    -0.000009    0.000009    0.000001    -0.000001

```

```

EL= 25  NODES= 22  25  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -734.83    269.09    -269.09    -163.32    163.32
  2 (J) -732.28    313.92    -313.92    -25.030    25.030
LOCATION  SMAX      SMIN
  1 (I) -302.41    -1167.2
  2 (J) -393.33    -1071.2
LOCATION  EPBLDIR    EPBLBYT    EPBLBYB    EPBLBZT    EPBLBZB
  1 (I) -0.000024    0.000009    -0.000009    -0.000005    0.000005
  2 (J) -0.000024    0.000010    -0.000010    -0.000001    0.000001

```

```

EL= 23  NODES= 23  24  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I) -734.83    -269.09    269.09    -163.32    163.32
  2 (J) -732.28    313.92    -313.92    -25.030    25.030
LOCATION  SMAX      SMIN
  1 (I) -302.41    -1167.2
  2 (J) -393.33    -1071.2
LOCATION  EPBLDIR    EPBLBYT    EPBLBYB    EPBLBZT    EPBLBZB
  1 (I) -0.000024    -0.000009    0.000009    -0.000005    0.000005
  2 (J) -0.000024    -0.000010    0.000010    -0.000001    0.000001

```

EL= 12 NODES= 11 12 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-579.84	280.76	-280.76	22.112	-22.112
2 (J)	-577.30	343.70	-343.70	-116.18	116.18
LOCATION	SMAK	SMIN			
1 (I)	-276.97	-882.72			
2 (J)	-117.42	-1037.2			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000019	0.000009	-0.000009	0.000001	-0.000001
2 (J)	-0.000019	0.000011	-0.000011	-0.000004	0.000004

EL= 10 NODES= 10 14 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-579.84	-280.76	280.76	22.112	-22.112
2 (J)	-577.30	-343.70	343.70	-116.18	116.18
LOCATION	SMAK	SMIN			
1 (I)	-276.97	-882.72			
2 (J)	-117.42	-1037.2			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000019	-0.000009	0.000009	0.000001	-0.000001
2 (J)	-0.000019	-0.000011	0.000011	-0.000004	0.000004

EL= 26 NODES= 25 26 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-732.28	313.92	-313.92	-25.030	25.030
2 (J)	-729.73	366.85	-366.85	113.27	-113.27
LOCATION	SMAK	SMIN			
1 (I)	-393.33	-1071.2			
2 (J)	-249.62	-1209.9			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000024	0.000010	-0.000010	-0.000001	0.000001
2 (J)	-0.000024	0.000012	-0.000012	0.000004	-0.000004

EL= 24 NODES= 24 28 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-732.28	-313.92	313.92	-25.030	25.030
2 (J)	-729.73	-366.85	366.85	113.27	-113.27
LOCATION	SMAK	SMIN			
1 (I)	-393.33	-1071.2			
2 (J)	-249.62	-1209.9			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	-0.000024	-0.000010	0.000010	-0.000001	0.000001
2 (J)	-0.000024	-0.000012	0.000012	0.000004	-0.000004

EL= 13 NODES= 12 13 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-0.66145E-12	50.472	-50.472	0.000000E+00	0.000000E+00
2 (J)	-0.66145E-12	-25.236	25.236	0.000000E+00	0.000000E+00
LOCATION	SMAK	SMIN			
1 (I)	50.472	-50.472			
2 (J)	25.236	-25.236			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000002	-0.000002	0.000000	0.000000
2 (J)	0.000000	-0.000001	0.000001	0.000000	0.000000

```

EL= 14  NODES= 13  14  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  0.66145E-12 -25.236      25.236      -0.79175E-13 0.79175E-13
  2 (J)  0.66145E-12  50.472      -50.472      0.60904E-13 -0.60904E-13
LOCATION  SMAX      SMIN
  1 (I)  25.236      -25.236
  2 (J)  50.472      -50.472
LOCATION  EPFLDIR  EPFLBYT  EPFLBYB  EPFLBZT  EPFLBZB
  1 (I)  0.000000  -0.000001  0.000001  0.000000  0.000000
  2 (J)  0.000000  0.000002  -0.000002  0.000000  0.000000

```

```

EL= 27  NODES= 26  27  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -0.13229E-11  50.472      -50.472      -0.79175E-13 0.79175E-13
  2 (J)  -0.13229E-11 -25.236      25.236      0.60904E-13 -0.60904E-13
LOCATION  SMAX      SMIN
  1 (I)  50.472      -50.472
  2 (J)  25.236      -25.236
LOCATION  EPFLDIR  EPFLBYT  EPFLBYB  EPFLBZT  EPFLBZB
  1 (I)  0.000000  0.000002  -0.000002  0.000000  0.000000
  2 (J)  0.000000  -0.000001  0.000001  0.000000  0.000000

```

```

EL= 28  NODES= 27  28  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  0.13229E-11 -25.236      25.236      0.12181E-13 -0.12181E-13
  2 (J)  0.13229E-11  50.472      -50.472      -0.24361E-13 0.24361E-13
LOCATION  SMAX      SMIN
  1 (I)  25.236      -25.236
  2 (J)  50.472      -50.472
LOCATION  EPFLDIR  EPFLBYT  EPFLBYB  EPFLBZT  EPFLBZB
  1 (I)  0.000000  -0.000001  0.000001  0.000000  0.000000
  2 (J)  0.000000  0.000002  -0.000002  0.000000  0.000000

```

```

EL= 40  NODES= 38  40  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -0.47868E-12 0.62060      -0.62060      0.11950E-10 -0.11950E-10
  2 (J)  -0.47868E-12 0.36879E-10 -0.36879E-10 0.14340E-10 -0.14340E-10
LOCATION  SMAX      SMIN
  1 (I)  0.62060      -0.62060
  2 (J)  0.50740E-10 -0.51698E-10
LOCATION  EPFLDIR  EPFLBYT  EPFLBYB  EPFLBZT  EPFLBZB
  1 (I)  0.000000  0.000000  0.000000  0.000000  0.000000
  2 (J)  0.000000  0.000000  0.000000  0.000000  0.000000

```

```

EL= 34  NODES= 37  38  MAT= 1
      BEAM4
LOCATION  SDIR      SBYT      SBYB      SBZT      SBZB
  1 (I)  -1.1333      -40.185      40.185      0.83650E-11 -0.83650E-11
  2 (J)  -1.1333      2.5652      -2.5652      0.21510E-10 -0.21510E-10
LOCATION  SMAX      SMIN
  1 (I)  39.051      -41.318
  2 (J)  1.4319      -3.6985
LOCATION  EPFLDIR  EPFLBYT  EPFLBYB  EPFLBZT  EPFLBZB
  1 (I)  0.000000  -0.000001  0.000001  0.000000  0.000000
  2 (J)  0.000000  0.000000  0.000000  0.000000  0.000000

```

EL= 42 NODES= 41 37 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.1333	-101.20	101.20	0.32340E-10	0.32340E-10
2 (J)	-1.1333	-40.185	40.185	0.21361E-10	0.21361E-10
LOCATION	SMAX	SMIN			
1 (I)	100.07	-102.33			
2 (J)	39.051	-41.318			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	-0.000003	0.000003	0.000000	0.000000
2 (J)	0.000000	-0.000001	0.000001	0.000000	0.000000

EL= 41 NODES= 36 41 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.1333	-70.307	70.307	0.57510E-10	0.57510E-10
2 (J)	-1.1333	-101.20	101.20	0.33161E-10	0.33161E-10
LOCATION	SMAX	SMIN			
1 (I)	69.174	-71.441			
2 (J)	100.07	-102.33			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	-0.000002	0.000002	0.000000	0.000000
2 (J)	0.000000	-0.000003	0.000003	0.000000	0.000000

EL= 33 NODES= 35 36 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-1.1333	2.5538	-2.5538	0.52730E-10	0.52730E-10
2 (J)	-1.1333	-70.307	70.307	0.57061E-10	0.57061E-10
LOCATION	SMAX	SMIN			
1 (I)	1.4205	-3.6871			
2 (J)	69.174	-71.441			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000000	0.000000	0.000000	0.000000
2 (J)	0.000000	-0.000002	0.000002	0.000000	0.000000

EL= 39 NODES= 35 39 MAT= 1

BEAM4

LOCATION	SDIR	SBYT	SBYB	SBZT	SBZB
1 (I)	-0.47868E-12	0.62060	-0.62060	-0.68115E-10	0.68115E-10
2 (J)	-0.47868E-12	0.40162E-11	-0.40162E-11	0.21510E-10	0.21510E-10
LOCATION	SMAX	SMIN			
1 (I)	0.62060	-0.62060			
2 (J)	0.25048E-10	-0.26005E-10			
LOCATION	EPELDIR	EPELBYT	EPELBYB	EPELBZT	EPELBZB
1 (I)	0.000000	0.000000	0.000000	0.000000	0.000000
2 (J)	0.000000	0.000000	0.000000	0.000000	0.000000

Analysis of the Shot Loading Trainer -- Fixed Supports

***** REACTION SOLUTION ***** TIME = 2.0000
LOAD STEP= 2 SUBSTEP = 1 CUM. ITER.= 2

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY	FZ	MX	MY	MZ
1	0.385899E-08	1665.00				
4		1665.00				
15	-0.270411E-07	2068.61	-0.550955E-10			
18		2068.61				
TOTAL	-0.231821E-07	7467.22	-0.550955E-10	0.000000E+00	0.000000E+00	0.000000E+00

*** NOTE *** CP= 3.010 TIME= 13:32:52
Totals may not be correct if any reaction nodes are in a rotated nodal coordinate system.

***** CONSTRAINT EQN. REACTION SOLUTION ***** TIME = 2.0000
LOAD STEP= 2 SUBSTEP = 1 CUM. ITER.= 2

NOTE - ALL VECTOR DOFS ARE IN NODAL COORDINATE SYSTEMS.

NODE	FX	FY	FZ	MX	MY	MZ
12	-455.669	-1504.28	-34.4521	240.976	-142.792	-684.191
14	455.669	-1504.28	-34.4521	240.976	142.792	684.191
26	-569.362	-1907.78	34.4521	-236.541	133.595	-738.219
28	569.362	-1907.78	34.4521	-236.541	-133.595	738.219
35	-0.916771E-08	3815.56	-68.9042	1506.65	0.119908E-07	0.985268E-06
38	0.576256E-08	3008.57	68.9042	-1515.51	0.745058E-08	-0.985275E-06
TOTAL	0.197880E-07	-0.311384E-07	-0.295586E-11	-0.316597E-07	0.208115E-07	0.627791E-06

*** NOTE *** CP= 3.020 TIME= 13:32:56
Totals may not be correct if any reaction nodes are in a rotated nodal coordinate system.

*** LOAD STEP 2 SUBSTEP 1 COMPLETED. CUM ITER = 2
*** TIME = 2.00000 TIME INC = 1.00000 OLD TRIANG MATRIX

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 3.120

PURGE ALL SOLUTION AND POST DATA
SAVE ALL MODEL DATA

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= fil1e.db
FOR POSSIBLE RESUME FROM THIS POINT

NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

APPENDIX F
Computer Output - Modal Analysis

Modal Analysis -- Spring Supports with Shot Mass

RESUME ANSYS DATA FROM FILE NAME=file.db

*** ANSYS GLOBAL STATUS ***

TITLE = Modal Analysis -- Spring Supports with Shot Mass

ANALYSIS TYPE = MODAL

NUMBER OF ELEMENT TYPES = 3

45 ELEMENTS CURRENTLY SELECTED. MAX ELEMENT NUMBER = 46

41 NODES CURRENTLY SELECTED. MAX NODE NUMBER = 41

MAXIMUM LINEAR PROPERTY NUMBER = 1
MAXIMUM REAL CONSTANT SET NUMBER = 7
ACTIVE COORDINATE SYSTEM = 0 (CARTESIAN)
MAXIMUM CONSTRAINT EQUATION NUMBER = 48
NUMBER OF SPECIFIED CONSTRAINTS = 7
NUMBER OF NODAL LOADS = 1

INITIAL JOBNAME = file

*** NOTE ***

CP= 1.290 TIME= 11:01:32

The element set contains elements that have only one structural degree of freedom per node. Viewing nodal displacements or forces in other than the nodal coordinate system may be invalid.

***** ANSYS SOLUTION ROUTINE *****

PERFORM A MODAL ANALYSIS
THIS WILL BE A NEW ANALYSIS

USE SUBSPACE ITERATION METHOD
EXTRACT 10 MODES
NORMALIZE THE MODE SHAPES TO THE MASS MATRIX

/OUTPUT FILE= ansuilst

PRINT BSI ITEMS WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.3-D
DEGREES OF FREEDOM. UX UY UZ ROTX ROTY ROTZ
ANALYSIS TYPEMODAL
EXTRACTION METHOD.SUBSPACE
NUMBER OF MODES TO EXTRACT. 10
NUMBER OF MODES TO EXPAND 10
ELEMENT RESULTS CALCULATIONOFF

Modal Analysis -- Spring Supports with Shot Mass

LOAD STEP OPTIONS

LOAD STEP NUMBER. 1
 INERTIA LOADS X Y Z
 ACEL 0.00000E+00 386.40 0.00000E+00
 PRINT OUTPUT CONTROLS
 ITEM FREQUENCY COMPONENT
 BASE ALL
 DATABASE OUTPUT CONTROLS. ALL DATA WRITTEN

***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS = 15.357

CENTROID	MOM. OF INERTIA ABOUT ORIGIN	MOM. OF INERTIA ABOUT CENTROID
XC = 47.000	IXX = 0.2067E+06	IXX = 0.1532E+05
YC = 104.35	IYY = 0.6737E+05	IYY = 9274.
ZC = 39.679	IZZ = 0.2100E+06	IZZ = 8895.
	IXY = -0.7531E+05	IXY = 0.0000E+00
	IYZ = -0.6350E+05	IYZ = 83.93
	IZX = -0.2864E+05	IZX = -0.3638E-11

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	5.93684
2	9.42000

Range of element maximum matrix coefficients in global coordinates
 Maximum= 3.24208E+11 at element 39.
 Minimum= 4920 at element 38.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.050	0.001
2	3	MASS21	0.000	0.000
3	4	COMBIN14	0.010	0.002

Time at end of element matrix formulation CP= 2.28999996.

Estimated number of active DOF= 219.

Maximum wavefront= 37.

Time at end of matrix triangularization CP= 2.42000008.

Modal Analysis -- Spring Supports with Shot Mass

SUBSPACE SIZE OF 14 VECTORS USED FOR CALCULATION OF FIRST 10 EIGENVECTORS.
 MAXIMUM ITERATIONS = 100
 NUMBER OF EQUATIONS = 219
 MAXIMUM WAVEFRONT = 37
 ITERATIONS PER SHIFT = 5
 MAXIMUM MODES STORED = 14
 MAXIMUM EIGENVALUE = 0.10000E+07
 WORK SPACE (MBYTE) = 0.18440

Equation solver maximum pivot= 8.113163456E+10 at node 40 ROTX.

Equation solver minimum pivot= 1233.74082 at node 41 UZ.

***** FREQUENCIES FROM SUBSPACE ITERATION *****

MODE	FREQUENCY (HERTZ)
1	0.86796637
2	2.2692947
3	4.5722991
4	5.6705447
5	7.5774771
6	12.777975
7	15.365290
8	15.464985
9	18.561221
10	51.443465

***** PARTICIPATION FACTOR CALCULATION ***** X DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC. FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	0.867966	1.1521	0.11871E-01	0.003106	0.140911E-03	0.948854E-05
2	2.26929	0.44067	3.8219	1.000000	14.6073	0.983623
3	4.57230	0.21871	-0.41198E-01	0.010779	0.169723E-02	0.983738
4	5.67054	0.17635	0.45886E-02	0.001201	0.210556E-04	0.983739
5	7.57748	0.13197	0.34664E-02	0.000907	0.120161E-04	0.983740
6	12.7780	0.78260E-01	0.18703E-02	0.000489	0.349800E-05	0.983740
7	15.3653	0.65082E-01	0.37270E-01	0.009752	0.138908E-02	0.983834
8	15.4650	0.64662E-01	0.43703	0.114349	0.191000	0.996695
9	18.5612	0.53876E-01	-0.24982E-02	0.000654	0.624088E-05	0.996695
10	51.4435	0.19439E-01	-0.22153	0.057963	0.490755E-01	1.00000
SUM OF EFFECTIVE MASSES=					14.8506	

***** PARTICIPATION FACTOR CALCULATION ***** Y DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC. FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	0.867966	1.1521	0.53446E-02	0.001364	0.285647E-04	0.186007E-05
2	2.26929	0.44067	-0.73620E-02	0.001879	0.541984E-04	0.538934E-05
3	4.57230	0.21871	-0.53916E-01	0.013764	0.290688E-02	0.194679E-03
4	5.67054	0.17635	3.9172	1.000000	15.3446	0.999400
5	7.57748	0.13197	0.91963E-01	0.023477	0.845725E-02	0.999950
6	12.7780	0.78260E-01	0.17914E-01	0.004573	0.320907E-03	0.999971
7	15.3653	0.65082E-01	-0.10222E-01	0.002610	0.104494E-03	0.999978
8	15.4650	0.64662E-01	0.60478E-02	0.001544	0.365763E-04	0.999981
9	18.5612	0.53876E-01	-0.14134E-03	0.000036	0.199774E-07	0.999981
10	51.4435	0.19439E-01	-0.17283E-01	0.004412	0.298716E-03	1.000000
SUM OF EFFECTIVE MASSES=					15.3568	

Modal Analysis -- Spring Supports with Shot Mass

***** PARTICIPATION FACTOR CALCULATION ***** Z DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	0.867966	1.1521	3.8883	1.000000	15.1191	0.989980
2	2.26929	0.44067	-0.14582E-01	0.003750	0.212622E-03	0.989994
3	4.57230	0.21871	-0.21221	0.054577	0.450341E-01	0.992942
4	5.67054	0.17635	-0.15183E-01	0.003905	0.230518E-03	0.992958
5	7.57748	0.13197	0.27630	0.071059	0.763411E-01	0.997956
6	12.7780	0.78260E-01	0.15045	0.038692	0.226342E-01	0.999438
7	15.3653	0.65082E-01	0.91257E-01	0.023469	0.832776E-02	0.999984
8	15.4650	0.64662E-01	-0.81788E-02	0.002103	0.668925E-04	0.999988
9	18.5612	0.53876E-01	0.77899E-02	0.002003	0.606819E-04	0.999992
10	51.4435	0.19439E-01	-0.11092E-01	0.002853	0.123029E-03	1.00000
SUM OF EFFECTIVE MASSES=					15.2721	

*** PROBLEM STATISTICS

ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 219

R.M.S. WAVEFRONT SIZE = 25.2

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 4.180

Modal Analysis -- Fixed Supports with Shot Mass

RESUME ANSYS DATA FROM FILE NAME=file.db

*** ANSYS GLOBAL STATUS ***

ANALYSIS TYPE = STATIC (STEADY-STATE)

NUMBER OF ELEMENT TYPES = 3

45 ELEMENTS CURRENTLY SELECTED. MAX ELEMENT NUMBER = 45

41 NODES CURRENTLY SELECTED. MAX NODE NUMBER = 41

MAXIMUM LINEAR PROPERTY NUMBER = 1
MAXIMUM REAL CONSTANT SET NUMBER = 8
ACTIVE COORDINATE SYSTEM = 0 (CARTESIAN)
MAXIMUM CONSTRAINT EQUATION NUMBER = 48
NUMBER OF SPECIFIED CONSTRAINTS = 7
NUMBER OF NODAL LOADS = 1

INITIAL JOBNAME = file

CURRENT JOBNAME = file

*** NOTE *** CP= 1.340 TIME= 13:09:34

The element set contains elements that have only one structural degree of freedom per node. Viewing nodal displacements or forces in other than the nodal coordinate system may be invalid.

Modal Analysis -- Fixed Supports with Shot Mass

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

ENTER /SHOW,DEVICE-NAME TO ENABLE GRAPHIC DISPLAY

ENTER FINISH TO LEAVE PREP7

PRINTOUT KEY SET TO /GOPR (USE /NOPR TO SUPPRESS)

DELETE SELECTED ELEMENTS FROM 35 TO 38 BY 1

DELETE SELECTED NODES FROM 31 TO 34 BY 1

***** ROUTINE COMPLETED ***** CP = 1.980

***** ANSYS SOLUTION ROUTINE *****

SPECIFIED CONSTRAINT UY FOR SELECTED NODES 1 TO 1 BY 1
REAL= 0.000000000E+00 IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UY FOR SELECTED NODES 4 TO 4 BY 1
REAL= 0.000000000E+00 IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UY FOR SELECTED NODES 15 TO 15 BY 1
REAL= 0.000000000E+00 IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UY FOR SELECTED NODES 18 TO 18 BY 1
REAL= 0.000000000E+00 IMAG= 0.000000000E+00

Modal Analysis -- Fixed Supports with Shot Mass

PERFORM A MODAL ANALYSIS
THIS WILL BE A NEW ANALYSIS

USE SUBSPACE ITERATION METHOD
EXTRACT 10 MODES
NORMALIZE THE MODE SHAPES TO THE MASS MATRIX

/OUTPUT FILE= ansu11at

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.3-D
DEGREES OF FREEDOM. UX UY UZ ROTX ROTY ROTZ
ANALYSIS TYPEMODAL
EXTRACTION METHOD.SUBSPACE
NUMBER OF MODES TO EXTRACT. 10
NUMBER OF MODES TO EXPAND 10
ELEMENT RESULTS CALCULATIONOFF

*** NOTE *** CP= 2.670 TIME= 13:13:42
Real constant set 3 is not used by any element types that require real constants.

*** NOTE *** CP= 2.690 TIME= 13:13:46
Real constant set 3 is not used by any element types that require real constants.

LOAD STEP OPTIONS

LOAD STEP NUMBER. 1
INERTIA LOADS X Y Z
ACEL 0.00000E+00 386.40 0.00000E+00
PRINT OUTPUT CONTROLS
ITEM FREQUENCY COMPONENT
BASE ALL
DATABASE OUTPUT CONTROLS.ALL DATA WRITTEN

Modal Analysis -- Fixed Supports with Shot Mass

***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS = 15.357

CENTROID	MOM. OF INERTIA ABOUT ORIGIN	MOM. OF INERTIA ABOUT CENTROID
XC = 47.000	IXX = 0.2067E+06	IXX = 0.1532E+05
YC = 104.35	IYY = 0.6737E+05	IYY = 9274.
ZC = 39.679	IZZ = 0.2100E+06	IZZ = 8895.
	IXY = -0.7531E+05	IXY = 0.0000E+00
	IYZ = -0.6350E+05	IYZ = 83.93
	IZX = -0.2864E+05	IZX = -0.3638E-11

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	5.93684
2	9.42000

Range of element maximum matrix coefficients in global coordinates

Maximum= 3.24208E+11 at element 39.

Minimum= 9230769.23 at element 17.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.120	0.003
2	3	MASS21	0.000	0.000

Time at end of element matrix formulation CP= 2.9000001.

Estimated number of active DOF= 215.

Maximum wavefront= 37.

Time at end of matrix triangularization CP= 3.03999996.

SUBSPACE SIZE OF 14 VECTORS USED FOR CALCULATION OF FIRST 10 EIGENVECTORS.

MAXIMUM ITERATIONS	=	100
NUMBER OF EQUATIONS	=	215
MAXIMUM WAVEFRONT	=	37
ITERATIONS PER SHIFT	=	5
MAXIMUM MODES STORED	=	14
MAXIMUM EIGENVALUE	=	0.10000E+07
WORK SPACE (MBYTE)	=	0.17907

Equation solver maximum pivot= 8.770236229E+10 at node 36 ROTX.

Equation solver minimum pivot= 1233.93749 at node 37 UZ.

Modal Analysis -- Fixed Supports with Shot Mass

***** FREQUENCIES FROM SUBSPACE ITERATION *****

MODE	FREQUENCY (HERTZ)
1	1.0361280
2	5.3092665
3	10.420206
4	13.600352
5	17.793177
6	27.085790
7	44.662350
8	56.423858
9	57.822600
10	62.684856

***** PARTICIPATION FACTOR CALCULATION ***** X DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.03613	0.96513	0.70468E-03	0.000187	0.496580E-06	0.345162E-07
2	5.30927	0.18835	3.7723	1.000000	14.2305	0.989132
3	10.4202	0.95967E-01	-0.58698E-03	0.000156	0.344547E-06	0.989132
4	13.6004	0.73528E-01	-0.27250E-02	0.000722	0.742576E-05	0.989132
5	17.7932	0.56201E-01	0.89425E-03	0.000237	0.799676E-06	0.989133
6	27.0858	0.36920E-01	-0.28908E-02	0.000766	0.835650E-05	0.989133
7	44.6623	0.22390E-01	-0.36975	0.098017	0.136716	0.998636
8	56.4239	0.17723E-01	-0.23861E-01	0.006325	0.569368E-03	0.998676
9	57.8226	0.17294E-01	-0.16481E-01	0.004369	0.271617E-03	0.998694
10	62.6849	0.15953E-01	-0.13705	0.036331	0.187832E-01	1.000000
SUM OF EFFECTIVE MASSES=					14.3869	

***** PARTICIPATION FACTOR CALCULATION ***** Y DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.03613	0.96513	0.56145E-03	0.000261	0.315229E-06	0.672526E-07
2	5.30927	0.18835	-0.32954E-01	0.015328	0.108595E-02	0.231749E-03
3	10.4202	0.95967E-01	0.65072E-02	0.003027	0.423431E-04	0.240782E-03
4	13.6004	0.73528E-01	-0.87337E-02	0.004062	0.762779E-04	0.257056E-03
5	17.7932	0.56201E-01	0.12273E-05	0.000001	0.150626E-11	0.257056E-03
6	27.0858	0.36920E-01	0.12041E-01	0.005601	0.144986E-03	0.287988E-03
7	44.6623	0.22390E-01	2.1499	1.000000	4.62206	0.986382
8	56.4239	0.17723E-01	0.44656E-01	0.020771	0.199412E-02	0.986808
9	57.8226	0.17294E-01	0.14081	0.065498	0.198289E-01	0.991038
10	62.6849	0.15953E-01	-0.20495	0.095332	0.420059E-01	1.000000
SUM OF EFFECTIVE MASSES=					4.68724	

Modal Analysis -- Fixed Supports with Shot Mass

***** PARTICIPATION FACTOR CALCULATION ***** Z DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.03613	0.96513	3.9043	1.000000	15.2434	0.995871
2	5.30927	0.18835	-0.64039E-03	0.000164	0.410094E-06	0.995871
3	10.4202	0.95967E-01	0.33257E-01	0.008518	0.110600E-02	0.995943
4	13.6004	0.73528E-01	0.15569	0.039875	0.242378E-01	0.997527
5	17.7932	0.56201E-01	-0.44720E-01	0.011454	0.199988E-02	0.997657
6	27.0858	0.36920E-01	0.31887E-01	0.008167	0.101678E-02	0.997724
7	44.6623	0.22390E-01	-0.34859E-02	0.000893	0.121516E-04	0.997725
8	56.4239	0.17723E-01	0.13117	0.033596	0.172053E-01	0.998849
9	57.8226	0.17294E-01	0.13274	0.033998	0.176192E-01	1.000000
10	62.6849	0.15953E-01	-0.16757E-02	0.000429	0.280808E-05	1.00000
SUM OF EFFECTIVE MASSES=					15.3066	

*** PROBLEM STATISTICS

ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 215

R.M.S. WAVEFRONT SIZE = 25.2

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 5.080

PERFORM AN EXPANSION PASS

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY. 3-D
 DEGREES OF FREEDOM. UX UY UZ ROTX ROTY ROTZ
 ANALYSIS TYPE MODAL
 EXTRACTION METHOD. SUBSPACE
 EXPANSION PASS ON
 NUMBER OF MODES TO EXPAND 10
 ELEMENT RESULTS CALCULATION OFF

LOAD STEP OPTIONS

LOAD STEP NUMBER. 1
 PRINT OUTPUT CONTROLS NO PRINTOUT
 DATABASE OUTPUT CONTROLS. ALL DATA WRITTEN

NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
 NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

Modal Analysis -- Spring Supports without Shot Mass

WHC-SD-W320-DA-006

Rev. 0

RESUME ANSYS DATA FROM FILE NAME=file.db

*** ANSYS GLOBAL STATUS ***

ANALYSIS TYPE = MODAL

NUMBER OF ELEMENT TYPES = 3

45 ELEMENTS CURRENTLY SELECTED. MAX ELEMENT NUMBER = 45

41 NODES CURRENTLY SELECTED. MAX NODE NUMBER = 41

MAXIMUM LINEAR PROPERTY NUMBER = 1

MAXIMUM REAL CONSTANT SET NUMBER = 7

ACTIVE COORDINATE SYSTEM = 0 (CARTESIAN)

MAXIMUM CONSTRAINT EQUATION NUMBER = 48

NUMBER OF SPECIFIED CONSTRAINTS = 7

NUMBER OF NODAL LOADS = 1

INITIAL JOBNAM = file

CURRENT JOBNAM = file

*** NOTE ***

CP= 1.270 TIME= 11:19:25

The element set contains elements that have only one structural degree of freedom per node. Viewing nodal displacements or forces in other than the nodal coordinate system may be invalid.

***** ANSYS ANALYSIS DEFINITION (PREP7) *****

ENTER /SHOW,DEVICE-NAME TO ENABLE GRAPHIC DISPLAY

ENTER FINISH TO LEAVE PREP7

PRINTOUT KEY SET TO /GOPR (USE /NOPR TO SUPPRESS)

REAL CONSTANT SET 8 ITEMS 1 TO 6
0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00

/OUTPUT FILE= ansuilst

MODIFY ELEMENT 43 (IF SELECTED) TO HAVE REAL = 8

ELEM MAT TYP REL ESYS NODES

43 1 2 3 0 41

PRODUCE ELEMENT PLOT IN DSYS = 0

***** ROUTINE COMPLETED ***** CP = 1.640

Modal Analysis -- Spring Supports without Shot Mass

***** ANSYS SOLUTION ROUTINE *****

PERFORM A MODAL ANALYSIS
THIS WILL BE A NEW ANALYSIS

USE SUBSPACE ITERATION METHOD
EXTRACT 10 MODES
NORMALIZE THE MODE SHAPES TO THE MASS MATRIX

PRINT BSI ITEMS WITH A FREQUENCY OF ALL
FOR ALL APPLICABLE ENTITIES

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.3-D
DEGREES OF FREEDOM. UX UY UZ ROTX ROTY ROTZ
ANALYSIS TYPEMODAL
EXTRACTION METHOD.SUBSPACE
NUMBER OF MODES TO EXTRACT. 10
NUMBER OF MODES TO EXPAND 10
ELEMENT RESULTS CALCULATIONOFF

*** NOTE *** CP= 1.800 TIME= 11:22:55
Real constant set 4 is not used by any element types that require real constants.

LOAD STEP OPTIONS

LOAD STEP NUMBER. 1
INERTIA LOADS X Y Z
ACEL 0.00000E+00 386.40 0.00000E+00
PRINT OUTPUT CONTROLS
ITEM FREQUENCY COMPONENT
BSI ALL
DATABASE OUTPUT CONTROLS.ALL DATA WRITTEN

Modal Analysis -- Spring Supports without Shot Mass

***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS = 9.3268

CENTROID	MOM. OF INERTIA ABOUT ORIGIN	MOM. OF INERTIA ABOUT CENTROID
XC = 47.000	IXX = 0.1244E+06	IXX = 0.1479E+05
YC = 100.05	IYY = 0.4602E+05	IYY = 9173.
ZC = 41.734	IZZ = 0.1224E+06	IZZ = 8455.
	IXY = -0.4386E+05	IXY = -0.1455E-10
	IYZ = -0.3907E+05	IYZ = -126.0
	IZX = -0.1829E+05	IZX = -0.1091E-10

*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE	MASS
1	5.93684
2	3.39000

Range of element maximum matrix coefficients in global coordinates
Maximum= 3.24208E+11 at element 39.
Minimum= 4920 at element 38.

*** ELEMENT MATRIX FORMULATION TIMES

TYPE	NUMBER	ENAME	TOTAL CP	AVE CP
1	38	BEAM4	0.080	0.002
2	3	MASS21	0.000	0.000
3	4	COMBIN14	0.010	0.002

Time at end of element matrix formulation CP= 1.94000006.

Estimated number of active DOF= 219.
Maximum wavefront= 37.

Time at end of matrix triangularization CP= 2.06999993.

SUBSPACE SIZE OF 14 VECTORS USED FOR CALCULATION OF FIRST 10 EIGENVECTORS.

MAXIMUM ITERATIONS	=	100
NUMBER OF EQUATIONS	=	219
MAXIMUM WAVEFRONT	=	37
ITERATIONS PER SHIFT	=	5
MAXIMUM MODES STORED	=	14
MAXIMUM EIGENVALUE	=	0.10000E+07
WORK SPACE (MBYTE)	=	0.18440

Equation solver maximum pivot= 8.113108276E+10 at node 40 ROTX.

Equation solver minimum pivot= 995.715619 at node 41 UZ.

Modal Analysis -- Spring Supports without Shot Mass

***** FREQUENCIES FROM SUBSPACE ITERATION *****

MODE FREQUENCY (HERTZ)

1	1.1223655
2	2.9718478
3	4.6182956
4	7.2540896
5	7.6520653
6	12.801205
7	15.425268
8	15.467253
9	18.566231
10	51.794314

***** PARTICIPATION FACTOR CALCULATION ***** X DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.12237	0.89098	-0.13627E-01	0.004654	0.185706E-03	0.210502E-04
2	2.97185	0.33649	2.3278	1.000000	8.57206	0.971683
3	4.61830	0.21653	0.81951E-01	0.027990	0.671589E-02	0.972444
4	7.25409	0.13785	0.17355E-02	0.000593	0.301210E-05	0.972445
5	7.65207	0.13068	-0.58409E-02	0.001995	0.341167E-04	0.972448
6	12.8012	0.78118E-01	-0.14359E-03	0.000049	0.206176E-07	0.972448
7	15.4253	0.64829E-01	0.92203E-01	0.031492	0.850146E-02	0.973412
8	15.4673	0.64653E-01	-0.42991	0.146838	0.184826	0.994363
9	18.5662	0.53861E-01	-0.49133E-03	0.000168	0.241401E-06	0.994363
10	51.7943	0.19307E-01	-0.22301	0.076170	0.497339E-01	1.00000
SUM OF EFFECTIVE MASSES=					8.82206	

***** PARTICIPATION FACTOR CALCULATION ***** Y DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.12237	0.89098	-0.51490E-02	0.001731	0.265124E-04	0.284260E-05
2	2.97185	0.33649	-0.69447E-02	0.002335	0.482285E-04	0.801356E-05
3	4.61830	0.21653	0.26563E-01	0.008930	0.705613E-03	0.836679E-04
4	7.25409	0.13785	2.9746	1.000000	8.34821	0.948769
5	7.65207	0.13068	-0.69022	0.232038	0.476400	0.999848
6	12.8012	0.78118E-01	-0.22836E-01	0.007677	0.521492E-03	0.999904
7	15.4253	0.64829E-01	0.20573E-01	0.006916	0.423268E-03	0.999949
8	15.4673	0.64653E-01	-0.23883E-02	0.000803	0.570393E-05	0.999950
9	18.5662	0.53861E-01	0.25233E-03	0.000085	0.636718E-07	0.999950
10	51.7943	0.19307E-01	-0.21629E-01	0.007271	0.467799E-03	1.00000
SUM OF EFFECTIVE MASSES=					9.32681	

Modal Analysis -- Spring Supports without Shot Mass

***** PARTICIPATION FACTOR CALCULATION ***** Z DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION
1	1.12237	0.89098	3.0146	1.000000	9.08761	0.983278
2	2.97185	0.33649	0.20995E-01	0.006965	0.440807E-03	0.983326
3	4.61830	0.21653	-0.22496	0.074625	0.506076E-01	0.988802
4	7.25409	0.13785	0.68131E-01	0.022600	0.464179E-02	0.989304
5	7.65207	0.13068	0.25986	0.086201	0.675267E-01	0.996610
6	12.8012	0.78118E-01	0.15240	0.050556	0.232267E-01	0.999123
7	15.4253	0.64829E-01	0.86745E-01	0.028775	0.752474E-02	0.999938
8	15.4673	0.64653E-01	0.19657E-01	0.006521	0.386406E-03	0.999979
9	18.5662	0.53861E-01	0.75146E-02	0.002493	0.564694E-04	0.999985
10	51.7943	0.19307E-01	-0.11596E-01	0.003847	0.134471E-03	1.00000
SUM OF EFFECTIVE MASSES=					9.24216	

*** PROBLEM STATISTICS

ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM = 219

R.M.S. WAVEFRONT SIZE = 25.2

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 3.620

***** ANSYS SOLUTION ROUTINE *****

PERFORM AN EXPANSION PASS

ERASE THE CURRENT PRINT OUTPUT CONTROL TABLE.

***** ANSYS SOLVE COMMAND *****

SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.3-D
 DEGREES OF FREEDOM. UX UY UZ ROTX ROTY ROTZ
 ANALYSIS TYPEMODAL
 EXTRACTION METHOD.SUBSPACE
 EXPANSION PASSON
 NUMBER OF MODES TO EXPAND10
 ELEMENT RESULTS CALCULATIONOFF

LOAD STEP OPTIONS

LOAD STEP NUMBER.1
 PRINT OUTPUT CONTROLSNO PRINTOUT
 DATABASE OUTPUT CONTROLS.ALL DATA WRITTEN
 0.078 MB WRITTEN ON RESULTS FILE: file.rst

FINISH SOLUTION PROCESSING

***** ROUTINE COMPLETED ***** CP = 4.020

NUMBER OF WARNING MESSAGES ENCOUNTERED= 0
 NUMBER OF ERROR MESSAGES ENCOUNTERED= 0

APPENDIX G

Computer Model Input Data (ANSYS)

/COM,ANSYS REVISION 5.0

A

11:20:52

09/20/1994

/NOPR

/TITLE, MODEL of the Shot Loading Trainer -- Fixed Supports

ANTYPE, 0

NUMOFF,NODE, 41

NUMOFF,ELEM, 45

NUMOFF,MAT, 1

NUMOFF,REAL, 8

NUMOFF,CEQN, 48

NUMOFF,TYPE, 3

NUMOFF,CSYS, 11

ET, 1, 4

ET, 2, 21

KEYOP, 2, 3, 2

ET, 3, 14

KEYOP, 3, 2, 2

DOF,UX,UY,UZ,ROTX,ROTY,ROTZ,

TYPE, 2

REAL, 7

R,RS.0, 1,LOC, 1, 2.75000000, 3.50000000, 3.50000000

R,RS.0, 1,LOC, 4, 3.00000000, 3.00000000,

R,RS.0, 3,LOC, 1, 4920.00000, ,

R,RS.0, 4,LOC, 1, 6.03000000, ,

R,RS.0, 5,LOC, 1, 60.3000000, 20263.0000, 20263.0000

R,RS.0, 5,LOC, 4, 52.0000000, 52.0000000, ,

R,RS.0, 6,LOC, 1, 2.04000000, ,

R,RS.0, 7,LOC, 1, 1.35000000, ,

R,RS.0, 3,LOC, 1, ,

LOCAL,RS.0,LOC, 11, 0, 0.00000000E+00, 0.00000000E+00, 81.0000000

LOCAL,RS.0,ANG, 11, 0, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00

LOCAL,RS.0,PRM, 11, 0, 1.00000000, 1.00000000

CSCIR, 11, 0, 0

CSYS, 0

N,RS.0,LOC, 1, 0.00000000E+00,

N,RS.0,LOC, 2, 1.50000000, 6.00000000, ,

N,RS.0,LOC, 3, 47.0000000, 6.00000000, ,

N,RS.0,LOC, 4, 94.0000000, ,

N,RS.0,LOC, 5, 92.5000000, 6.00000000, ,

N,RS.0,LOC, 6, 83.0000000, 42.0000000, ,

N,RS.0,LOC, 7, 11.0000000, 42.0000000, ,

N,RS.0,LOC, 8, 20.5000000, 78.0000000, ,

N,RS.0,LOC, 9, 73.5000000, 78.0000000, ,

N,RS.0,LOC, 10, 70.9062500, 87.0000000, ,

N,RS.0,LOC, 11, 23.0937500, 87.0000000, ,

N,RS.0,LOC, 12, 25.6875000, 96.0000000, ,

N,RS.0,LOC, 13, 47.0000000, 96.0000000, ,

N,RS.0,LOC, 14, 68.3125000, 96.0000000, ,

N,RS.0,LOC, 15, 0.00000000E+00, 0.00000000E+00, 81.0000000

N,RS.0,LOC, 16, 1.50000000, 6.00000000, 81.0000000

N,RS.0,LOC, 17, 47.0000000, 6.00000000, 81.0000000

N,RS.0,LOC, 18, 94.0000000, 0.00000000E+00, 81.0000000

N,RS.0,LOC, 19, 92.5000000, 6.00000000, 81.0000000

N,RS.0,LOC, 20, 83.0000000, 42.0000000, 81.0000000

N,RS.0,LOC, 21, 11.0000000, 42.0000000, 81.0000000

N,RS.0,LOC, 22, 20.5000000, 78.0000000, 81.0000000

N,RS.0,LOC, 23, 73.5000000, 78.0000000, 81.0000000

N,RS.0,LOC, 24, 70.9062500, 87.0000000, 81.0000000

N,RS.0,LOC, 25, 23.0937500, 87.0000000, 81.0000000

N,RS.0,LOC, 26, 25.6875000, 96.0000000, 81.0000000

N,RS.0,LOC, 27, 47.0000000, 96.0000000, 81.0000000

N,RS.0,LOC, 28, 68.3125000, 96.0000000, 81.0000000

N,RS.0,LOC, 29, 20.5000000, 78.0000000, 40.5000000

N,RS.0,LOC, 30, 73.5000000, 78.0000000, 40.5000000

N,RS.0,LOC, 35, 47.0000000, 111.0000000, 81.0000000

N,RS.0,LOC, 36, 47.0000000, 111.0000000, 65.0000000

N,RS.0,LOC, 37, 47.0000000, 111.0000000, 12.0000000

N,RS.0,LOC, 38, 47.0000000, 111.0000000, ,

N,RS.0,LOC, 39, 47.0000000, 111.0000000, 38.5000000

N,RS.0,LOC, 40, 47.0000000, 111.0000000, -7.5000000

N,RS.0,LOC, 41, 47.0000000, 111.0000000, 36.5000000

EN,RS.0,ATTR, 2, 1, 1, 1, 1, 0

EN,RS.0,NODE, 1, 2, , , , ,

EN,RS.0,ATTR, 2, 1, 1, 1, 2, 0

EN,RS.0,NODE, 2, 3, , , , ,

EN,RS.0,ATTR, 2, 1, 1, 1, 3, 0

EN,RS.0,NODE, 3, 5, , , , ,

EN,RS.0,ATTR, 2, 1, 1, 1, 4, 0

EN,RS.0,NODE, 5, 4, , , , ,

FIXED-SUPPORT MODELUSED FOR STATIC-EQUIVALENT ANALYSIS OF
VIBRATOR OPERATING LOADS

EN,R5.0,ATTR,	2,	1,	1,	1,	5,	0
EN,R5.0,NODE,	5,	6,				
EN,R5.0,ATTR,	2,	1,	1,	1,	6,	0
EN,R5.0,NODE,	6,	9,				
EN,R5.0,ATTR,	2,	1,	1,	1,	7,	0
EN,R5.0,NODE,	2,	7,				
EN,R5.0,ATTR,	2,	1,	1,	1,	8,	0
EN,R5.0,NODE,	7,	8,				
EN,R5.0,ATTR,	2,	1,	1,	1,	9,	0
EN,R5.0,NODE,	9,	10,				
EN,R5.0,ATTR,	2,	1,	1,	1,	10,	0
EN,R5.0,NODE,	10,	14,				
EN,R5.0,ATTR,	2,	1,	1,	1,	11,	0
EN,R5.0,NODE,	8,	11,				
EN,R5.0,ATTR,	2,	1,	1,	1,	12,	0
EN,R5.0,NODE,	11,	12,				
EN,R5.0,ATTR,	2,	1,	1,	1,	13,	0
EN,R5.0,NODE,	12,	13,				
EN,R5.0,ATTR,	2,	1,	1,	1,	14,	0
EN,R5.0,NODE,	13,	14,				
EN,R5.0,ATTR,	2,	1,	1,	1,	15,	0
EN,R5.0,NODE,	15,	16,				
EN,R5.0,ATTR,	2,	1,	1,	1,	16,	0
EN,R5.0,NODE,	16,	17,				
EN,R5.0,ATTR,	2,	1,	1,	1,	17,	0
EN,R5.0,NODE,	17,	19,				
EN,R5.0,ATTR,	2,	1,	1,	1,	18,	0
EN,R5.0,NODE,	19,	18,				
EN,R5.0,ATTR,	2,	1,	1,	1,	19,	0
EN,R5.0,NODE,	19,	20,				
EN,R5.0,ATTR,	2,	1,	1,	1,	20,	0
EN,R5.0,NODE,	20,	23,				
EN,R5.0,ATTR,	2,	1,	1,	1,	21,	0
EN,R5.0,NODE,	16,	21,				
EN,R5.0,ATTR,	2,	1,	1,	1,	22,	0
EN,R5.0,NODE,	21,	22,				
EN,R5.0,ATTR,	2,	1,	1,	1,	23,	0
EN,R5.0,NODE,	23,	24,				
EN,R5.0,ATTR,	2,	1,	1,	1,	24,	0
EN,R5.0,NODE,	24,	28,				
EN,R5.0,ATTR,	2,	1,	1,	1,	25,	0
EN,R5.0,NODE,	22,	25,				
EN,R5.0,ATTR,	2,	1,	1,	1,	26,	0
EN,R5.0,NODE,	25,	26,				
EN,R5.0,ATTR,	2,	1,	1,	1,	27,	0
EN,R5.0,NODE,	26,	27,				
EN,R5.0,ATTR,	2,	1,	1,	1,	28,	0
EN,R5.0,NODE,	27,	28,				
EN,R5.0,ATTR,	2,	1,	1,	1,	29,	0
EN,R5.0,NODE,	8,	29,				
EN,R5.0,ATTR,	2,	1,	1,	1,	30,	0
EN,R5.0,NODE,	29,	22,				
EN,R5.0,ATTR,	2,	1,	1,	1,	31,	0
EN,R5.0,NODE,	9,	30,				
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MPDATA,R5.0, 1, DENS, 1, 1, 7.320000000E-04,						

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KUSE, 0
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TREF, 0.000000000E+00
ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DMPRAT, 0.000000000E+00
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CRPLIM, 0.100000000
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NEQIT, 25
PRED,OFF,,OFF
ERESX,DEFA
OUTPR,BASI, ALL,
ACEL, 0.000000000E+00, 386.400000 , 0.000000000E
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model.fix

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WHC-SD-W320-DA-006.
Rev. 0

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DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOME, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
IRLF, 0
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D, 1,UY , 0.000000000E+00, 0.000000000E+00
D, 4,UY , 0.000000000E+00, 0.000000000E+00
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D, 15,UZ , 0.000000000E+00, 0.000000000E+00
D, 18,UY , 0.000000000E+00, 0.000000000E+00
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/COM,ANSYS REVISION 5.0

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09/20/1994

/NOPR

/TITLE,

MODEL OF THE SHOT LOADING TRAINER -- SPRING SUPPORTS

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NUMOFF,ELEM, 45

NUMOFF,MAT, 1

NUMOFF,REAL, 8

NUMOFF,CEQN, 48

NUMOFF,TYPE, 3

NUMOFF,CSYS, 11

ET, 1, 4

ET, 2, 21

KEYOP, 2, 3, 2

ET, 3, 14

KEYOP, 3, 2, 2

DOF,UX,UY,UZ,ROTX,ROTY,ROTZ,

TYPE, 2

REAL, 7

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R,RS.0, 3,LOC, 1, 4920.00000,

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R,RS.0, 5,LOC, 1, 60.8000000, 20263.0000, 20263.0000

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R,RS.0, 6,LOC, 1, 2.04000000,

R,RS.0, 7,LOC, 1, 1.35000000,

R,RS.0, 8,LOC, 1,

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LOCAL,RS.0,ANG, 11, 0, 0.00000000E+00, 0.00000000E+00, 0.00000000E+00

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CSCIR, 11, 0, 0

CSYS, 0

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N,RS.0,LOC, 34, 94.0000000, 0.00000000E+00, 81.0000000

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EN,RS.0,NODE,	5,	4,				
EN,RS.0,ATTR,	2,	1,	1,	1,	5,	0
EN,RS.0,NODE,	5,	6,				
EN,RS.0,ATTR,	2,	1,	1,	1,	6,	0
EN,RS.0,NODE,	6,	9,				
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EN,RS.0,NODE,	2,	7,				
EN,RS.0,ATTR,	2,	1,	1,	1,	8,	0
EN,RS.0,NODE,	7,	8,				
EN,RS.0,ATTR,	2,	1,	1,	1,	9,	0
EN,RS.0,NODE,	9,	10,				
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EN,RS.0,NODE,	36,	41,				

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NSUBST, 1
KBC, 0
KUSE, 0
TIME, 0.000000000E+00
TREF, 0.000000000E+00
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Model.spr
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ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DPRAD, 0.000000000E+00
TIMINT, OFF, STRD
CAPLIN, 0.100000000
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NCNT, 0
NEQIT, 15
PRAD, OFF, OFF
EMEX, DATA
OUTR, BASI, ALL, 186.100000, 0.000000000E+00
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OMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
COLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
INTE, 0
D, 1, UX, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 15, UX, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 15, UZ, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 31, UY, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 32, UY, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 33, UY, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
D, 34, UY, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
Z, 36, FX, 1533.33333, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
/GOFB

APPENDIX H

Structural Evaluation Wind, Seismic, and Deadweight Loads

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing 4-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 5/24/94
(9) Checker Randy Jansen Date 12/5/94

(10)

Component Weight

$$\text{pipe} = (8\text{ft}) \left[(52\text{in})^2 - (51\frac{1}{4}\text{in})^2 \right] \frac{\pi}{4} \left(\frac{1.42}{144\text{in}^2} \right) \left(\frac{490\text{lb}}{\text{ft}^3} \right) = 1655.6\text{lbs}$$

$$\text{stiffener ring} = \left[(58.5\text{in} \times 29.5\text{in}) + (29.25\text{in})^2 \frac{\pi}{2} - \left(\frac{52\text{in}}{2} \right)^2 \pi \left(\frac{1\text{in}}{12\text{in}} \right) \left(\frac{1.42}{144\text{in}^2} \right) \left(\frac{490\text{lb}}{\text{ft}^3} \right) \right]$$

$$= 268.2\text{lbs/each}$$

$$3\text{ stiffener rings} = 3(268.2\text{lbs}) = 804.7\text{lbs}$$

$$4\text{ half couplings} \approx 8\text{lbs}$$

$$\frac{3}{16}\text{'' annulus plates} = (7\text{in} + 48\text{in}) \left[(55\frac{3}{8}\text{in})^2 - (55\text{in})^2 \right] \frac{\pi}{4} \left(\frac{490\text{lb}}{\text{ft}^3} \right) \left(\frac{12\text{in}}{144\text{in}^2} \right) = 507\text{lbs}$$

$$\frac{1}{2}\text{'' plates} = 4 \left(\frac{1}{2}\text{in} \times 8\text{in} \times 8\text{in} \right) (.284\text{lb/in}^3) = 36.4\text{lbs}$$

$$\text{TS } 3\text{X}3\text{X}\frac{1}{4} = \left[(99.4\text{in} \times 4) + (42.625\text{in} \times 2) + (92\text{in} \times 2) + (77\text{in} \times 2) \right] \left(\frac{15}{12\text{in}} \right) \left(\frac{8.81\text{lb}}{\text{ft}^3} \right)$$

$$= 602.6\text{lbs}$$

$$\text{base plates} = 4(1\text{in} \times 18\text{in} \times 18\text{in} \times .284) = 368.1\text{lbs}$$

$$\text{empty wt} = \underline{3982.4\text{lbs}}$$

Shot wt

use 450 lb/ft³ steel shot wt solid steel = 490 lb/ft³ Ref AISC 9th Ed p. 6-8
steel shot is not as compact as solid steel

$$A = ((55\text{in})^2 - (52\text{in})^2) \frac{\pi}{4} = 252.1\text{in}^2 \text{ annulus cross section area}$$

$$4\text{ft annulus} = (48\text{in}) \left(252.1\text{in}^2 \right) \left(\frac{450\text{lb/ft}^3}{(12\text{in}) \left(\frac{144\text{in}^2}{\text{ft}^2} \right)} \right) = 3151.4\text{lbs}$$

$$7\text{in annulus} = (7\text{in}) (252.1\text{in}^2) \left(\frac{450\text{lb/ft}^3}{(12\text{in}) \left(\frac{144\text{in}^2}{\text{ft}^2} \right)} \right) = 459.6\text{lbs}$$

$$\text{full wt} = 3982.4\text{lbs} + 3151.4\text{lbs} + 459.6\text{lbs} = \underline{7593.4\text{lbs}}$$

$$\text{assume full wt.} = 7600\text{lbs}$$

$$\text{assume empty wt.} = 4000\text{lbs}$$

DESIGN CALCULATION

WHC-SD-W320-DA-Q06

Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Shirley Peterson Date 6/7/94
 (9) Checker Randy Jensen Date 12/5/94

(10)

The height requirement for the shot loading trainer is based on a requirement that the top of the trainer be at the same height as the container on the hydraulic trailer.

From AMRO measurement - 81'4" from ground to strong back base pin

From Strongback drawings - 36.275" from base pin to ϕ of strongback to container attachment bolt
 H-2-83717

From 44' Container drawings - 22'5 1/2" from container attachment bolt to top of container stiffener ring
 H-2-83724

Total height from ground to top of container stiffener ring is 11'-8 1/2"

DESIGN CALCULATION

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Theresa Peterson Date 7/1/94
 (9) Checker Randy Jounian Date 12/5/94

(10) Footprint Soil Bearing

Fully loaded wt = 7600 lbs

4 plates 1" x 18" x 18" for feet

$$A_f = (1.5\text{ ft} \times 1.5\text{ ft}) = 2.25\text{ ft}^2 \quad (\text{area of each foot})$$

$$F = \frac{7600\text{ lbs}}{4(2.25\text{ ft}^2)} = 844\text{ lb/ft}^2$$

$$F_a = 1500\text{ psf} > 844\text{ psf} \quad \text{UBC 1991 p. 590 Table 29.8 \#4}$$

Soil bearing load ok

DESIGN CALCULATION

WHC-SD-W320-DA-006

Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Therese Peterson Date 5/24/94
 (9) Checker Randy Harris Date 11/23/94

(10)

Wind Loading

using ASCE 7-88
 from Table 4 p.10.

Other structures

$$F = q_z G_h C_p A_f$$

$$q_z = 0.00256 K_z (1V)^2 \quad (Eq. 3 p.11)$$

$$V = 70 \text{ mph}$$

$$I = 1.07 \quad (\text{from Table 5 p. 11}) \quad \text{and (SDC 4.1 Rev 12 Safety Class 3)}$$

$$K_z = 0.80 \quad (\text{from Table 6 p. 12 Exposure C @ 0-15ft})$$

$$q_z = 0.00256 (0.80) (1.07 (70))^2 = 11.489$$

$$G_h = 1.32 \quad (\text{from Table 8 p. 15 Exposure C @ 0-15 ft})$$

$$C_p = 0.53 \quad (\text{from Table 12 p. 24 Round } h/D = 2.74)$$

$$A_f = \left(\frac{59 \text{ in}}{12 \text{ in/ft}} \right) (8 \text{ ft}) = 39.3 \text{ ft}^2$$

$$F = (11.489) (1.32) (0.53) (39.3 \text{ ft}^2)$$

$$F = 315.88 \text{ lbs}$$

Overturning on empty trainer

$$F_1 = \frac{(4000 \text{ lbs})(47 \text{ in}) - (315.88 \text{ lbs})(132.25 \text{ in})(1.5)}{94 \text{ in}}$$

$$F_1 = 1333.38 \text{ lbs} \uparrow$$

$$F_2 = \frac{(4000 \text{ lbs})(47 \text{ in}) + (315.88 \text{ lbs})(132.25 \text{ in})(1.5)}{94 \text{ in}}$$

$$F_2 = 2666.62 \text{ lbs} \uparrow$$

OK for overturning with safety factor of 1.5

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 5/24/94
(9) Checker Barry J. J. J. Date 11/23/94

(10) Wind Loading

using ASCE 7-88
from Table 4 p. 10
Other Structures

$$F = q_z G_h C_f A_f$$

$$q_z = 0.00256 K_z (V)^2 \quad (\text{Eq. 3 p. 11})$$

$$V = 70 \text{ mph}$$

$$I = 1.07 \quad (\text{from Table 5 p. 11}) \text{ and } (\text{SDC 4.1 Rev. 12 Safety Class 3})$$

$$K_z = 0.80 \quad (\text{from Table 6 p. 12 Exposure C @ 0-15 ft})$$

$$q_z = 11.489$$

$$G_h = 1.32 \quad (\text{from Table 8 p. 15 Exposure C @ 0-15 ft})$$

$$C_f = 1.329 \quad (\text{from Table 12 p. 21 Square (wind normal) } h/p = 2.74)$$

$$A_f = \left(\frac{59 \text{ in}}{2}\right)^2 \frac{\pi}{4} = 18.99 \text{ ft}^2$$

$$F = (11.489)(1.32)(1.329)(18.99 \text{ ft}^2)$$

$$F = 382.7 \text{ lbs} \quad (\text{assuming ends are covered})$$

conservative

for overturning on empty trainer

$$\sum M = 0 \quad \text{around } R_2$$

$$R_1(81 \text{ in}) + (382.7 \text{ lbs})(132.25 \text{ in})(1.5) - (4000 \text{ lbs})(40.5 \text{ in}) = 0$$

$$R_1 = 1062.7 \text{ lbs} \uparrow$$

$$R_2 = 4000 \text{ lbs} - 1062.7 \text{ lbs} = 2937.3 \text{ lbs} \uparrow$$

OK for overturning with 1.5 safety factor

DESIGN CALCULATION

WHC-SD-W320-DA-006

Rev. 0

(1) Drawing H-2-33742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Theresa S Peterson Date 7/1/94
 (9) Checker Randy J. J. J. Date 11/23/94

(10)

Lifting Lugs

use 2 point pick

use 8 1/2 Ton shackles

Consider fully loaded wt = 7600 lbs

pin size = 1 1/8"

hole size = 1 3/16"

$$R = (1 \frac{3}{16} \text{ in}) 1.5 = 1.78 \text{ in}$$

use $R = 1 \frac{7}{8}"$ min

use 1" plate

$$\text{Allowable } P = \frac{1.67 F_t e^2}{d}$$

$$P = \frac{1.67 (\frac{36 \text{ ksi}}{2}) (1 \text{ in}) (1.875 \text{ in} - 1.1875 \text{ in})^2}{1.1875 \text{ in}}$$

$$P = 7.97 \text{ kips} > 7.6 \text{ kips over 2 lugs}$$

OK for tensile tearing

check weld for fully loaded trainer

$$S_w = \frac{d^2}{3} = \frac{(4 \text{ in})^2}{3} = 5.33 \text{ in}^2$$

$$M = \left(\frac{7600 \text{ lbs}}{2} \right) (2 \text{ in}) = 7600 \text{ lbs-in}$$

$$f_1 = \frac{M}{S_w} = \frac{7600 \text{ lbs-in}}{5.33 \text{ in}^2} = 1425 \text{ lb/in}$$

$$A_w = 2(4 \text{ in}) = 8 \text{ in}$$

$$P = \frac{7600 \text{ lbs}}{2} = 3800 \text{ lbs}$$

$$f_2 = \frac{P}{A_w} = \frac{3800 \text{ lbs}}{8 \text{ in}} = 475 \text{ lb/in}$$

$$f_w = f_1 + f_2 = 1425 \text{ lb/in} + 475 \text{ lb/in} = 1900 \text{ lb/in} = 1.9 \text{ kip/in}$$

$$\text{weld min} = \frac{1.9 \text{ kip/in}}{7.2 \text{ ksi}} = 0.264 \text{ in} < \frac{1}{2} \text{ in weld}$$

weld ok

Ref. AISC Engineering Journal
 Fourth Quarter 1991
 Design + construction of Lifting Beams.
 p 152, 157 (welds)

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 5/24/94
(9) Checker Gandy Johnson Date 11/23/94

(10) Seismic Loading

Using SDC 4.1 Rev 12 for safety class 3

$$Z = 0.12 \quad \text{SDC 4.1 p. 15}$$

$$I = 1.25 \quad \text{SDC 4.1 p. 15}$$

$$V = \frac{ZICW}{R_w} \quad \text{Ref. UBC-1991 Eq. 34-1 p. 162}$$

$$C = 2.75 \quad \text{Ref. UBC-1991 p. 162}$$

$$W = 7600 \text{ lbs} \quad \text{see weight calculations}$$

$$R_w = 3 \quad \text{Ref. UBC-91 Table 23-Q p. 192}$$

$$V = \frac{(0.12)(1.25)(2.75)(7600 \text{ lbs})}{3}$$

$$V = 1045 \text{ lbs}$$

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 5/24/94
(9) Checker Randy Jounin Date 11/23/94

(10) Buckling

Front base bracing TS 3X3X1/4
unbraced length approx. $L = 92$ in.

$r = 1.10$ in ref. AISC 9th ed p. 3-43

$K = 1$

$$\frac{KL}{r} = \frac{(1)(92 \text{ in})}{1.10 \text{ in}} = 83.6$$

$F_a = 14.9$ ksi ref. AISC 9th ed p. 3-16

$A = 2.59$ in² ref. AISC 9th ed p. 3-43

$F = 1045$ lbs due to lateral seismic forces

$$P = \frac{F}{A} = \frac{1045 \text{ lbs}}{2.59 \text{ in}^2} = 403.5 \text{ psi} < 14.9 \text{ ksi}$$

front base bracing ok for buckling from compressive forces due to seismic forces

DESIGN CALCULATION

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Theresa Peterson Date 5/24/94
 (9) Checker Randy Johnson Date 12/4/94

(10) Buckling

Side bracing - TS 3x3x1/4
 unbraced length approx. $L = 77$ in.
 $r = 1.10$ in ref. AISC 9th ed p 3-43

$K = 1$

$\frac{KL}{r} = \frac{(1)(77 \text{ in})}{1.10 \text{ in}} = 70$

$F_c = 16.43$ ksi ref. AISC 9th ed p 3-16

$A = 2.59$ in² ref. AISC 9th ed p 3-43

$F = 1045$ lbs due to lateral seismic forces

$P = \frac{F}{A} = \frac{1045 \text{ lbs}}{2.59 \text{ in}^2} = 403.5 \text{ psi} < 16.43 \text{ ksi}$

Side bracing ok for buckling from compressive forces due to seismic forces

DESIGN CALCULATION

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Therapy Division Date 5/24/94
 (9) Checker Barry J. J. J. Date 12/4/94

(10) Buckling

4 legs - TS 3x3x1/4

unbraced length of legs approx. $L = 76.4$ in

$r = 1.10$ in

ref. AISC 9th ed p. 3-43

$K = 0.5$

$$\frac{KL}{r} = \frac{(0.5)(76.4 \text{ in})}{1.10 \text{ in}} = 34.7$$

$F_a = 19.65$ ksi

ref. AISC 9th ed p. 3-16

$A = 2.59$ in²

ref. AISC 9th ed p. 3-43

$W_t = 7600$ lbs

full weight of trainer

$$W = \frac{7600 \text{ lbs}}{4} = 1900 \text{ lb}$$

weight per leg

$$P = \frac{W}{A}$$

$$P = \frac{1900 \text{ lb}}{2.59 \text{ in}^2} = 733.6 \text{ psi} < 19.65 \text{ ksi}$$

4 legs ok for buckling

DESIGN CALCULATION

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Theresa Peterson Date 11/22/94
 (9) Checker Randy Johnson Date 12/6/94

(10) Shot Loading Vibrators

The shot loading vibrators on the shot Loading Trainer (SLT) are Global C3-6A-4AC pneumatic vibrators.

Wt = 44 lbs each (2 used on shot Loading Trainer)

Vibrators are connected to the SLT by (2) $\frac{3}{4}$ "-10UNC-2A X $3\frac{1}{2}$ " Grade 8 heavy hex bolts 8 inches apart per manufacturer's recommendation

weld

$$F_y = 44 \text{ lbs}$$

$$A_w = 2(12 \text{ in}) + 2(12 \text{ in}) = 48 \text{ in}$$

$$F_w = \frac{44 \text{ lbs}}{48 \text{ in}} = .92 \text{ lbs/in} = 9.2 \times 10^{-4} \text{ kip/in}$$

$$\text{min weld} = \frac{9.2 \times 10^{-4} \text{ kip/in}}{7.2 \text{ ksi}} = 1.27 \times 10^{-4} \text{ in}$$

weld is ok

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 11/28/94
(9) Checker David J. Jamin Date 12/6/94

(10)

Shot Unloading Hatch Door

Because the two hatch doors are of identical design, only the size is different, the larger hatch door will see higher stresses. Therefore only the large hatch door will be analyzed.

use 450 lbs/ft³ of steel shot for density

$$\text{Volume of shot acting on door} = (18\text{ in} \times 6\text{ in} \times 3\frac{1}{2}\text{ in}) + 2(22\text{ in} \times 2\text{ in} \times 1\frac{1}{2}\text{ in}) + 2(6\text{ in} \times 2\text{ in} \times 1\frac{1}{2}\text{ in})$$

$$= 566.25\text{ in}^3$$

$$\text{Wt of shot on door} = \frac{566.25\text{ in}^3}{\left(\frac{12\text{ in}}{24} \times \frac{144\text{ in}^2}{4\text{ ft}^2}\right)} (450\text{ lb/ft}^3) = 147.5\text{ lbs}$$

pin holding door closed = $\frac{5}{8}$ " ϕ Bar x $4\frac{1}{2}$ " Long
 $\frac{1}{2}$ " of pin rests on door in closed position

$$\text{Stress on pin} = \frac{147.5\text{ lbs}}{\left(\frac{.625\text{ in}}{2}\right)^2 \pi} = 480.8\text{ psi}$$

pin ok

Welds

$$A_w = (19\text{ in} + 7\text{ in})2 = 52\text{ in}$$

$$F_w = \frac{147.5\text{ lbs}}{52\text{ in}} = 2.84\text{ lbs/in}$$

$$\text{min weld} = \frac{2.84\text{ lb/in}}{7.2\text{ ksi}} = 3.94 \times 10^{-4}\text{ in}$$

$\frac{1}{8}$ fillet weld ok

(MIN. WELD IS $\frac{3}{16}$ " FOR $\frac{3}{8}$ " PL - AISC TABLE J2.4 - THIS WELD NOT STRUCTURAL O.K.)

DESIGN CALCULATION

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Shot Loading Trainer
 (8) Originator Theresa Peterson Date 11/30/94
 (9) Checker Randy Gossier Date 12/6/94

(10) Wheels

The shot loading trainer is mounted on four sets of wheels.

Two legs of the trainer are mounted on "Rol-Quick," 18x5.7-8, rigid, dual wheel casters, McMaster-Carr 94 No. 2788T58.

The other two legs are mounted on "Rol-Quick," 18x5.7-8, swivel, dual wheel casters, McMaster-Carr 94 No. 2788T18.

The wheels are bolted to each leg with (4) 1/2" diameter ASTM A325 bolts.

AISC Table 1-D p 4-5 1/2" bolts are not listed.
 shear allowable = $A(F_u) = \pi(.25in)^2(21ksi) = 4.1 \text{ kip/bolt}$

Because there are 4 bolts per wheel, they are capable of 16.493 lbs of force in shear. This is greater than the weight on each leg when fully loaded.

The bolts are ok by inspection

DESIGN CALCULATION

WHC-SD-W320-DA-006
Rev. 0

(1) Drawing H-2-83742 (2) Doc. No. _____ (3) Page _____ of _____
(4) Building _____ (5) Rev. _____ (6) Job No. _____
(7) Subject Shot Loading Trainer
(8) Originator Theresa Peterson Date 11/28/94
(9) Checker Bandy Jowen Date 12/6/94

(10) Eccentric Loading on Legs due to off center wheels
using formulas for interaction from AISC 9th ed p 3-9, 3-10

when $f_a/F_a \leq 0.15$ Eq. H1-3 may be used

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$$

using fully loaded trainer

wt = 7600 lbs over 4 legs

$$A = 2.59 \text{ in}^2$$

Ref. AISC 9th ed p. 1-96

$$f_a = \frac{(7600 \text{ lbs}/4)}{2.59 \text{ in}^2} = 733.6 \text{ psi}$$

$$\frac{KL}{r} = \frac{2(.96 \text{ in})}{1.10 \text{ in}} = 174.5$$

$$F_a = 14.9 \text{ ksi}$$

Ref. AISC 9th ed p 3-16

$$\frac{f_a}{F_a} = \frac{.7336 \text{ ksi}}{14.9 \text{ ksi}} = 0.15 \leq 0.15 \therefore \text{Eq. H1-3 may be used}$$

$$f_b = \frac{M}{S} = \frac{(7600 \text{ lbs}/4)(6 \text{ in})}{2.10} = 5428.6 \text{ psi}$$

$$F_b = 0.6 F_y$$

$$F_b = 0.6(46 \text{ ksi}) = 27.6 \text{ ksi}$$

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} = 0.15 + \frac{5.4286 \text{ ksi}}{27.6 \text{ ksi}} = 0.35 \leq 1.0$$

$\therefore$ OK in combined axial and bending loading

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject LIFTING/MOVING SLT

Originator CALCS FOR INDEPENDENT REVIEW

Date 1/25/95

Checker R. L. JORISSEN

Date _____

LIFTING SLT

LIFTING SLT BY LUGS WELDED TO TOP OF SLT -

- USE 2-POINT PICK, $8\frac{1}{2}$ -TON SHACKLES ($1\frac{1}{8}$ " PIN DIA.)
(PER CALCS IN APP. H).

MOVING SLT ON WHEELS

W = 4000 LB EMPTY, 7600 LB. FULL

COEFF. OF FRICTION -

SLT ROLLED ON CONC. OR GRAVEL SURFACES ONLY

$\mu = .042$ CONC. ("MARK'S MECH. ENGRS. HANDBOOK"

6th ED. -
Pg 3-45, TABLE 2
 $\mu = .042$ PEAK VALUE)

PEAK $\mu_{\text{LOOSE SAND}} = .46$

ASSUME $\mu_{\text{GRAVEL}} = 0.20$

ANALYTICAL CALCULATIONS

Page ____ of ____

Subject LIFTING / MOVING SLT

Originator CALC FOR INDEPENDENT REVIEW

Date 1/25/95

Checker R.L. JORISSEN

Date _____

LEG BENDING -

$$M = 200 (111.25") = 22,250 \text{ in.-lb.}$$

→ TO & AXLE

$$f_b = \frac{22,250}{2.10} = 10,595 \text{ psi} \quad \text{OK}$$

$$F_b = 0.60 F_y = .60 (42) = 25,200 \text{ psi}$$

→ AISC - 9th ED. EOW F2-2

CROSS-MEMBER BENDING

$$P = 4 (200 \text{ lb/WHEEL}) = 800 \text{ lb.}$$

$$M = \frac{PL}{4} = \frac{800 (94")}{4}$$

$$= 18,800 \text{ in.-lb.}$$

$$f_b = \frac{18,800}{2.10} = 8950 \text{ psi} \quad \text{OK}$$

$$F_b = 25,200 \text{ psi}$$

ATTACH CHAIN OR CABLE TO TUBE STEEL CROSS-MEMBER FOR PULLING.