STRUCTURAL/DYNAMICS ANALYSIS REPORT

APOLLO 14 LRRR

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J.M. Brueger

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ABSTRACT

The attached structural analysis is divided into three sections. Section I presents the component level stress analysis. This analysis is based on an assumed limit loading of 20g's in any direction. Section II is the dynamics analysis of the structure designed on the basis of the 20g limit load assumption. Section II shows that in general, limit loads are below those assumed in Section I, but that exceptional forces do occur in some locations. Section III is a computer analysis of the redundant grid structure based on the load patterns derived in Section II.

STRUCTURAL/DYNAMICS ANALYSIS REPORT - LRRR

SECTION 1

COMPONENT STRESS ANALYSIS

SECTION 1

1.0 INTRODUCTION

This section of the report consists of the stress analysis performed to substantiate that the LRRR structural frame, fittings, etc. are structurally satisfactory based on load factors, weights and C. G.'s developed from Ref. (1), and for handling loads from Ref. (2).

The weight of the total package used for analysis is 42 lbs. rather than 48 lbs as given in Ref. (1). Preliminary studies showed this to be a feasible value and final package weight is expected to be close to this value.

Throughout the analysis a factor of safety of 1.5 has been used on limit to obtain ultimate loads.

Margins of safety, in general, are high. Items not shown have been investigated and can be shown to have high safety margins using conservative load assumptions.

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REFERENCES

(1) Exhibit B-1 Design and Performance Specification for the Laser Ranging Retro-Reflector Experiment (Revised March 30, 1970)

(2) Letter No. 9783-951-009 Bendix Internal Memorandum, Force Emission Capability of the Suited Astronaut

(3) LID 360-22811 GAEC Interface Drawing

(4) Bendix Drawing 2342000 - ICD Retroflector Array - Support Structure

(5) ADP-LR^3 Array Flight Model-R7028 Rev. E Sect. 2.0 Equipment Log - A. D. Little Co.

(6) Bendix Dwg. 2345727 LRRR Structure Assembly

(7) Roark, R. J., "Formulas for Stress and Strain" McGraw-Hill Book Co. Inc., 1943

(8) MIL-HDBK-5A "Metallic Materials and Elements for Aerospace Vehicle Structures" Dept. of Defense, Washington 25, D. C.

(9) A. S. Niles and J. S. Newell, "Airplane Structures", John Wiley and Sons, Inc.

(10) E. F. Bruhn, "Analysis and Design of Flight Vehicle Structures", Tri-State Offset Company, Cincinnati.

2.0 INTERFACE POINT LOADS

The following pages give the point loads at the LM-LR^3 interface points based on information from References 1, 3 and 6 and for 20 G's limit load acting independently along each major axis.

Reaction points have been chosen based on a study of attachment details.

For loadings along the X-X (Page 1-6) axis loads were assumed reacted at all four support points with magnitudes assumed inversely proportional to the distance from the package C. G.

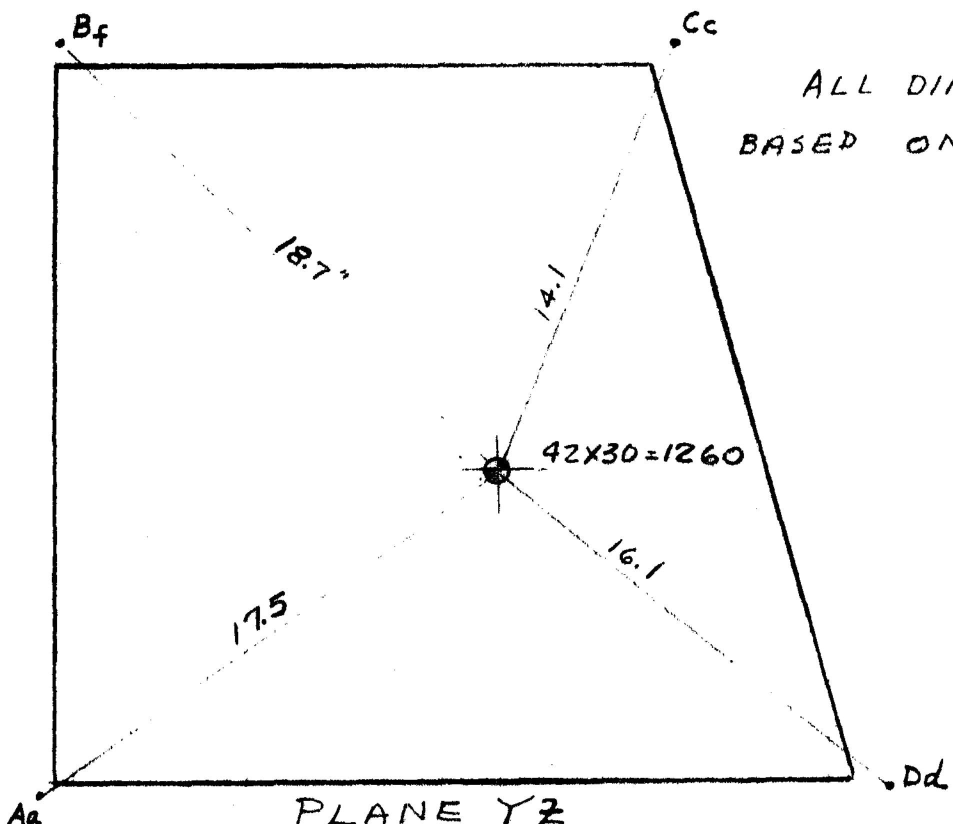
Loadings along the Y-Y axis (Page 1-7) can be reacted at both fore and aft points. However, the load paths to the aft points are much more flexible than to the forward points. In addition, the aft pins are loose and the amount of engagement is subject to variation with tolerances. It has, therefore, been assumed that all side load (along Y-Y) axis has been reacted at either forward point Aa or Dd. Forward mounting pins are also loose to facilitate deployment and it is not reasonable to assume a more equitable distribution.

The aft pins are free to slide and cannot be relied upon to resist loads along the Z-Z axis. This is also true of forward pins at Aa and Dd in this direction. Therefore loads along the Z-Z axis (Page __) are assumed reacted at Ab and De. These points elongated slots with pins that can only react fore and aft loads. The astronaut removes these pins at deployment.

FINAL ANALYSIS ~ LRRR STRUCTURE

LM INTERFACE POINT LOADS

COND. n_x = 20G. LIM. (REF. 1) EXP'M'T + STRUCT WT = 42# (SEE PG. 1-2)
30G. ULT. (SEE PG. 1-2) $n_x W = 30 \times 42 = 1260$#



ALL DIMENSIONS BASED ON REF (3)

PLANE YZ
(X-X AXIS NORMAL TO PLANE OF PAPER)

$$X_{Aa} = \frac{\frac{1}{17.5}}{\frac{1}{17.5}+\frac{1}{18.7}+\frac{1}{14.1}+\frac{1}{16.1}}(1260) = \frac{.057(1260)}{.057+.0535+.0708+.0621} = \frac{.057}{.2434}(1260) = 295\#$$

$$X_{Bf} = \frac{\frac{1}{18.7}}{.2434}(1260) = \frac{.0535}{.2434}(1260) = 277\#$$

$$X_{Dd} = \frac{\frac{1}{16.1}}{.2434}(1260) = \frac{.062}{.2434}(1260) = 321\#$$

$$X_{Cc} = \frac{\frac{1}{14.1}}{.2434}(1260) = \frac{.0708}{.2434}(1260) = 367\#$$

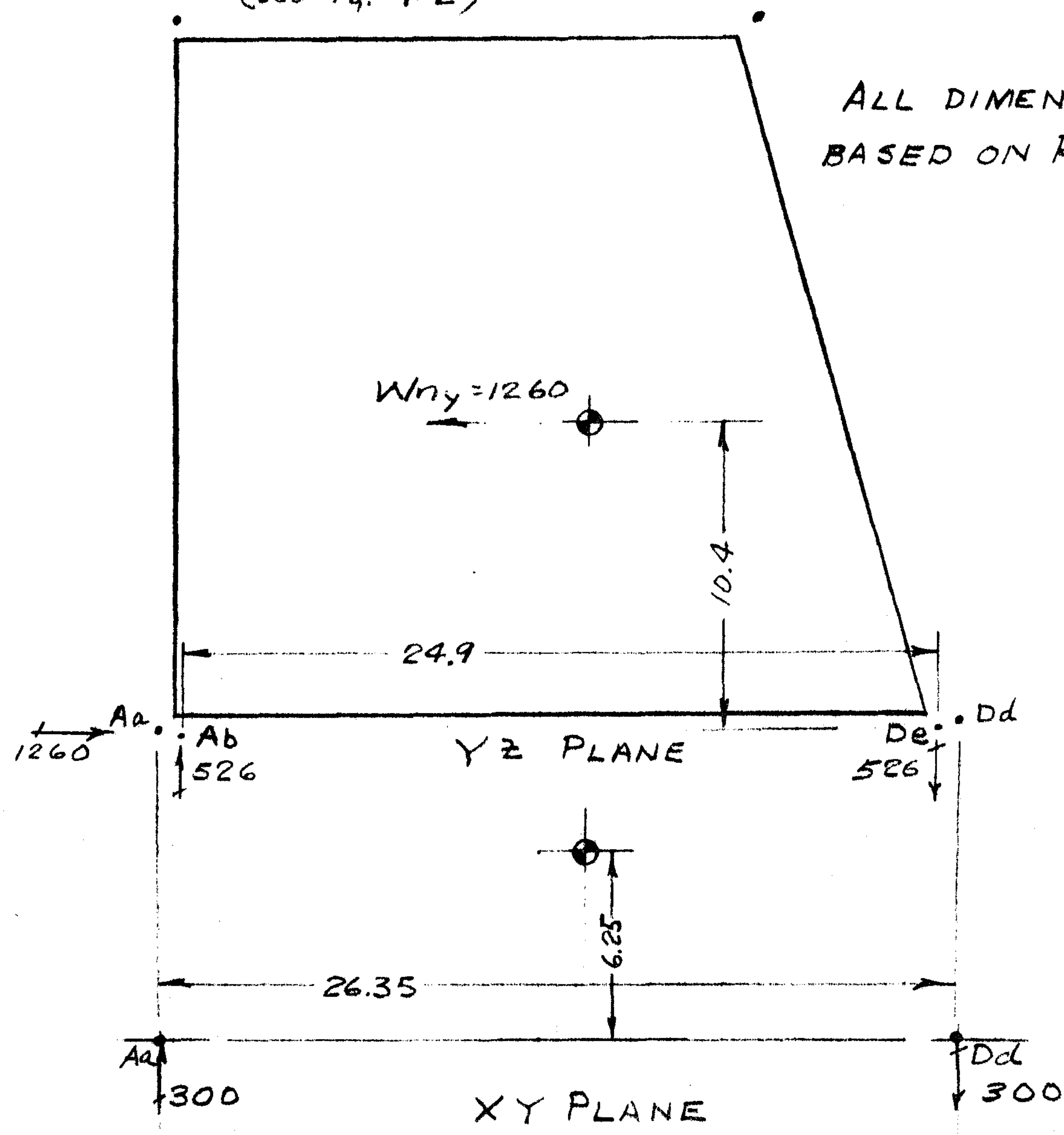
FINAL ANALYSIS ~ LRRR STRUCTURE

LM INTERFACE POINT LOADS

COND. n_y = 20 G. LIM. (REF. 1) EXP'M'T + STRUCT. W = 42# (SEE PG. 1-2)

30 G. ULT. (SEE PG. 1-2) $n_y W = 30 \times 42 = 1260$#

ALL DIMENSIONS BASED ON REF. (3)



Y_{Aay} OR $Y_{Ddy} = 1260$

$$Y_{Aax} = -Y_{Ddx} = \frac{1260 \times 6.25}{26.35} = 300$$

$$Y_{Abz} = -Y_{Dez} = \frac{1260 \times 10.4}{24.9} = 526$$

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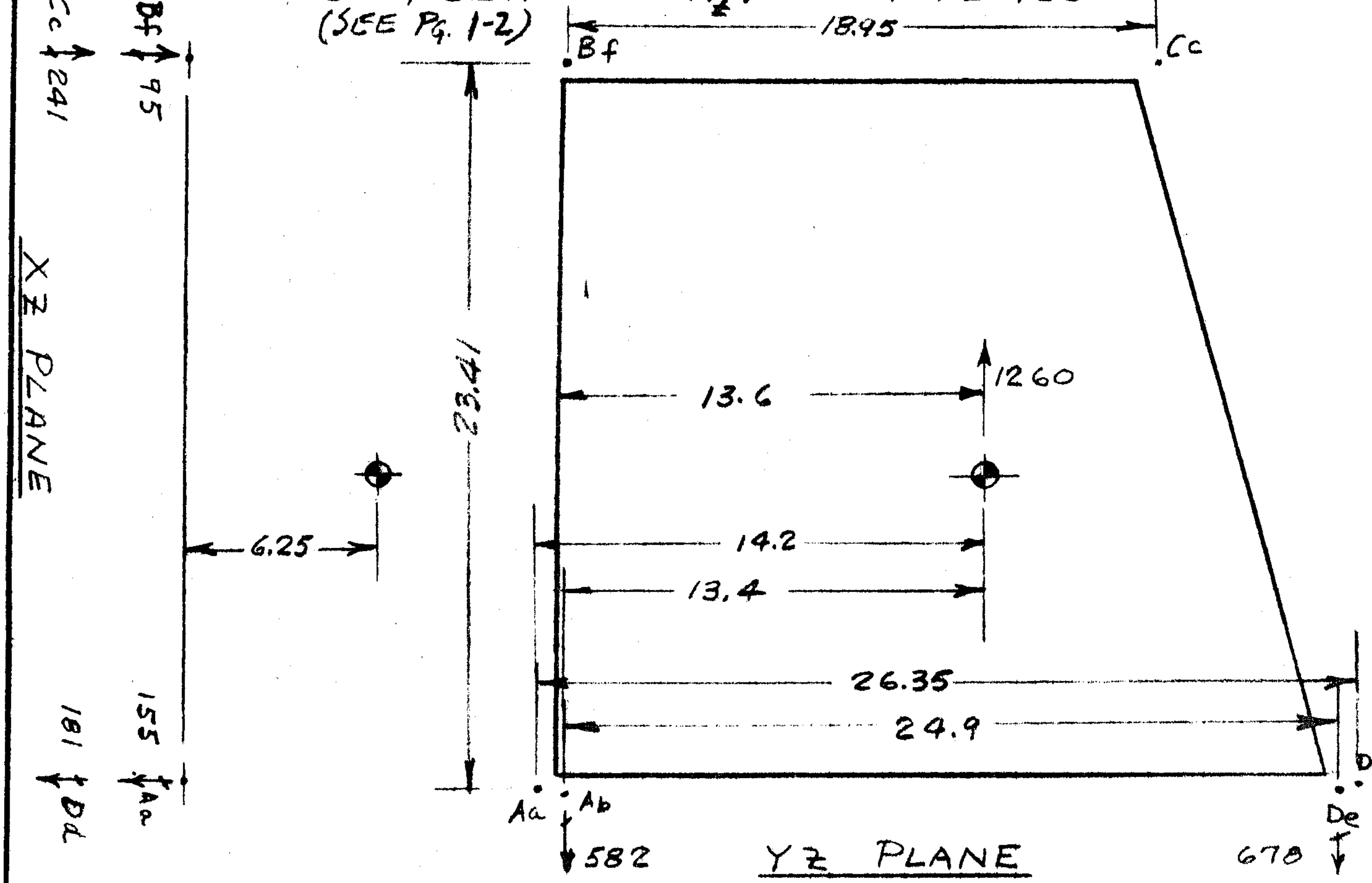
REVISED BY		MODEL LRRR

FINAL ANALYSIS ~ LRRR STRUCTURE

LM INTERFACE POINT LOADS

COND. n_z = 20G. LIM. (REF 1) EXP'M'T. + STRUCT. WT = 42# (SEE Pg 1-2)

30G. ULT. (SEE Pg. 1-2) $n_z W = 30 \times 42 = 1260$#



$$Z_{Ab} = \frac{1260(24.9-13.4)}{24.9} = \frac{11.5}{24.9} \times 1260 = 582^{\#}$$

$$Z_{De} = \frac{13.4}{24.9} \times 1260 = 678^{\#}$$

ALL DIMENSIONS BASED ON REF. (3)

$$Z_{Aax} = \frac{6.25 \times 1260}{23.41} \times \frac{26.35-14.2}{26.35} = 155$$

$$Z_{Ddx} = \frac{6.25 \times 1260}{23.41} \times \frac{14.2}{26.35} = 181$$

$$Z_{Bfx} = \frac{6.25 \times 1260}{23.41} \times \frac{18.95-13.6}{18.95} = 95$$

$$Z_{Ccx} = \frac{6.25 \times 1260}{23.41} \times \frac{13.6}{18.95} = 241$$

3.0 EXPERIMENT SUPPORT POINT LOADS

The following pages develop the loads on the structure at the experiment array points. Dimensions, C.G., wts., etc. are from References (4) and (5). Fore and aft loads (along Z-Z axis page 1-14) are applied at points H and J. Side loads (along Y-Y axis page 1-13) are applied at points G and K. These are rational assumptions since all fittings are in double shear with the aft fitting pins normal to Z-Z axis and the forward fitting pins normal to Y-Y axis. (See pages 1-28 and 1-31 for fitting details.) Basically aft fittings are stiffer along Z-Z and forward fittings are stiffer along Y-Y.

Loads along the X-X axis are assumed acting at all four points.

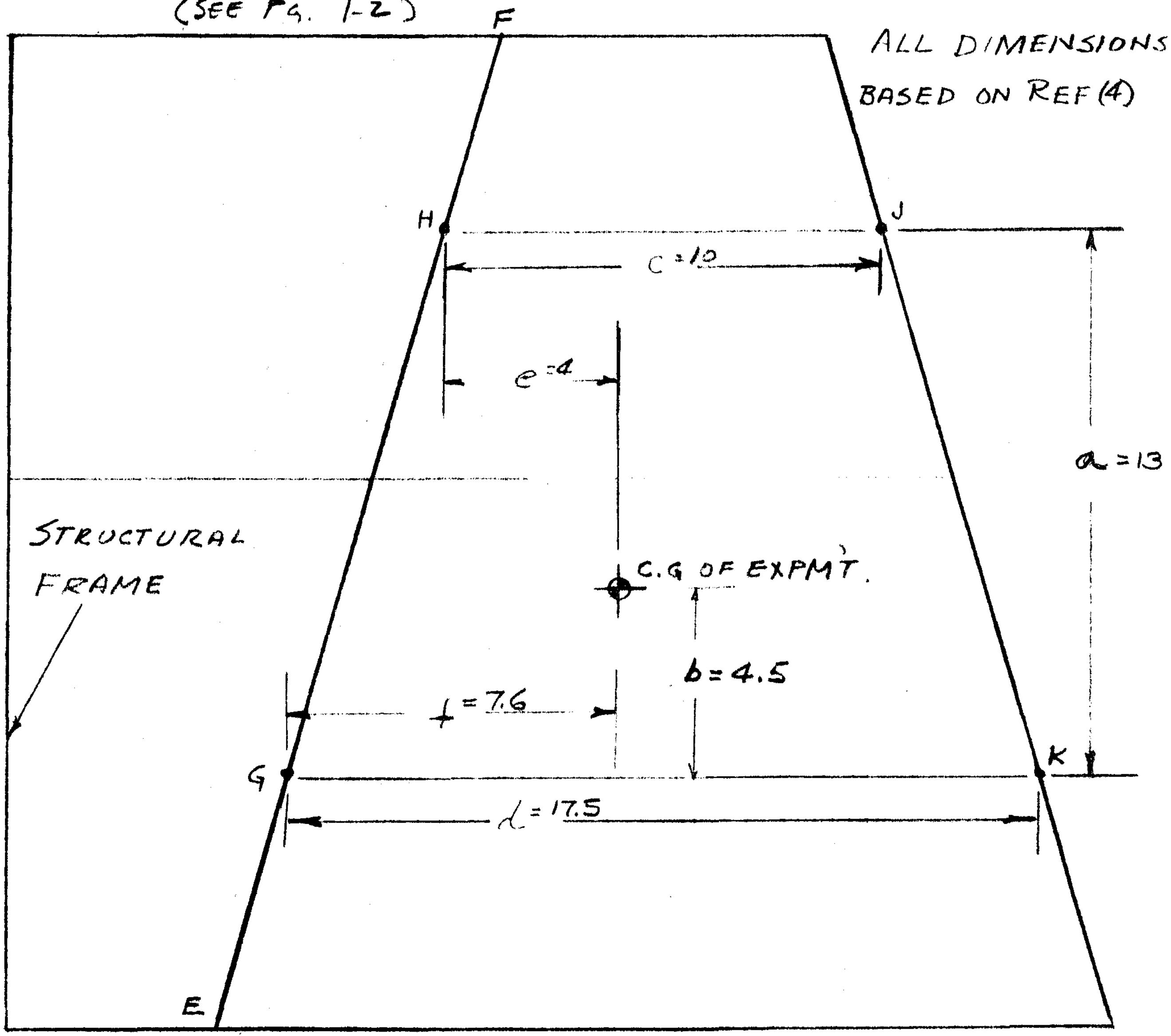
FINAL ANALYSIS ~ LRRR STRUCTURE

BASIC LOADS - EXPERIMENT SUPPORT POINTS

COND. $n_x = 20g$. LIM. (REF. 1) EXPM'T. WT = 32# (REF. 5)

30G. ULT. $n_x W = 30 \times 32 = 960$#

(SEE PG. 1-2)



YZ PLANE (X-X AXIS N

FRAME LOADING DIAGRAM

n_x ACTING NORMAL TO STRUCTURAL FRAME

G, H, J, K ARE EXPERIMENT SUPPORT POINTS

FINAL ANALYSIS ~ LRRR STRUCTURE

BASIC LOADS - EXPERIMENT SUPPORT POINTS

COND. n_x (CONTINUED)

$$X_G = \left(\frac{a-b}{a}\right)\left(\frac{d-f}{d}\right) n_x W = \left(\frac{8.5}{13}\right)\left(\frac{9.9}{17.5}\right) 960 = 356$$

$$X_H = \left(\frac{b}{a}\right)\left(\frac{c-e}{c}\right) n_x W = \left(\frac{4.5}{13}\right)\left(\frac{6}{10}\right) 960 = 200$$

$$X_J = \left(\frac{b}{a}\right)\left(\frac{e}{c}\right) n_x W = \left(\frac{4.5}{13}\right)\left(\frac{4}{10}\right) 960 = 133$$

$$X_K = \left(\frac{a-b}{a}\right)\left(\frac{f}{d}\right) n_x W = \left(\frac{8.5}{13}\right)\left(\frac{7.6}{17.5}\right) 960 = 271$$

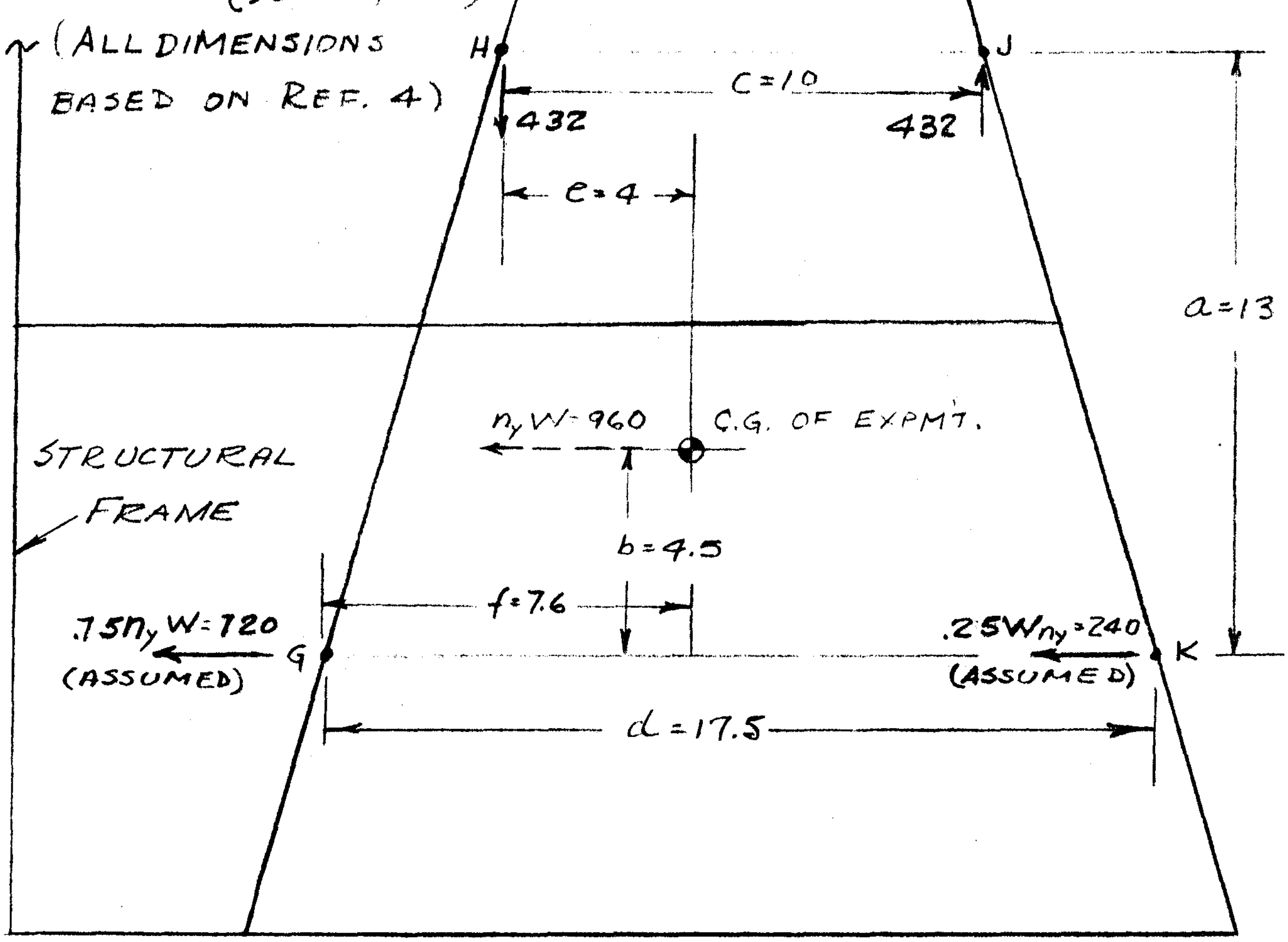
960# CHECK

FINAL ANALYSIS ~ LRRR STRUCTURE

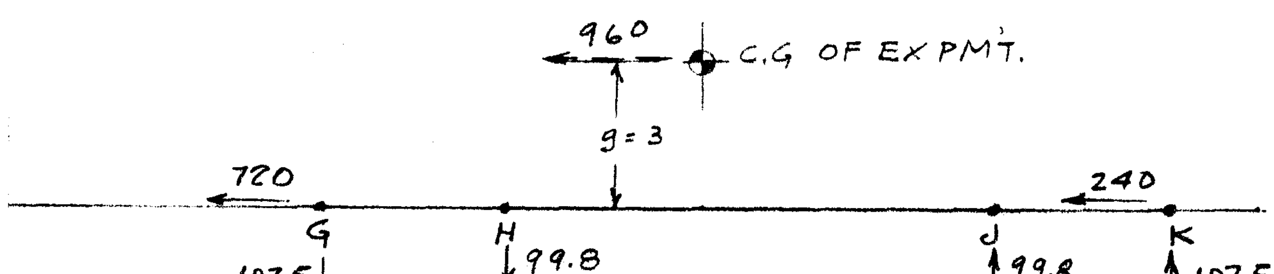
BASIC LOADS ~ EXPERIMENT SUPPORT POINTS

COND n_y = 20G. LIM. (REF 1) EXPM'T WT = 32# (REF. 5)

30G. ULT. $n_y W$ = 30X32 = 960#
(SEE PG. 1-2)



FRAME LOADING DIAGRAM - YZ PLANE



XY PLANE

FINAL ANALYSIS ~ LRRR STRUCTURE

BASIC LOADS ~ EXPERIMENT SUPPORT POINTS

COND n_y (CONTINUED)

ASSUMPTIONS

1. LOADS IN Y DIRECTION AT G & K ONLY
2. LOADS IN Z DIRECTION AT H & J ONLY
3. LOADS IN X DIRECTION AT ALL FOUR POINTS

$$Y_{Gx} = (n_y W) g \left(\frac{a-b}{a}\right)\frac{1}{d} = (960)3\left(\frac{8.5}{13}\right)\frac{1}{17.5} = 107.5$$

$$Y_{Hx} = (n_y W) g \left(\frac{b}{a}\right)\frac{1}{c} = (960)3\left(\frac{4.5}{13}\right)\frac{1}{10.0} = 99.8$$

$$Y_{Hz} = (n_y W)\frac{b}{c} = (960)\frac{4.5}{10} = 432$$

$$Y_{Jx} = -Y_{Hx} = -99.8$$

$$Y_{Jz} = -Y_{Hz} = -432$$

$$Y_{Kx} = -Y_{Gx} = -107.5$$

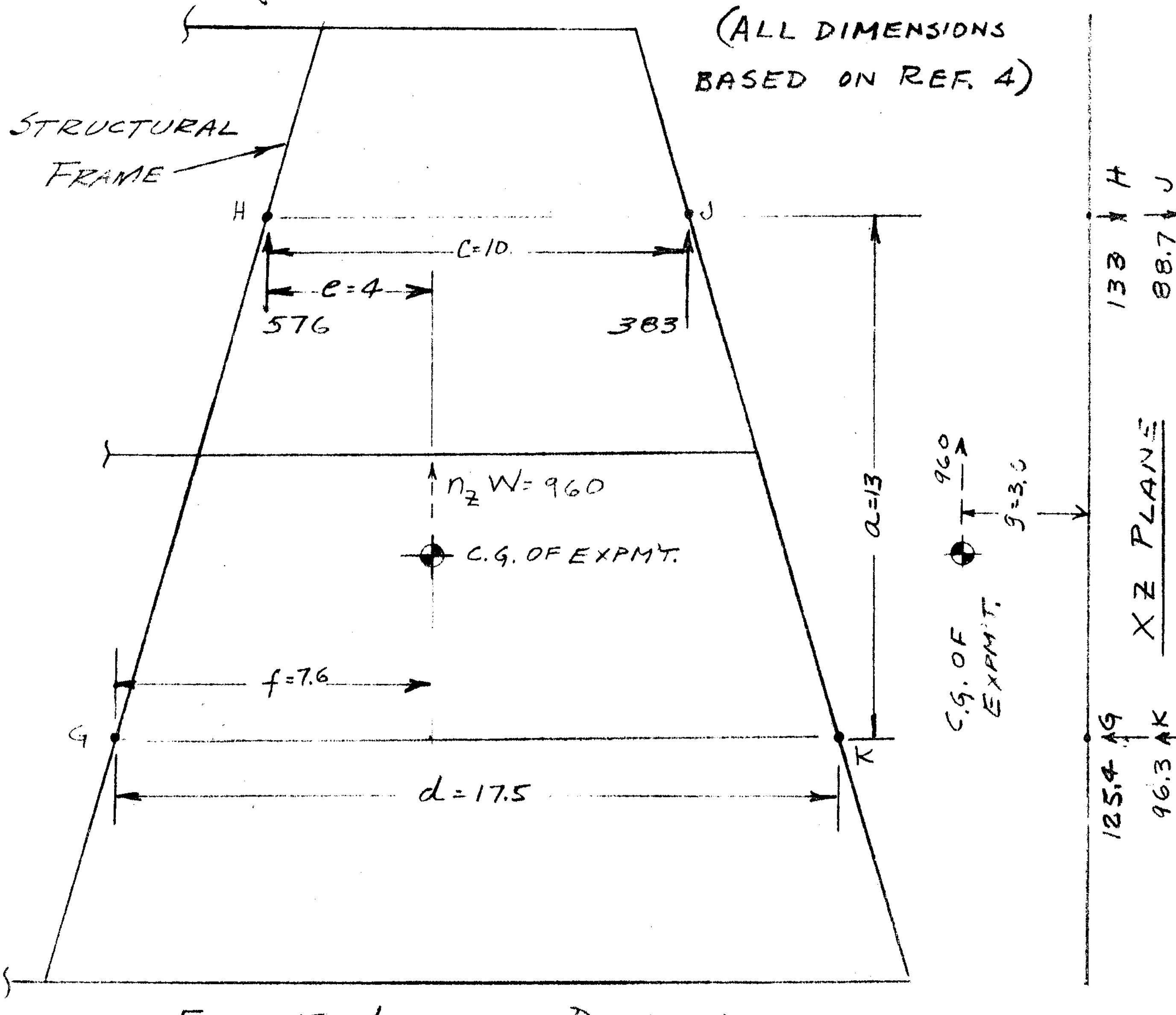
FINAL ANALYSIS ~ LRRR STRUCTURE

BASIC LOADS ~ EXPERIMENT SUPPORT POINTS

COND. $n_z = 20G$. LIM.(REF. 1) EXPMT. WT. = 32# (REF. 5)

30G ULT. $n_z W = 30 \times 32 = 960$#

(SEE PG. 1-2)



FRAME LOADING DIAGRAM
YZ PLANE

FINAL ANALYSIS ~ LRRR STRUCTURE

BASIC LOADS ~ EXPERIMENT SUPPORT POINTS

COND. n_z (CONTINUED)

ASSUMPTIONS

1. LOADS IN Z DIRECTION AT H & J ONLY
2. LOADS IN X DIRECTION AT ALL FOUR POINTS

$$Z_{Gx} = (n_z W)\frac{g}{a}\left(\frac{d-f}{d}\right) = (960)\frac{3}{13}\left(\frac{9.9}{17.5}\right) = 125.4$$

$$Z_{Hx} = (n_z W)\frac{g}{a}\left(\frac{c-e}{c}\right) = (960)\frac{3}{13}\left(\frac{6}{10}\right) = 133$$

$$Z_{Hz} = (n_z W)\frac{c-e}{c} = 576$$

$$Z_{Jx} = (n_z W)\frac{g}{a}\left(\frac{e}{c}\right) = (960)\frac{3}{13}\left(\frac{4}{10}\right) = 88.7$$

$$Z_{Jz} = (n_z W)\frac{e}{c} = (960)\frac{4}{10} = 383$$

$$Z_{Kx} = (n_z W)\frac{g}{a}\left(\frac{f}{d}\right) = (960)\frac{3}{13}\left(\frac{7.6}{17.5}\right) = 96.3$$

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ENGINEERING REPORT
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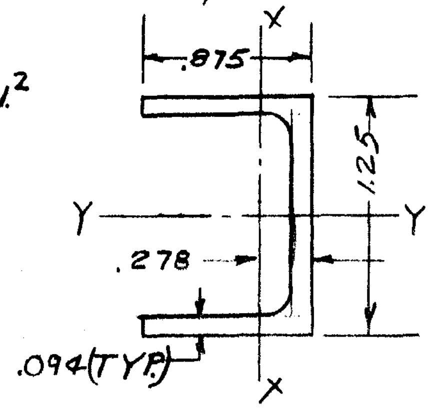
FINAL ANALYSIS ~ LRRR STRUCTURE

PRIMARY FRAME MEMBERS

SECTION PROPERTIES ~ TYPICAL FOR ALL UNGUSSETED SECTIONS (REF. #6. DWG. 2345127)

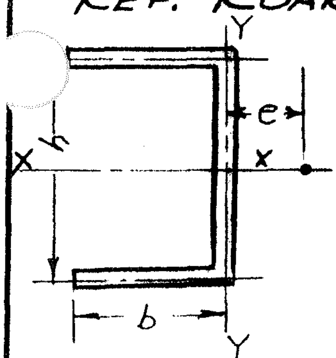
AREA = .267 IN.^{2}
I_{xx} = .019 IN.^{4}
I_{yy} = .065 IN.^{4}
ρ_{xx} = .267 IN.
ρ_{yy} = .493 IN.



MATERIAL: 2024T3511
F_{tu} = 61000 PSI
REF. MIL HDBK5A (REF 8)

SECTION SHEAR CENTER

REF. ROARK TABLE V No. 5 (REF. 7)



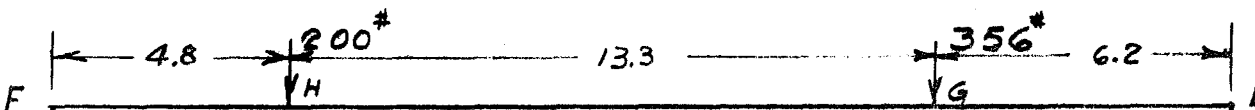
$$e = \frac{b^2 h^2 t}{4 I_x} = \frac{.828^2 \times 1.156^2 \times .094}{4 \times .065} = .331$$

ANALYSIS OF MEMBERS

NOTE:- ALSO SEE RESULTS OF COMPUTER ANALYSIS

MEMBER FE ~

COND n_x = 30G (REF. PAGE 1-10)



$(6.2 \times 356 + 19.5 \times 200)\frac{1}{24.3} = 251.0^{\#}$

$(4.8 \times 200 + 18.1 \times 356)\frac{1}{24.3} = 305^{\#}$

$M_H = 251 \times 4.8 = 1205''^{\#}$

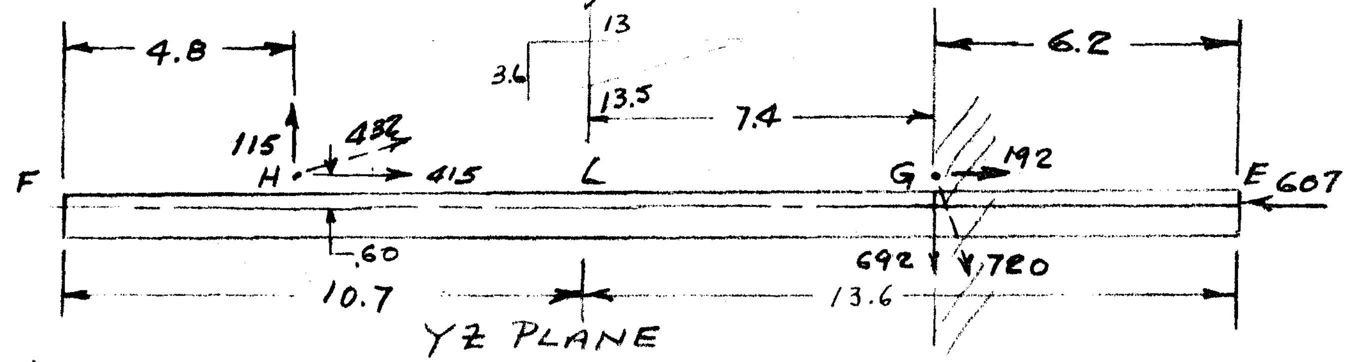
$M_G = 305 \times 6.2 = 1890''^{\#}$

BxA 542

FINAL ANALYSIS - LRRR STRUCTURE

ANALYSIS OF MEMBERS (CONTINUED)

MEMBER FE - COND $n_y = 30G$ (REF. PAGE 1-12)



ASSUMPTIONS:

1. SUPPORTS AT F, L, & G.
2. SINCE FE IS HEAVILY GUSSETED & REINFORCED IN THIS PLANE FROM G TO E (REF. DWG 2345727) PT. G IS ASSUMED FIXED.

ANALYZE AS A CONTINUOUS BEAM USING NILES & NEWELL "AIRPLANE STRUCTURES" ARTICLES 5.2 & 5.3. (REF. 9)

$$M_F \ell_1 + 2M_L(\ell_1 + \ell_2) + M_G(\ell_2) = \frac{W_1 a_1 (\ell_1^2 - a_1^2)}{\ell_1} + m_1\left(\ell_1 - \frac{3a_1^2}{\ell_1}\right)$$

$M_F = 0$

$$2M_L(10.7 + 7.4) + M_G(7.4) = \frac{115 \times 4.8(\overline{10.7}^2 - \overline{4.8}^2)}{10.7} - 415 \times .6\left(10.7 - \frac{3 \times \overline{4.8}^2}{10.7}\right)$$

$$36.2 M_L + 7.4 M_G = 51.6(114.5 - 23.1) - 249(10.7 - 6.46)$$

$$36.2 M_L + 7.4 M_G = 4720 - 1060 = 3660$$

$M_L(7.4) + 2M_G(7.4) = 0 \qquad M_L = -2M_G$

$-72.4 M_G + 7.4 M_G = 3660 \qquad M_G = -56.3 \quad M_L = 112.6$

$$R_F = \frac{115 \times 5.9}{10.7} + \frac{415 \times .60}{10.7} - \frac{112.6}{10.7} = 63.3 + 23.3 - 10.5 = 76.1$$

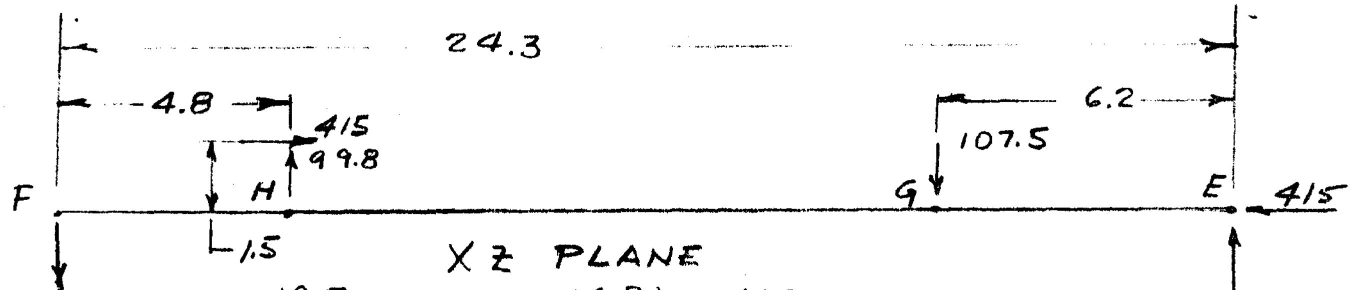
$M_{-H} = 76.1 \times 4.8 = \underline{\underline{365}} \qquad M_{+H} = -415 \times .6 + 365$

$= -249 + 365 = 116$

FINAL ANALYSIS ~ LRRR STRUCTURE

ANALYSIS OF MEMBERS (CONTINUED)

MEMBER FE ~ COND. $n_y = 30g$ (CONTINUED)



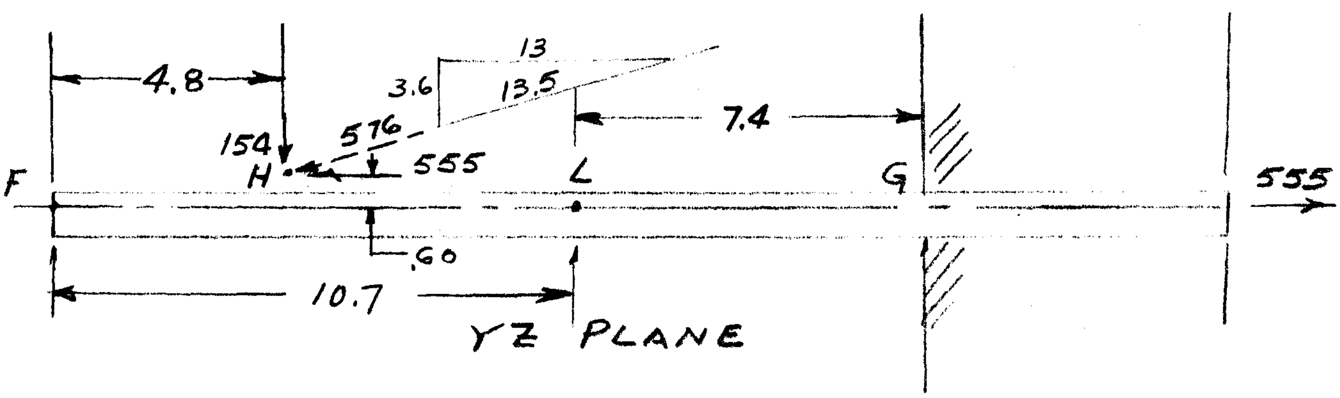
$R_F = 99.8\left(\frac{19.5}{24.3}\right) - 107.5\left(\frac{6.2}{24.3}\right) + \frac{415 \times 1.5}{24.3} = 80 - 27.4 + 25.6 = 78.2$

$R_E = 99.8\left(\frac{4.8}{24.3}\right) - 107.5\left(\frac{18.1}{24.3}\right) - \frac{415 \times 1.5}{24.3} = 19.7 - 80 - 25.6 = -85.9$

$M_H = 78.2 \times 4.8 = 375''^{\#}$

$M_G = -85.9 \times 6.2 = -532''^{\#}$

MEMBER FE ~ COND $n_z = 30g$ (REF PAGE 1-14)



USE SAME ASSUMPTIONS AND METHOD OF ANALYSIS AS FOR COND. $n_y = 30g$. $M_F = 0$

$2M_L(10.7 + 7.4) + M_G(7.4) = -\frac{154(4.8)(10.7^2 - 4.8^2)}{10.7} + 555 \times .6\left(10.7 - \frac{3 \times 4.8^2}{10.7}\right)$

$36.2 M_L + 7.4 M_G = -6320 + 1410 = -4910$

$-74.4 M_G + 7.4 M_G = -4910 \quad M_L = -2M_G$

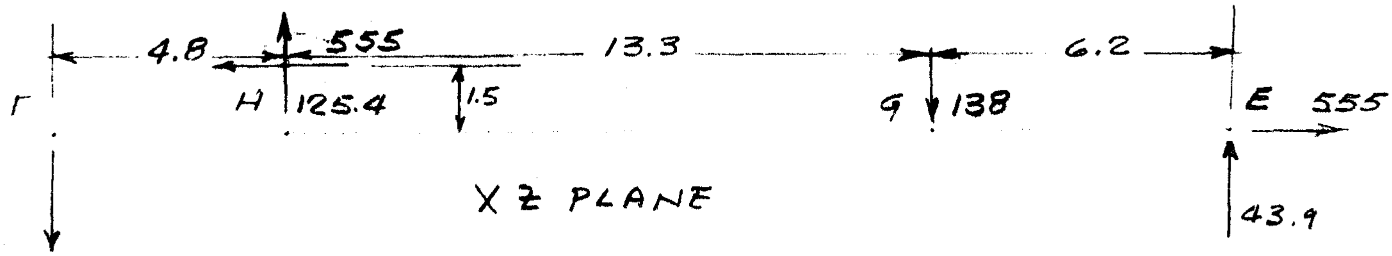
$M_G = 75.5 \quad M_L = -151 \quad R_F = 154 \times \frac{5.9}{10.7} + \frac{555 \times .60}{10.7} - \frac{151}{10.7}$

$M_H = 102 \times 4.8 = 490 \quad M_H = 490 - 333 = 157''^{\#} \quad = 85 + 31.1 - 14.1 = 102^{\#}$

FINAL ANALYSIS ~ LRRR STRUCTURE

ANALYSIS OF MEMBERS (CONTINUED)

MEMBER FE ~ COND. $n_z = 30G$ (CONTINUED)



$$R_F = 125.4\left(\frac{19.5}{24.3}\right) - 138\left(\frac{6.2}{24.3}\right) - \left(\frac{555 \times 1.5}{24.3}\right) = 100.5 - 35.2 - 34.3 = 31.0$$

$$R_G = 125.4 \times \frac{4.8}{24.3} - 138\left(\frac{18.1}{24.3}\right) + 34.3 = 24.8 - 103 + 34.3 = -43.9$$

$M_H = 31 \times 4.8 = 149''^{\#}$ $M_H = 149 + 832 = 981''^{\#}$ $M_G = 43.9 \times 6.2 = 272''^{\#}$

MEMBER FE ~ STRESS CALCULATIONS

COND $n_x = 30G$ (REF. PG 1-16 FOR SECT. PROPERTIES) ←

POINT H

$$\sigma_{yy} = \frac{1205 \times .625}{.065} = 11600\ \#/\square'' \qquad M.S. = \frac{61000}{11600} - 1 = \underline{\underline{4.27}}$$

POINT G

$$\sigma_{yy} = \frac{1890 \times .625}{.065} = 18200\ \#/\square'' \qquad M.S. = \frac{61000}{18200} - 1 = \underline{\underline{2.35}}$$

COND $n_y = 30G$

POINT H

$$\sigma_{xx} = \frac{365 \times .597}{.019} = 11500\ \#/\square''$$

$$\sigma_{yy} = \frac{375 \times .625}{.065} = 3610\ \#/\square''$$

$$15110\ \#/\square''$$

$$M.S. = \frac{61000}{15110} - 1 = \underline{\underline{3.03}}$$

POINT G

$$\sigma_{xx} = \frac{112.6 \times .597}{.019} = 3550$$

$$\sigma_{yy} = \frac{532 \times .625}{.065} = 5120$$

$$8670\ \#/\square''$$

$$M.S. = \frac{61000}{8670} - 1 = \underline{\underline{6.02}}$$

FINAL ANALYSIS ~ LRRR STRUCTURE

ANALYSIS OF MEMBERS ~ (CONTINUED)

MEMBER FE ~ STRESS CALCULATIONS

COND. $n_z = 30G$

POINT H

$$\sigma_{xx} = \frac{490 \times .597}{.019} = 15450$$

$$\sigma_{yy} = \frac{981 \times .625}{.065} = 9420$$

$$24870$$

$$M.S. = \frac{61000}{24870} - 1 = \underline{\underline{1.45}}$$

POINT G

$$\sigma_{xx} = \frac{75.5 \times .597}{.019} = 2380$$

$$\sigma_{yy} = \frac{272 \times .625}{.065} = 2610$$

$$4990$$

$$M.S. = \frac{61000}{4990} - 1 = \underline{\underline{11.25}}$$

NOTE:- OTHER MEMBERS HAVE THE SAME STRUCTURAL SECTION AS FE BUT ARE LESS HIGHLY LOADED. THEREFORE NO ADDITIONAL ANALYSES ARE DEEMED NECESSARY.

STRESSES FOR THESE MEMBERS ARE ALSO GIVEN IN SECTION 3 - REDUNDANT GRID/FRAME ANALYSIS.

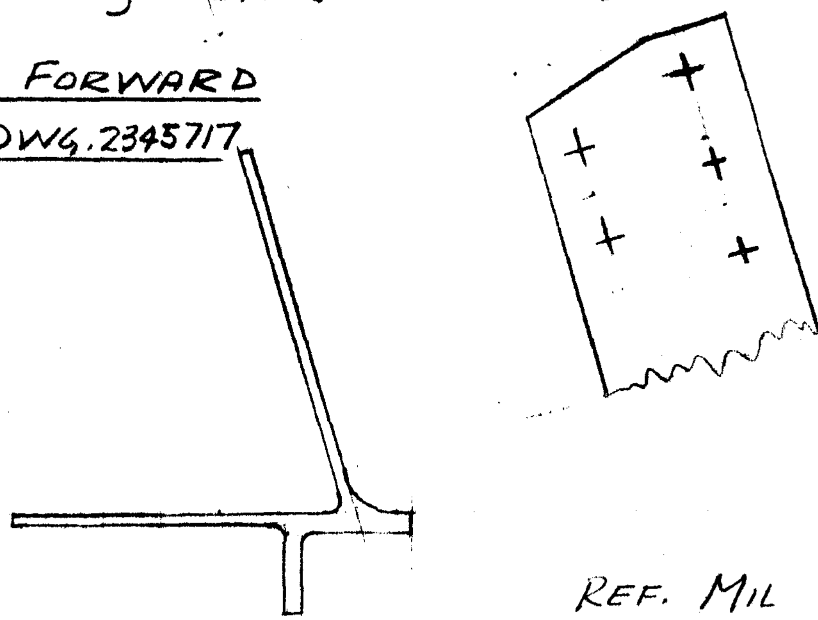
FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET, INTERFACE RIGHT FORWARD

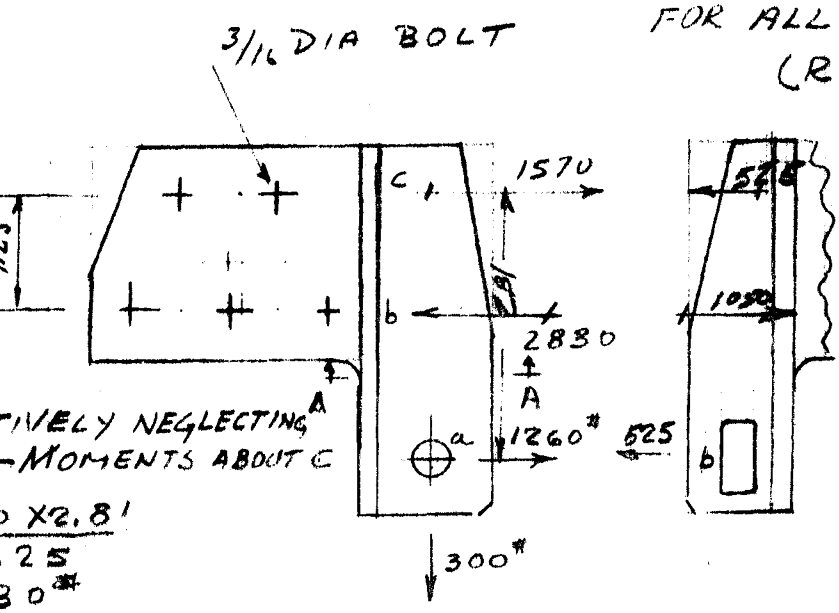
DWG. 2345716 (REF. 10) PT D (REF PG. 1-7)

COND. $n_y = 30g$ ULT. (REF PG. 1-7)

NOTE:- LEFT FORWARD BRACKET ~ DWG. 2345717 IS SIMILAR



REF. MIL HDBK5A FOR ALL ALLOWABLES (REF. 8)



NOTE: - BOLTS IN THIS PLANE OBVIOUSLY NOT CRITICAL.

CONSERVATIVELY NEGLECTING 300# AT A - MOMENTS ABOUT C

$$R_b = \frac{1260 \times 2.81}{1.25} = 2830^{\#}$$

$$P_{BOLT} = \frac{2830}{3} = 945^{\#}$$

ASSUME 125000#/□" UTS BOLT 3/16 D.

P_{ALLOW} BRG = 84000 X .094 X .188 = 1480# ON 2024T3511 EXT.

P_{ALLOW} = 2126 SHEAR (REF. 8)

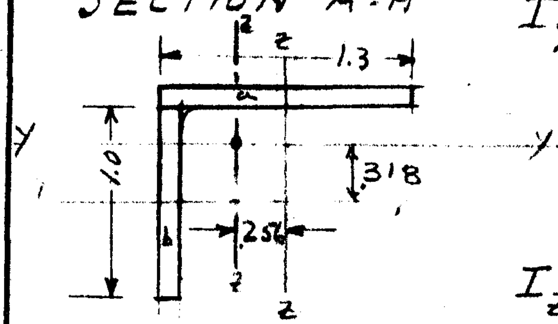
$$M.S. = 1480/945 - 1 = .57$$

$$M.S. = \frac{2126}{945} - 1 = 1.25$$

FINAL ANALYSIS ~ LRRR STRUCTURE BRACKET
DWG. 23?5716

FITTING AT D COND $n_y = 30g$ I

SECTION A-A



$I_{yy} = 1 \times .125 \times \overline{.318}^2 + 1.3 \times .125 \times \overline{.2445}^2 + \frac{1^3 \times .125}{12} + \frac{1.3 \times \overline{.125}^3}{12}$

$= .0126 + .0097 + .0104 + .0002$

$= .0329$

$I_{zz} = 1 \times .125 \times \overline{.3315}^2 + 1.3 \times .125 \times \overline{.256}^2 + \frac{\overline{1.3}^3 \times .125}{12} + \frac{1 \times \overline{.125}^3}{12}$

$= .0137 + .01065 + .0229 + .00016$

$= .04741$

AREA $= (1+1.3).125 = .287$

$\bar{z} = \frac{.5625 \times 1.3 \times .125}{.287} = .318''$

$\bar{y} = \frac{.5875 \times 1.0 \times .125}{.287} = .256$

$B.M._{zz} = 1260 \times 1.0 - 300 \times .4 = 1260 - 120 = 1140$

$BM_{yy} = 525 \times 1.0 = 525$

$\sigma_x = \frac{1140 \times .906}{.04741} + \frac{525 \times .307}{.0329} = 21800 + 4900 = 26700$ #/□"

$\sigma_{cy} = 64000$ #/□" FOR 7075T6

$M.S. = \frac{64000}{26700} - 1 = 1.40$

NOTE:-

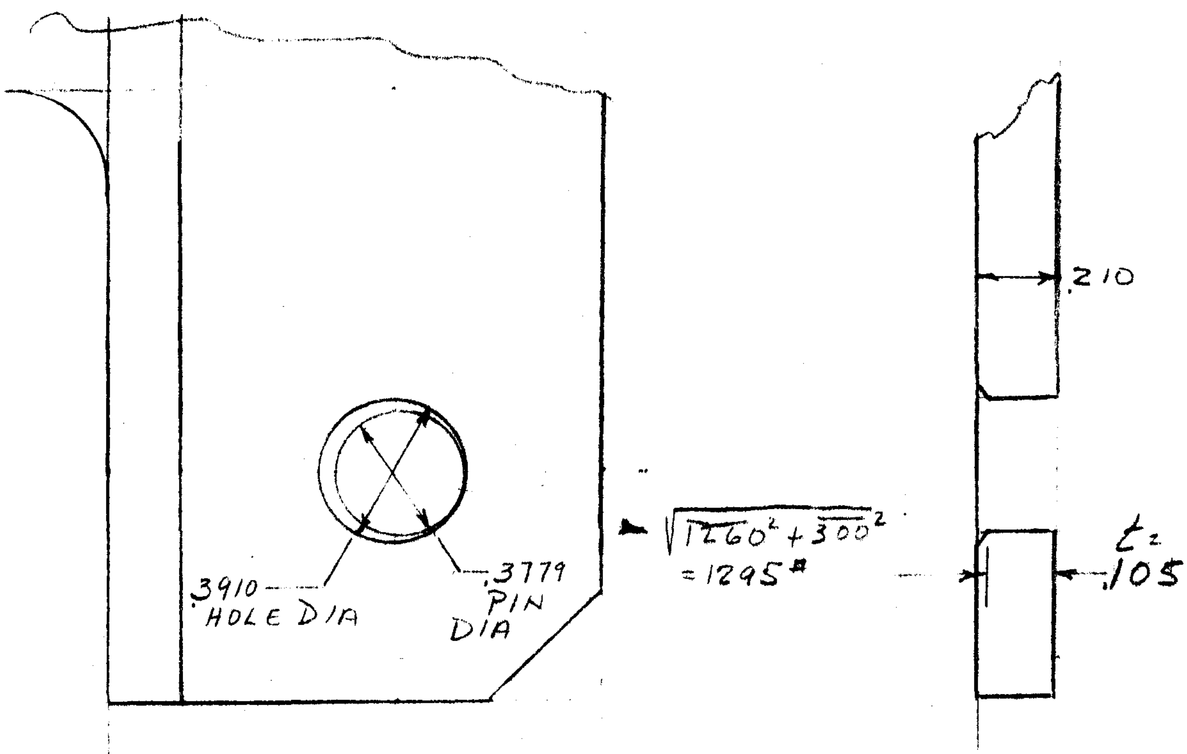
THIS ANALYSIS IS BASED ON A SECTION THICKNESS OF .125. IN FINAL DESIGN THIS SECTION WAS INCREASED TO .188

FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET, INTERFACE RIGHT FORWARD (CONTINUED)

DWG. 2345716 (REF. 10)

HOLE AT a



BEARING STRESS

ANALYZE PER ROARK "FORMULAS FOR STRESS & STRAIN" TABLE XIV CASE 6 (REF. 7)

$$p = \frac{1295}{.105} = 12300\ \#/\text{IN}$$

$$\text{MAX } \sigma_{br} = .798\sqrt{\frac{p\,\frac{D_1-D_2}{D_1 D_2}}{\left[\frac{1-\nu^2}{E_1}+\frac{1-\nu^2}{E_2}\right]}} = .798\sqrt{\frac{12300\left(\frac{.3910-.3779}{.3910\times.3779}\right)}{\frac{.91}{10^7}+\frac{.932}{28\times10^6}}}$$

$$= .798\sqrt{\frac{12300\times.08863\times10^{6}}{.091+.0333}} = 74500\ \#/\square'' \text{ ULT} \quad 61000\ \#/\square'' \text{ LIM.}$$

FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET ~ INTERFACE RIGHT FORWARD (CONTINUED)

DWG. 2345716

BEARING STRESS (CONTINUED)

$$b = 1.6\sqrt{P\frac{D_1 D_2}{D_1 - D_2}\left[\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}\right]}$$

$$= 1.6\sqrt{12300 \times .08863 \times \left[\frac{.91}{10^7} + \frac{.932}{28 \times 10^6}\right]} = \frac{1.6 \times 11.6}{10^3} = .0186 \text{ ULT}$$

$$= .0153 \text{ LIM}$$

CHANGE t TO .125

$$p = \frac{1295}{.125} = 10350 \ \#/\square$$

$\sigma_c = 68000 \ \#/\square''$ 55700 #/□" LIM

$F_{cy} = 41000$ $\quad M.S. = \frac{41000}{55700} - 1 = -.26$ FOR 2024T351

CHANGE MATERIAL TO 7075T651

$F_{cy} = 68000$ $\quad M.S. = \frac{68000}{55700} - 1 = .22$ FOR 7075T651

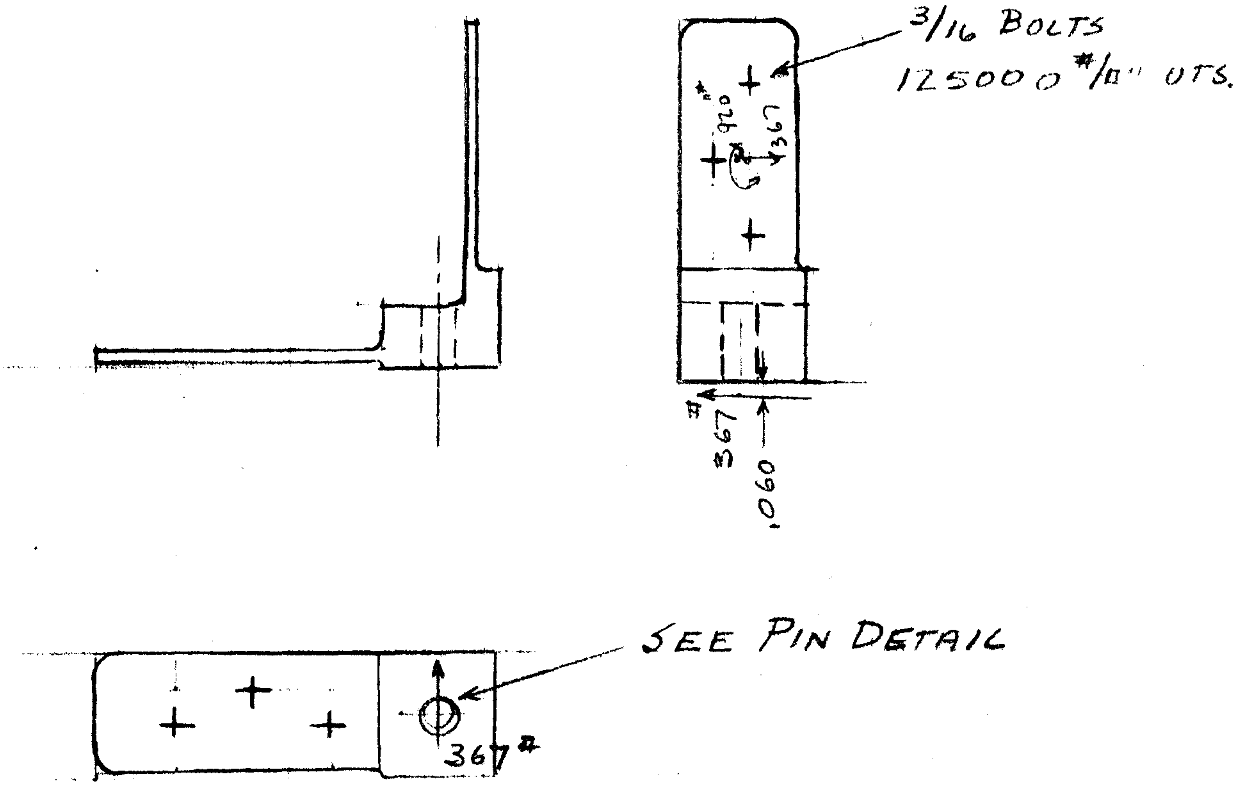
SEE MIL-HDBK5A FOR ALLOWABLES (REF. 8)

OTHER AREAS HAVE BEEN INVESTIGATED AND FOUND NOT TO BE CRITICAL

FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET, INTERFACE, LEFT REAR DWG. No. 2345714 (REF. 11)

DWG No. 2345715 IS SIMILAR



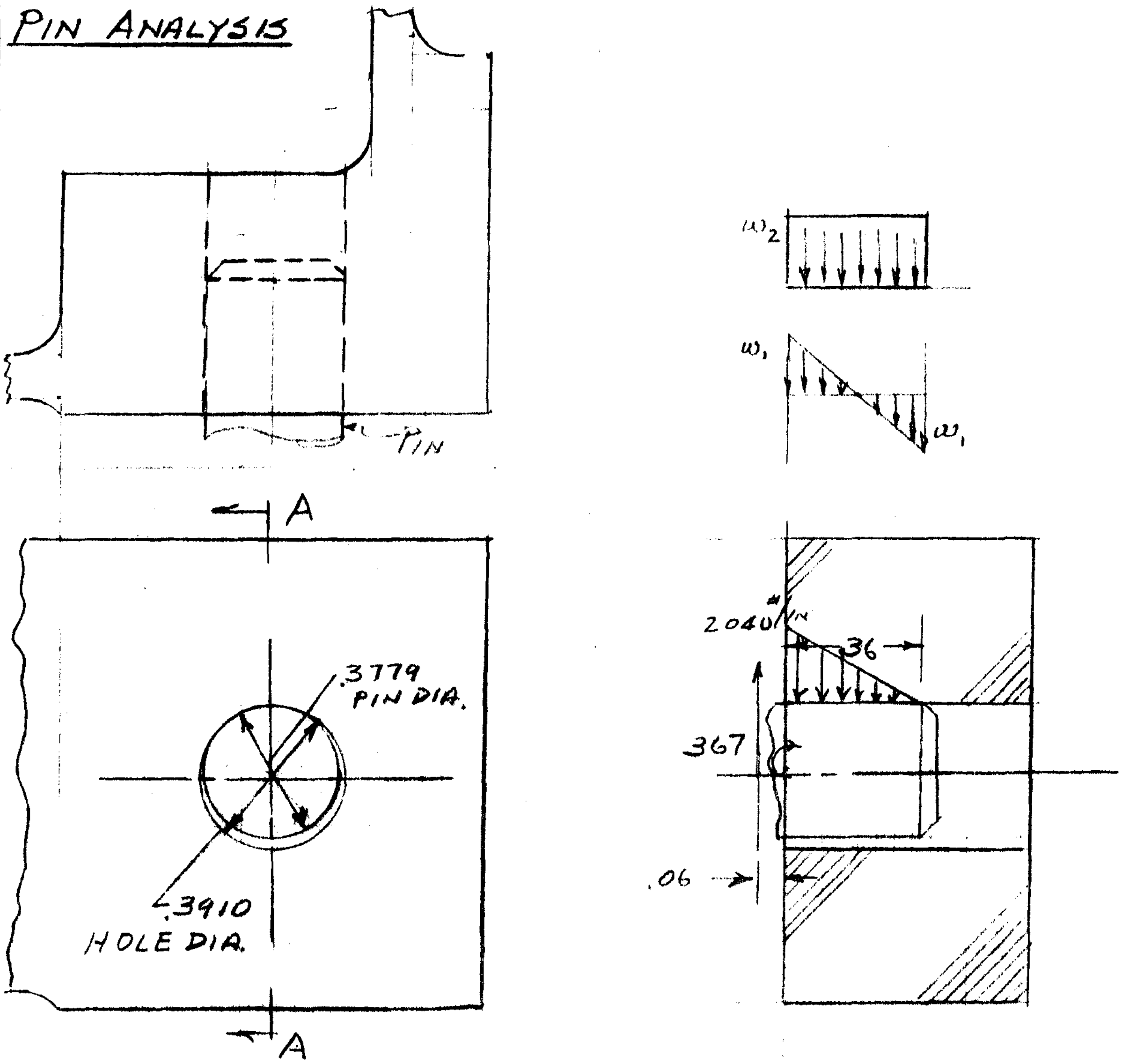
NOTE:- PIN LOAD MAY ACT ALONG EITHER LEG.

CONSERVATIVELY MAX. LOAD HAS BEEN ASSUMED REACTED ON LONGER LEG.

FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET, INTERFACE, LEFT REAR DWG. No. 2345714 (CONT.)

PIN ANALYSIS



$$w_1 = \frac{367 \times .06}{.36 \times .66} \times \frac{2}{.18} = 1020^{\#}/_{IN}$$

$$w_2 = \frac{367}{.36} = 1020^{\#}/_{IN}$$

$$w_{MAX} = 2040^{\#}/_{IN}$$

FINAL ANALYSIS ~ LRRR STRUCTURE

BRACKET, INTERFACE, LEFT REAR DWG. NO. 2345714 (CONT.)

PIN ANALYSIS (CONT.)

COMPRESSION - BEARING STRESS

ANALYZE PER ROARK "FORMULAS FOR STRESS & STRAIN" TABLE XIV

$p = 2040\,\#/\text{IN ULT.}$

$$\sigma_c = .798\sqrt{\frac{p\left(\frac{D_1 - D_2}{D_1 D_2}\right)}{\left[\frac{1-\nu^2}{E_1} + \frac{1-\nu^2}{E_2}\right]}} = .798\sqrt{\frac{2040\left(\frac{.3910 - .3779}{.3910 \times .3779}\right)}{\frac{.91}{10^7} + \frac{.932}{28\times10^6}}}$$

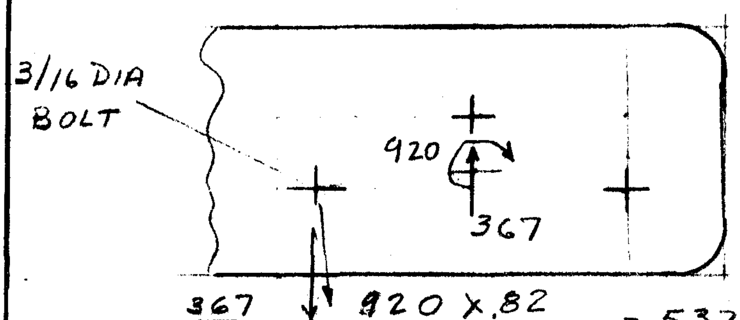
$$= .798\sqrt{\frac{2040 \times .08863 \times 10^6}{.091 + .0333}} = 30400\,\#/\square''\ \text{ULT}$$

$$25000\,\#/\square''\ \text{LIM.}$$

$\sigma_{cy} = 68000\,\#/\square''$ FOR 7075T651 ~ REF. MIL HDBK5A REF. (8)

$$M.S. = \frac{68000}{25000} - 1 = \underline{1.72}$$

BOLT PATTERN ANALYSIS



$$\frac{367}{3} = 122\,\# \qquad \frac{920 \times .82}{2 \times \overline{.82}^2 + \overline{.25}^2} = 532\,\#$$

$$P_{ALLOW} = 84000 \times .094 \times .188 = 1480\,\#/\text{BOLT}$$

$$M.S. = \frac{1480}{532} - 1 = 1.78$$

PREPARED BY J.H.O.
CHECKED BY
REVISED BY

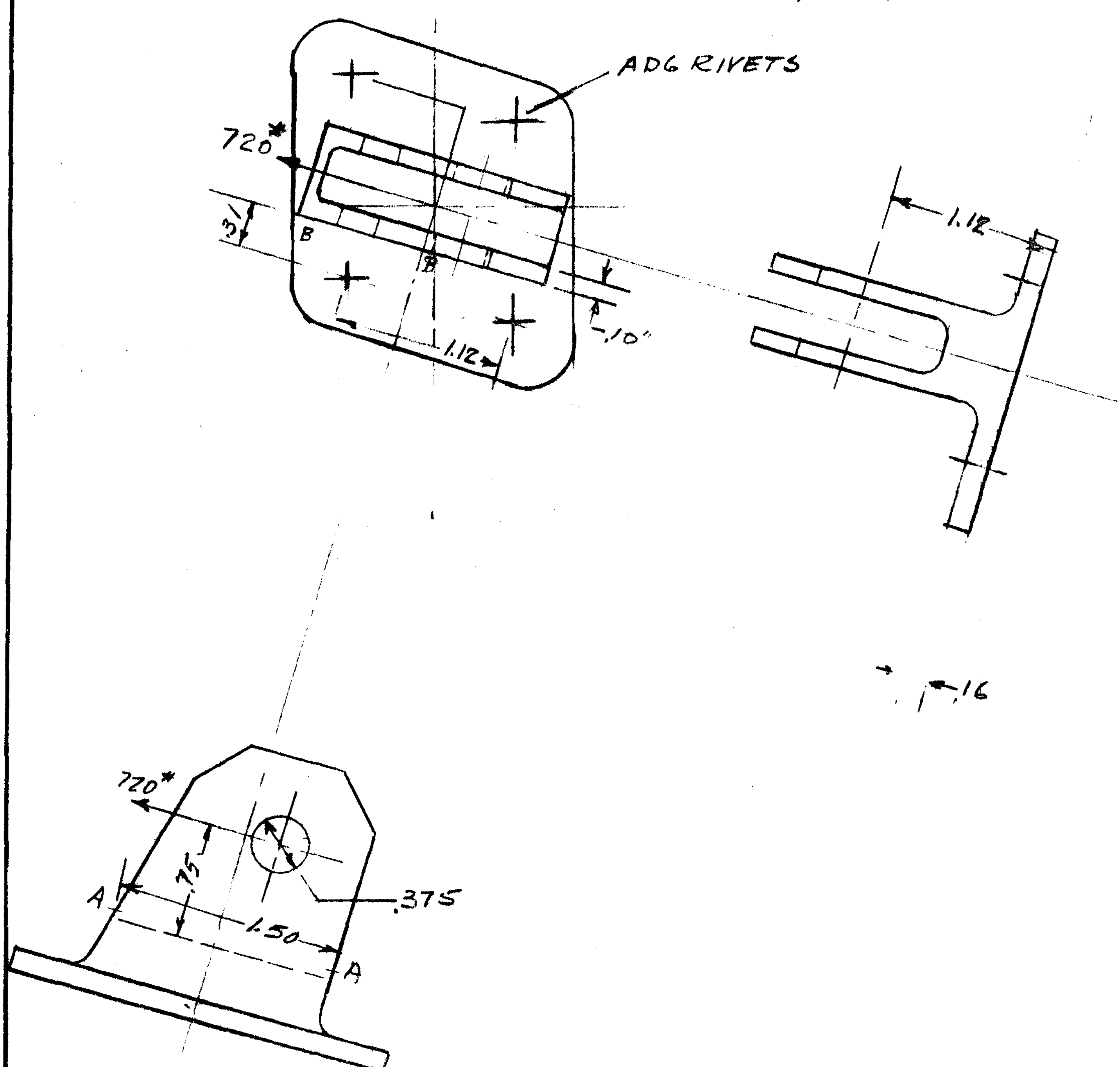
ENGINEERING REPORT
Bendix Aerospace Systems Division

DATE 4-30-70 PAGE 1-28
REPORT No. ATM 871
MODEL LRRR

FINAL ANALYSIS ~ LRRR STRUCTURE

L.H. FORWARD INTERFACE BRACKET DWG 2345748

MATERIAL
7075T651



BxA 542

FINAL ANALYSIS ~ LRRR STRUCTURE

L.H FORWARD ~ INTERFACE BRACKET ~ DWG. 2345748

SECT A-A

ASSUME 60% PER LUG

$M = .60 \times 720 \times .75 = 324''\#$

$\sigma_b = \frac{6 \times 324}{.10 \times 1.5^2} = 8650 \#/\square''$

CONSERVATIVELY ASSUME A 10% SIDE LOAD

$\sigma_b = \frac{6 \times 32.4}{.10^2 \times 1.5} = 13000 \#/\square''$ $F_{tu} = 69000$ REF MIL HDBK5A (REF 8)

$\Sigma \sigma_b = 21650 \#/\square''$ $M.S. = \frac{69000}{21650} - 1 = 2.18$

BEARING ON HOLE

$\frac{720}{2 \times .1 \times .375} = 9600 \#/\square''$ $F_{br} = (64 \times 1.5)10^3 = 96000$

$M.S. = \frac{96000}{9600} - 1 = 9.00$

RIVET ANALYSIS

$P_s/RIVET = \frac{720}{4} = 180\#$ $P_{ALLOW} = 862\#$

$P_t/RIVET = \frac{720 \times 1.12}{2 \times 1.12} = 360\#$ $P_{ALLOW} = 1094\#$

(REF. 12) BRUHN ANALYSIS & DESIGN OF FLIGHT VEHICLE STRUCTURES

DETERMINE M.S. BY COMBINED FORMULA

$\frac{X^3}{a^3} + \frac{Y^2}{b^2} = 1$ $\frac{\overline{180}^3}{\overline{862}^3} + \frac{\overline{360}^2}{\overline{1094}^2} = .00912 + .1085 = .11762$

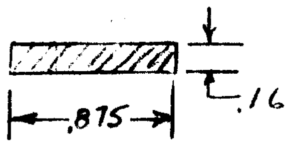
$M.S. = \frac{1}{.11762} - 1 = 7.5$

FINAL ANALYSIS ~ LRRR STRUCTURE

L.H. FORWARD ~ INTERFACE BRACKET ~ DWG. 2345748

BENDING AT B-B

ASSUME A SECT.



$B.M. = 360 \times .31 = 111.5$

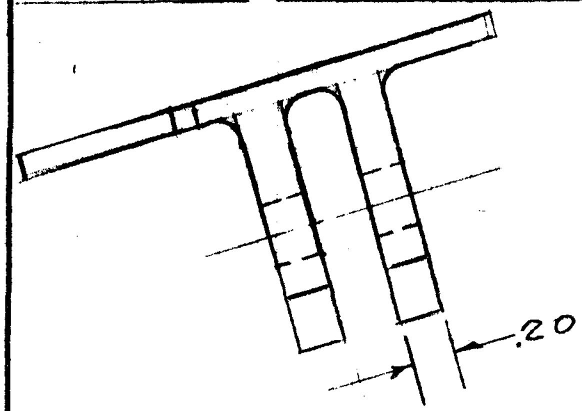
$$\sigma_b = \frac{6M}{bd^2} = \frac{6 \times 111.5}{.875 \times .16^2} = 29800 \text{ PSI}$$

$F_{tu} = 69000$

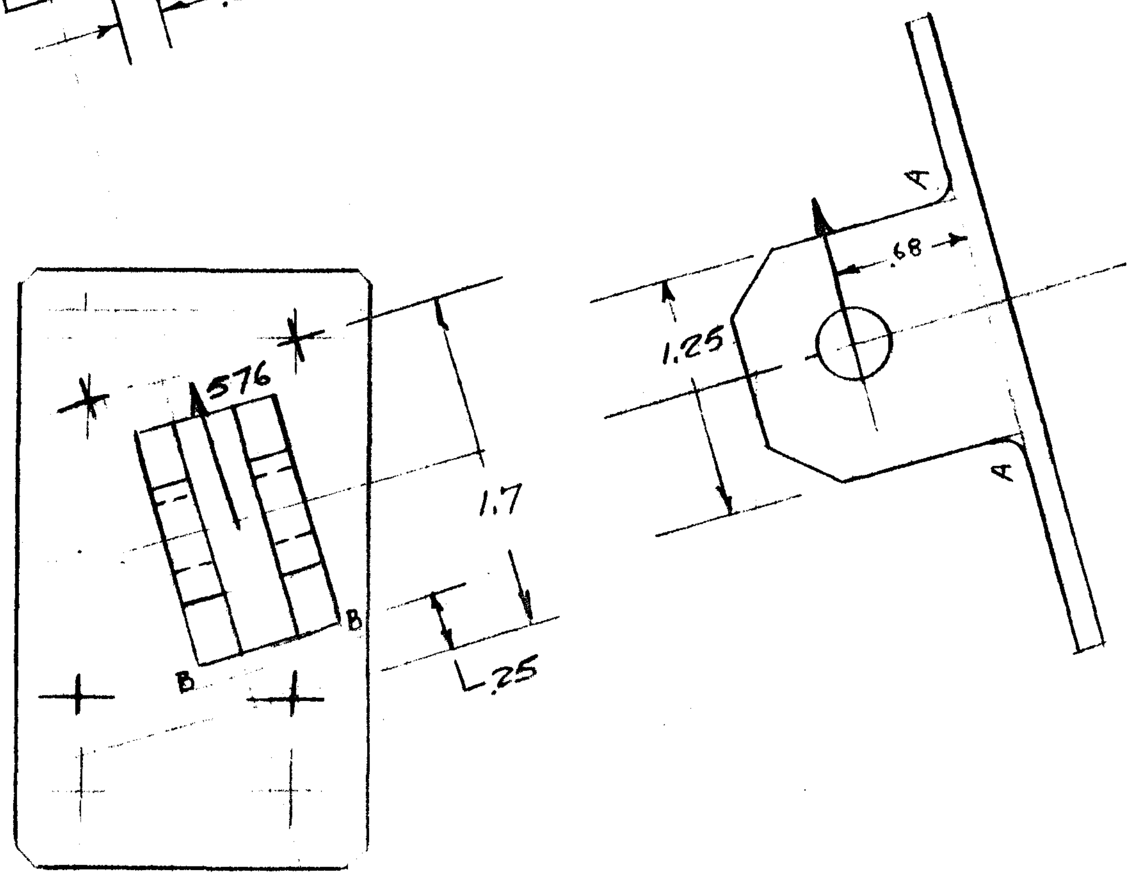
$$M.S. = \frac{69000}{29800} - 1 = 1.31$$ (REF. 8 MIL HDBK 5A)

FINAL ANALYSIS ~ LRRR STRUCTURE

L.H. REAR ~ INTERFACE BRACKET ~ DWG. 2345746



MATERIAL ~
7075 T651



FINAL ANALYSIS ~ LRRR STRUCTURE

L.H. REAR ~ INTERFACE BRACKET ~ DWG. 2345746

SECT. A-A

ASSUME 60% PER LUG

$M. = .60 \times 576 \times .68 = 235''^{\#}$ $\qquad F_{tu} = 69000$

REF. MIL HDBK5A

$\sigma_b = \frac{6M}{bd^2} = \frac{6 \times 235}{.20 \times \overline{1.25}^2} = 4520 \#/\square''$

CONSERVATIVELY ASSUME A 10% SIDE LOAD

$\sigma_b = \frac{6 \times 23.5}{\overline{.20}^2 \times 1.25} = 2810 \#/\square''$

$\Sigma\sigma_b = 4250 + 2810 = 7060 \#/\square''$ $\qquad M.S. = \frac{69000}{7060} - 1 = 8.80$

BEARING ON HOLE

$\frac{576 \times .6}{.2 \times .375} = 4620 \#/\square''$ $\qquad F_{br} = 64000 \times 1.5 = 96000$

$M.S. = \frac{96000}{4620} - 1 = 19.8$

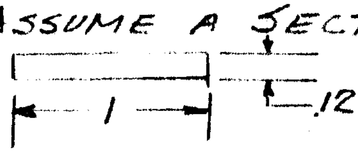
RIVET ANALYSIS

$P_s/RIVET = \frac{576}{4} = 119^{\#}$ $\qquad$ M.S AMPLE

$P_t/RIVET = \frac{576 \times 68}{1.7} = 231^{\#}$

BENDING AT B-B

ASSUME A SECT.



$B.M. = 231 \times .25 = 57.7$ $\qquad F_{tu} = 69000$ (REF MIL HDBK5A)

$\sigma_b = \frac{6M}{bd^2} = \frac{6 \times 57.7}{1 \times \overline{.12}^2} = 24000$

$M.S. = \frac{69000}{24000} - 1 = 1.77$

FINAL ANALYSIS ~ LRRR STRUCTURE

INTERFACE BRACKETS ~ GAP INVESTIGATION

BASIC RELATIONSHIPS

INTERFACE BRACKETS WILL BE ASSEMBLED WITH .002" GAP. THE EFFECT OF BOLT PRELOAD ON THIS GAP IS TO BE INVESTIGATED.

$\frac{PL^3}{3EI} = \delta = .002$ $\frac{6M}{bd^2} = 30000$ ~ MAX. ALLOW. RESIDUAL STRESS ~ 50% OF YIELD

$\frac{PL^3 \times 12}{3\times10^7 \times bd^3} = .002$ $\frac{6PL}{bd^2} = 30000$ $PL = \frac{30000bd^2}{6} = 5000bd^2$

EQUATE PL & SOLVE FOR d

$\frac{5000\, bd^2 L^2 \times 12}{3\times10^7 \times bd^3} = .002$ $d = \frac{5000\, L^2 \times 12}{3\times10^7 \times .002} = L^2$

FOR $L = .625$ ON REAR FITTING $d = .39$ MAX

FOR $L = .750$ ON FRONT FITTING $d = .563$ MAX.

SINCE $d = .120$ STRESSES ARE OBVIOUSLY SATISFACTORY

BOLT PRELOADS

REAR

$P \times .680^3 = .002 \times 3\times10^7 \times 1.25 \times .120^3/12$

$P = 34.6$# SMALL

FRONT

$P \times .75^3 = .002 \times 3\times10^7 \times 1.25 \times .120^3/12$

$P = 25.6$# SMALL

OBVIOUSLY BOLTS CAN BE TIGHTENED TO THEIR RATED TORQUES.

FINAL ANALYSIS ~ LRRR STRUCTURE

ASTRONAUT HANDLE ANALYSIS DWG 2345750

DESIGN LOADS:

REFERENCE.

(2) LETTER NO. 9783-951-009 "FORCE EMISSION CAPABILITY OF THE SUITED ASTRONAUT."

LIMIT DESIGN LOAD = 20 X 1.5 = 30# (REF. 1 & 2)

ULT. DESIGN LOAD = 30 X 1.5 = 45#

CONDITIONS:

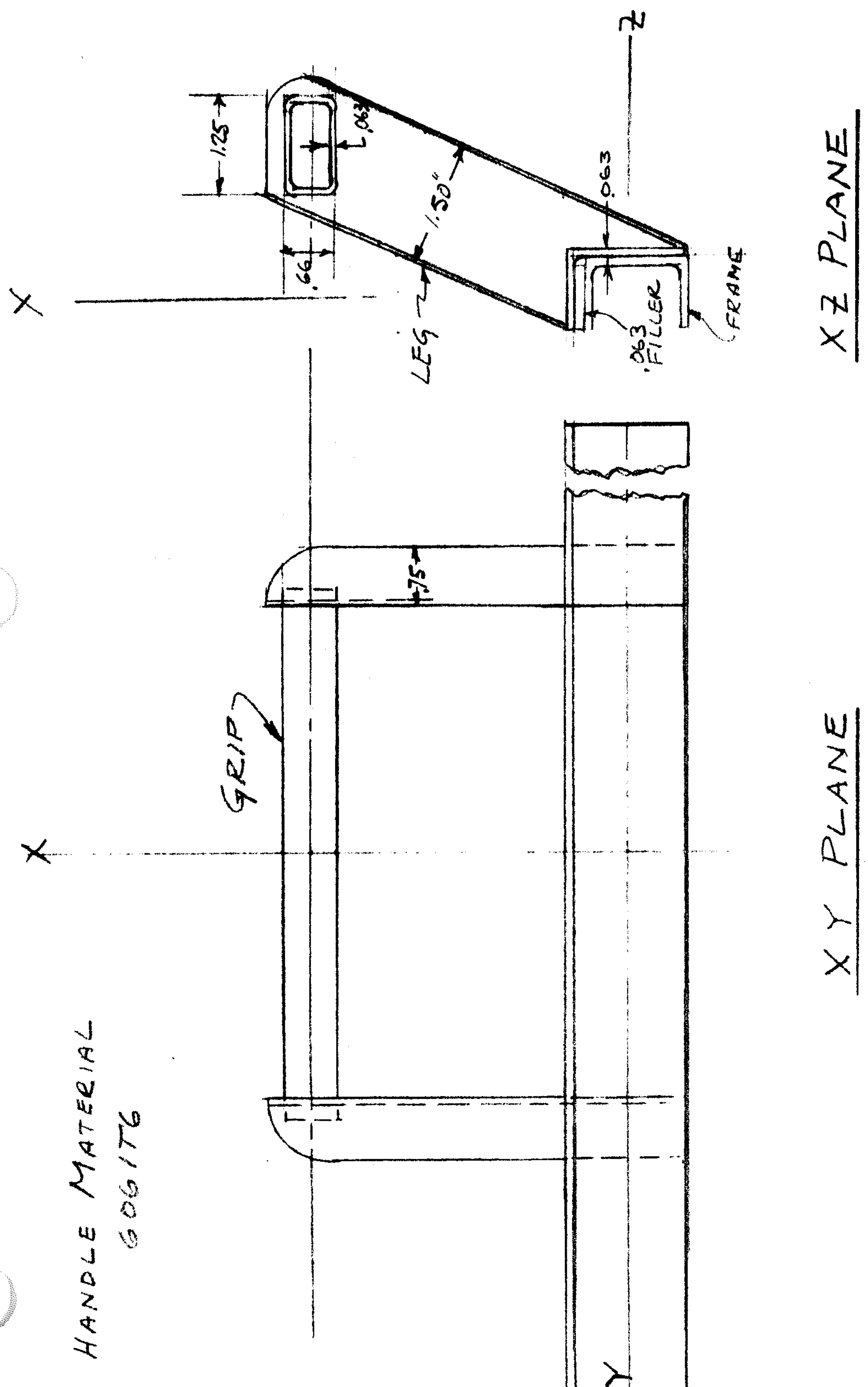
1. 45# SPREAD OVER 3" AT CENTER OF HANDLE IN X DIRECTION.
2. 45# SPREAD OVER 3" AT CENTER OF HANDLE IN Z DIRECTION.
3. 45# SPREAD OVER 3" AT EDGE OF HANDLE IN X DIRECTION
4. 45# SPREAD OVER 3" AT EDGE OF HANDLE IN Z DIRECTION.
5. 45# AT EDGE OF HANDLE IN Y DIRECTION.

NOTE:

SINCE IT IS APPARENT THAT MARGINS OF SAFETY ON THE HANDLE ARE HIGH, CONSERVATIVE ASSUMPTIONS WILL BE MADE TO EXPEDITE ANALYSIS AND DESIGN.

FINAL ANALYSIS ~ LRRR STRUCTURE

ASTRONAUT HANDLE ANALYSIS ~ DWG 2345750



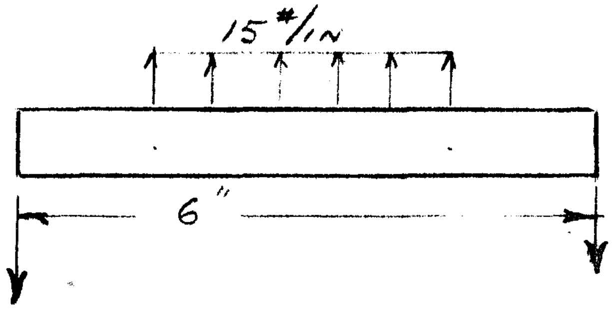
PREPARED BY J.H.O. CHECKED BY REVISED BY	**ENGINEERING REPORT** Bendix Aerospace Systems Division	DATE 4-23-70 PAGE E-36 REPORT No. ATM 871 MODEL LRRR

FINAL ANALYSIS ~ LRRR STRUCTURE

ASTRONAUT HANDLE ANALYSIS DWG 2345750

CONDITION 1 ~ CRITICAL FOR HANDLE GRIP -

ASSUME SIMPLE SUPPORT



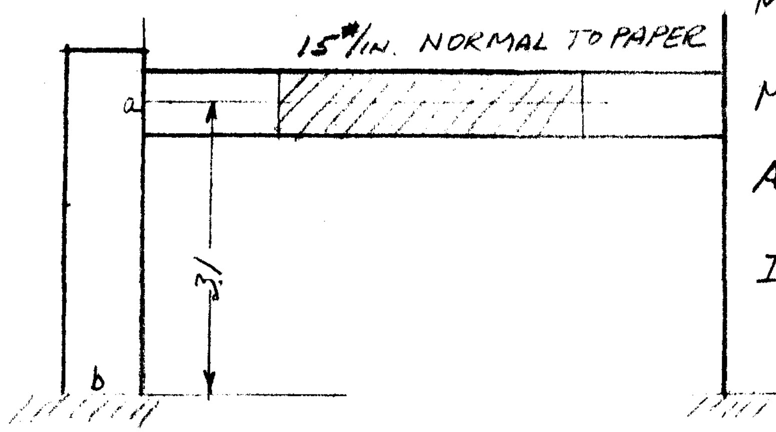
$$M_{MAX} = \frac{45}{2} \times 3 - \frac{15 \times \overline{1.5}^2}{2}$$

$$= 67.5 - 16.85 = 50.65$$

FROM TUBING HANDBOOK ASSUME RECT. TUBE 1.25 X .50 t = .065

$\frac{S}{2} = .0332$ $\sigma_b = \frac{50.65}{.0332} = 1525\ \#/\square''$ M.S AMPLE.

CONDITION 2 ~ ASSUME HANDLE GRIP FIXED AT ENDS. THIS CONDITION CRITICAL FOR TWISTING OF LEGS.



$$M_a = T_b = \frac{2}{3} \times 50.65 = 33.7\ ''\#$$

$$M_b = \frac{45}{2} \times 3.1 = 69.7\ ''\#$$

ASSUME A CHANNEL (.75, 1.5, t = .063)

$$I = \frac{.75 \times .063 \times \overline{1.44}^2}{2} + \frac{\overline{1.38}^3 \times .063}{12}$$

$$= .049 + .0138 = .0628$$

$$\sigma_b = \frac{69.7 \times .75}{.0628} = 832\ \#/\square''$$

$$\tau_s = \frac{3T}{\Sigma b t^2} = \frac{3 \times 33.7}{3 \times \overline{.063}^2} = 8500\ \#/\square''$$

M.S. AMPLE

PREPARED BY J.H.O.	ENGINEERING REPORT Bendix Aerospace Systems Division	DATE 4-23-70 PAGE 1-37
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REVISED BY		MODEL LRRR

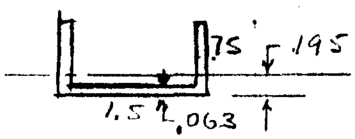
FINAL ANALYSIS ~ LRRR STRUCTURE

ASTRONAUT HANDLE ANALYSIS DWG 2345750

CONDITION 5

ASSUME $.75 \times 45 = 33.7^{\#}$ ON ONE LEG

$B.M. = 33.7 \times 3.1 = 105^{\text{"\#}}$



$$I = \frac{.75^3 \times .063 \times 2}{12} + .75 \times .063 \times 2 \times \overline{.18}^2 + 1.375 \times .063 \times \overline{.164}^2$$

$$= .0043 + .00306 + .00223 = .00959$$

$$\sigma_b = \frac{33.7 \times .555}{.00959} = 1950^{\#}/\square''$$

M.S. AMPLE

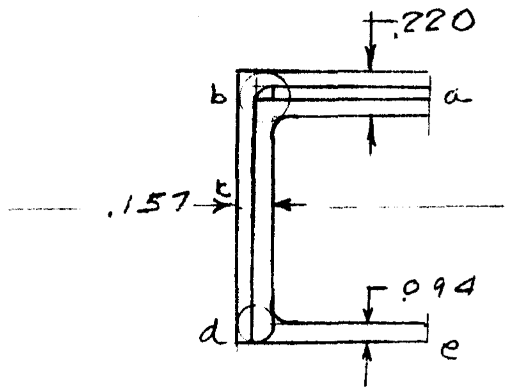
NOTE:

CONDITIONS 3 & 4 ARE OBVIOUSLY NOT CRITICAL

NAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY

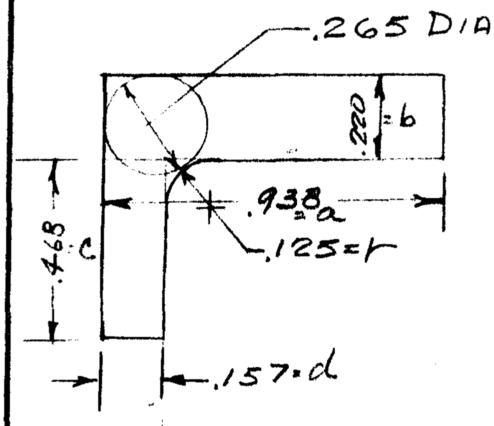
BACKUP STRUCTURE



NOTE:- THIS IS A BUILT UP SECTION, BUT IT WILL BE ANALYZED AS A SOLID SECTION SINCE IT IS RIVETED TOGETHER AT CLOSE INTERVALS. LOCAL STRESS PATTERNS MAY VARY BUT OVERALL STRESS & TWIST SHOULD APPROXIMATE THAT OF A SOLID SECTION.

REF.(7) ROARK "FORMULAS FOR STRESS AND STRAIN" TABLE IX CASE 20

SECT. a b c



$$K_1 = ab^3\left[\frac{1}{3} - 0.21\frac{b}{a}\left(1 - \frac{b^4}{12a^4}\right)\right]$$

$$= .938 \times \overline{.220}^3\left[.333 - .21 \times \frac{.220}{.938}\left(1 - \frac{\overline{.220}^4}{12 \times \overline{.938}^4}\right)\right]$$

$$= .010\left[.333 - .0492\right] = .00284$$

$$K_2 = cd^3\left[\frac{1}{3} - 0.105\frac{d}{c}\left(1 - \frac{d^4}{192c^4}\right)\right]$$

$$= .468 \times \overline{.157}^3\left[.333 - .105 \times \frac{.157}{.468}\right]$$

$$= .00181\left[.333 - .035\right] = .00054$$

$$\alpha = \frac{b}{d}\left(.07 + .076\frac{r}{b}\right) = \frac{.220}{.157}\left(.07 + .076 \times \frac{.125}{.220}\right)$$

$$= .159$$

$$K = K_1 + K_2 + \alpha D^4 = .00284 + .00054 + .159(.265)^4$$

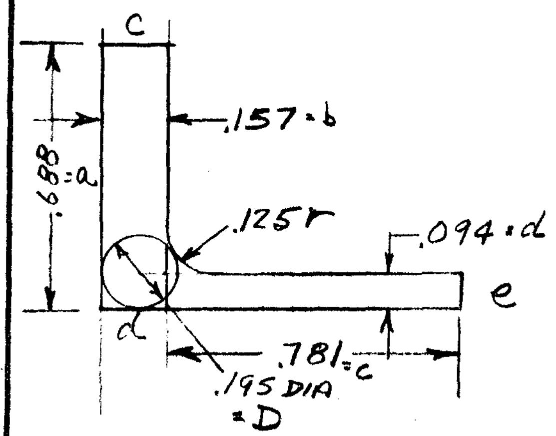
$$= .00284 + .00054 + .000786 = .003166$$

FINAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY

BACKUP STRUCTURE (CONTINUED)

SECT. cde



$$K_1 = ab^3\left[\frac{1}{3} - 0.21\frac{b}{a}\left(1 - \frac{b^4}{12a^4}\right)\right]$$

$$= .688 \times .157^3\left[.333 - .21 \times \frac{.157}{.688}\left(1 - \frac{.157^4}{12 \times .688^4}\right)\right]$$

$$= .00266[.333 - .0478] = .000758$$

$$K_2 = cd^3\left[\frac{1}{3} - 0.105\frac{d}{c}\left(1 - \frac{d^4}{192c^4}\right)\right]$$

$$= .781 \times .094^3\left[.333 - .105 \times \frac{.094}{.781}\right]$$

$$= .00083[.333 - .0013] = .000276$$

$$\alpha = \frac{b}{d}\left(.07 + .076\frac{r}{b}\right) = \frac{.157}{.094}\left(.07 + .076 \times \frac{.125}{.157}\right)$$

$$= 1.67(.07 + .0605) = .218$$

$$K = .000758 + .000276 + .218(.195)^4 =$$

$$= .000758 + .000276 + .000316 = .001350$$

$$\Sigma K = .003166 + .00135 = .004516$$

$$C = \frac{D}{1 + \frac{\pi^2 D^4}{16A^2}}\left[1 + .15\left(\frac{\pi^2 D^4}{16A^2} - \frac{D}{2r}\right)\right]$$

$$A = .267 + .656 \times .063 + 1.375 \times .063 + .875 \times .063$$

$$= .267 + .0413 + .0866 + .055$$

$$= .450$$

$$C_1 = \frac{.265}{1 + \frac{9.85 \times .265^4}{16 \times .450^2}}\left[1 + .15\left(\frac{9.85 \times .265^4}{16 \times .45^2} - \frac{.265}{.25}\right)\right]$$

.149 -

$$= \frac{.265}{1 + .149}\left[1 + (-.136)\right] = .200$$

$F_{SU} = 31000$ #/□
REF 8 - MIL HDBK5A

$$T_{ULT} = \frac{780}{2} = 390 \text{ "\#/SIDE}$$

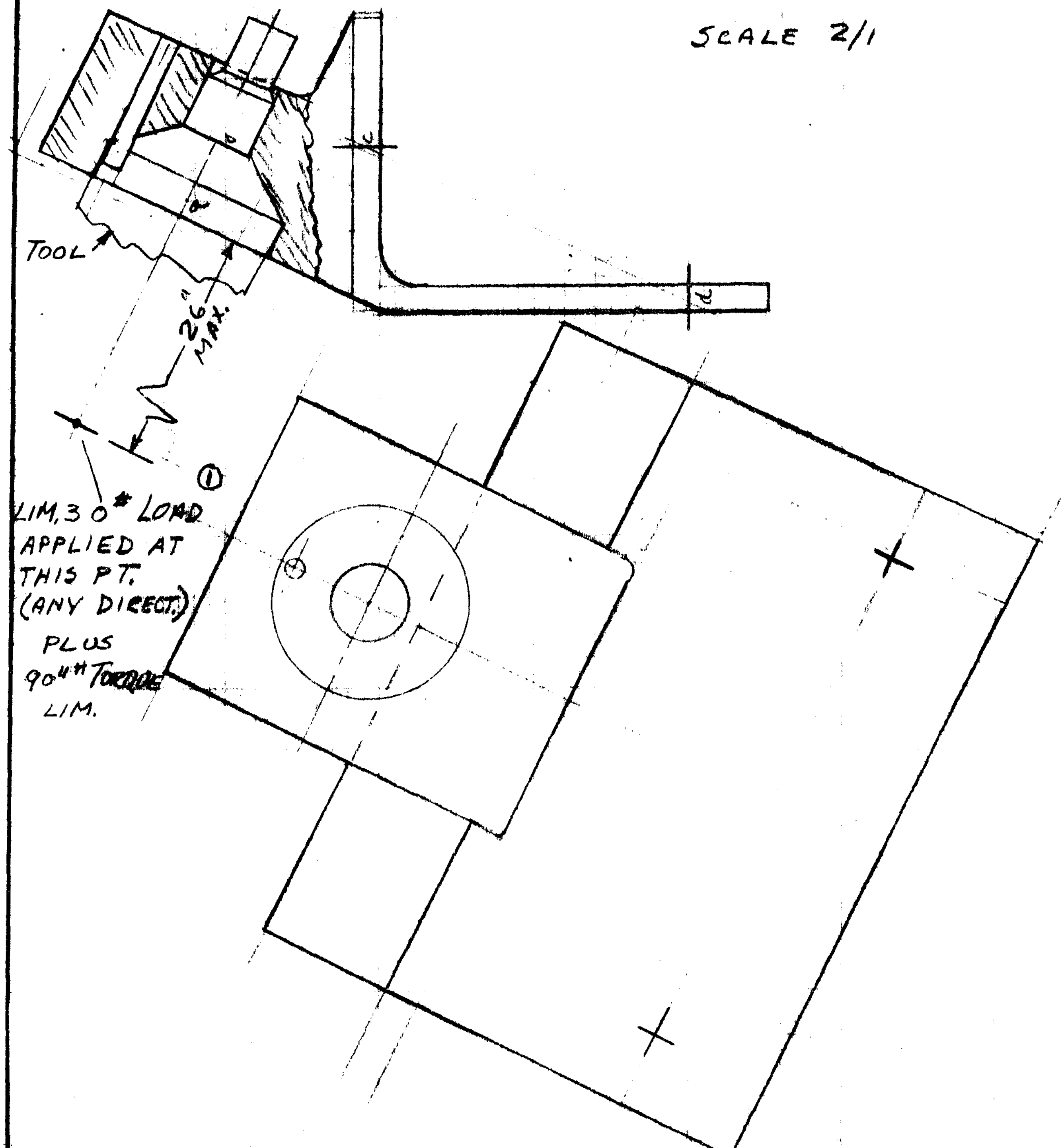
$$\tau = \frac{Tc}{\Sigma K} = \frac{390 \times .200}{.004516} = 17300 \text{ \#/□"}$$

$$M.S. = \frac{31000}{17300} - 1$$

$$= .79$$

FINAL ANALYSIS ~ LRRR STRUCTURE

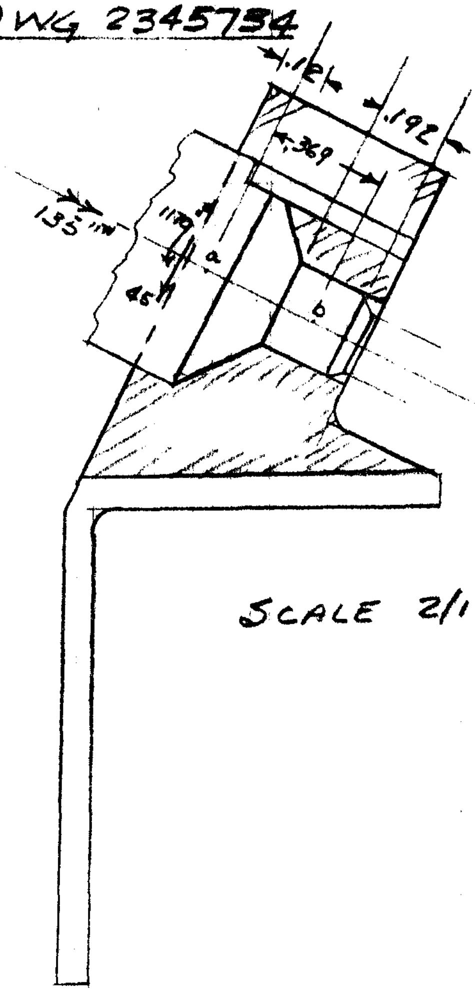
HANDLING SOCKET ASSEMBLY ~ DWG. 2345734



① REF 2. - LETTER NO. 9783-951-009 FORCE EMISSION CAPABILITY OF SUITED ASTRONAUT

FINAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY ~ DWG 2345734



SCALE 2/1

LOADS ON SOCKET ~ ULT.

$B.M. = (26 \times 30)1.5 = 1170''\#$

$T: 90 \times 1.5 = 135''\#$

$V: 30 \times 1.5 = 45\#$

$P_a = \frac{1170}{.369} + 45 = 3170 + 45 = 3215\#$

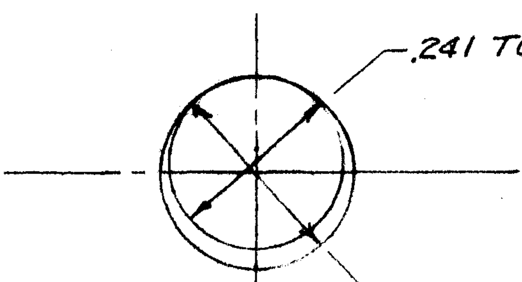
$P_b = 3170\#$

$p_a = \frac{3215}{.12} = 26800\#/in$

$p_b = \frac{3170}{.192} = 16500\#/in.$

BEARING COMPRESSION ANALYSIS

AT b



MATERIAL ~ TOOL & SOCKET 17-4PH STEEL

$F_{tu} = 190000$, $F_{cy} = 178000$ } REF. MIL HDBK 5A

$\sigma_c = .591\sqrt{pE\frac{D_1 - D_2}{D_1 D_2}}$ ① $= .591\sqrt{\frac{16500 \times 30 \times 10^6 (.250 - .241)}{.250 \times .241}} = 160000\#/\square''$ ULT

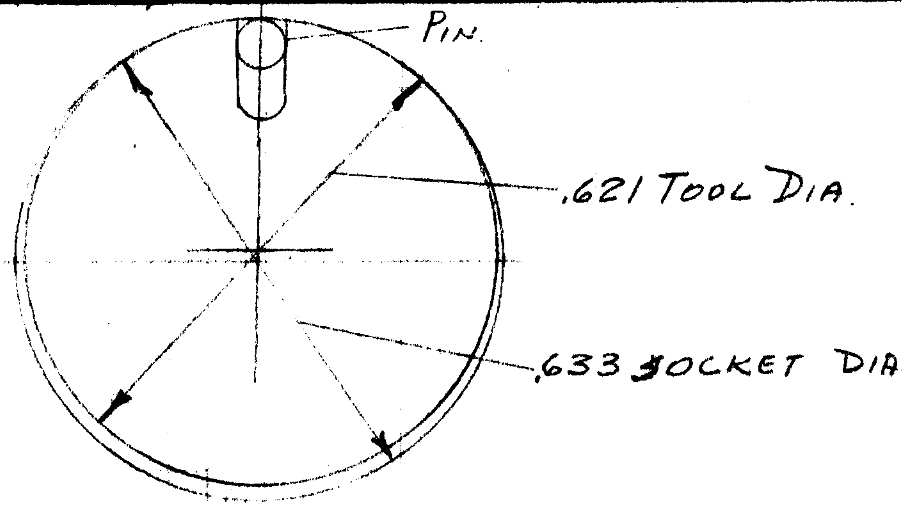
$\sigma_c = \frac{160000}{1.22} = 131000$ LIM. $M.S. = \frac{178000}{131000} - 1 = .36$

REF. TROARK "FORMULAS FOR STRESS & STRAIN"
TABLE XIV CASE 6

FINAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY ~ DWG. 2345134 (CONT.)

BEARING-COMPRESSION ANALYSIS AT a



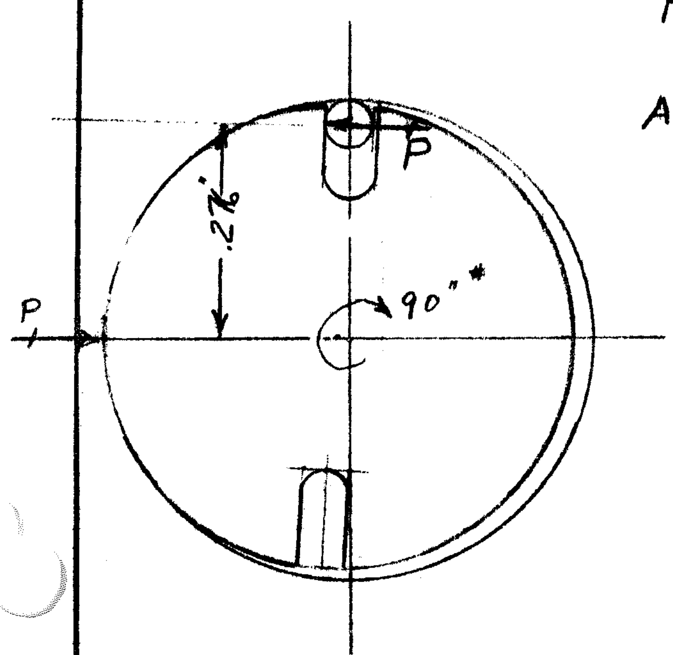
$$\sigma_c = .591\sqrt{pE\,\frac{D_1 - D_2}{D_1 D_2}} = .591\sqrt{\frac{26800 \times 30 \times 10^6 (.633 - .621)}{.633 \times .621}}$$

$$= .591 \times 157000 = 92500\ \#/\square'' \quad ULT$$

$$\sigma_c = \frac{92500}{1.22} = 76000\ LIM.$$

$$M.S. = \frac{178000}{76000} - 1 = 1.34$$

PIN LOAD AT a



$$P = \frac{90}{.276} = 325^{\#}$$

PIN MATERIAL
300M VAR STEEL

ASSUME .0625 DIA PIN

$F_{su} = 150000$ PSI (250 000 UTS)

$$P_{ALLOW} = (.0312)^2 \times 3.14 \times 150000$$

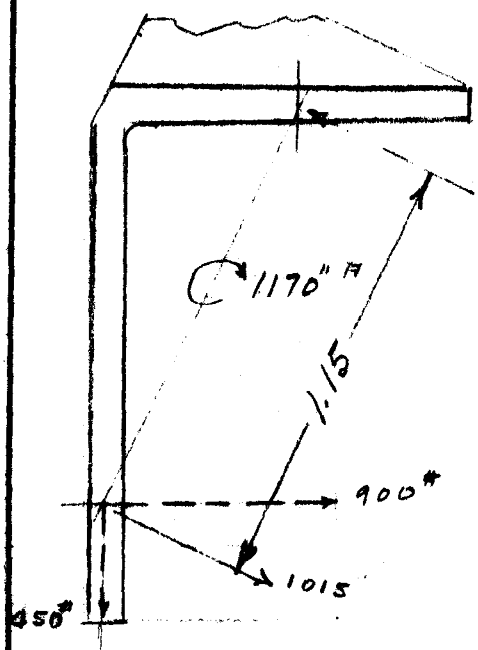
$$= 457^{\#}$$

$$M.S. = \frac{457}{325} - 1 = .41$$

FINAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY ~ DWG. 2345734 (CONT.)

SOCKET ATTACHMENT TO FRAME



FOR 125000 UTS BOLTS.

$P_{ALLOW} = 2629$ REF MIL HDBK 5A

$M.S. = \frac{2629}{450} - 1 = 4.85$

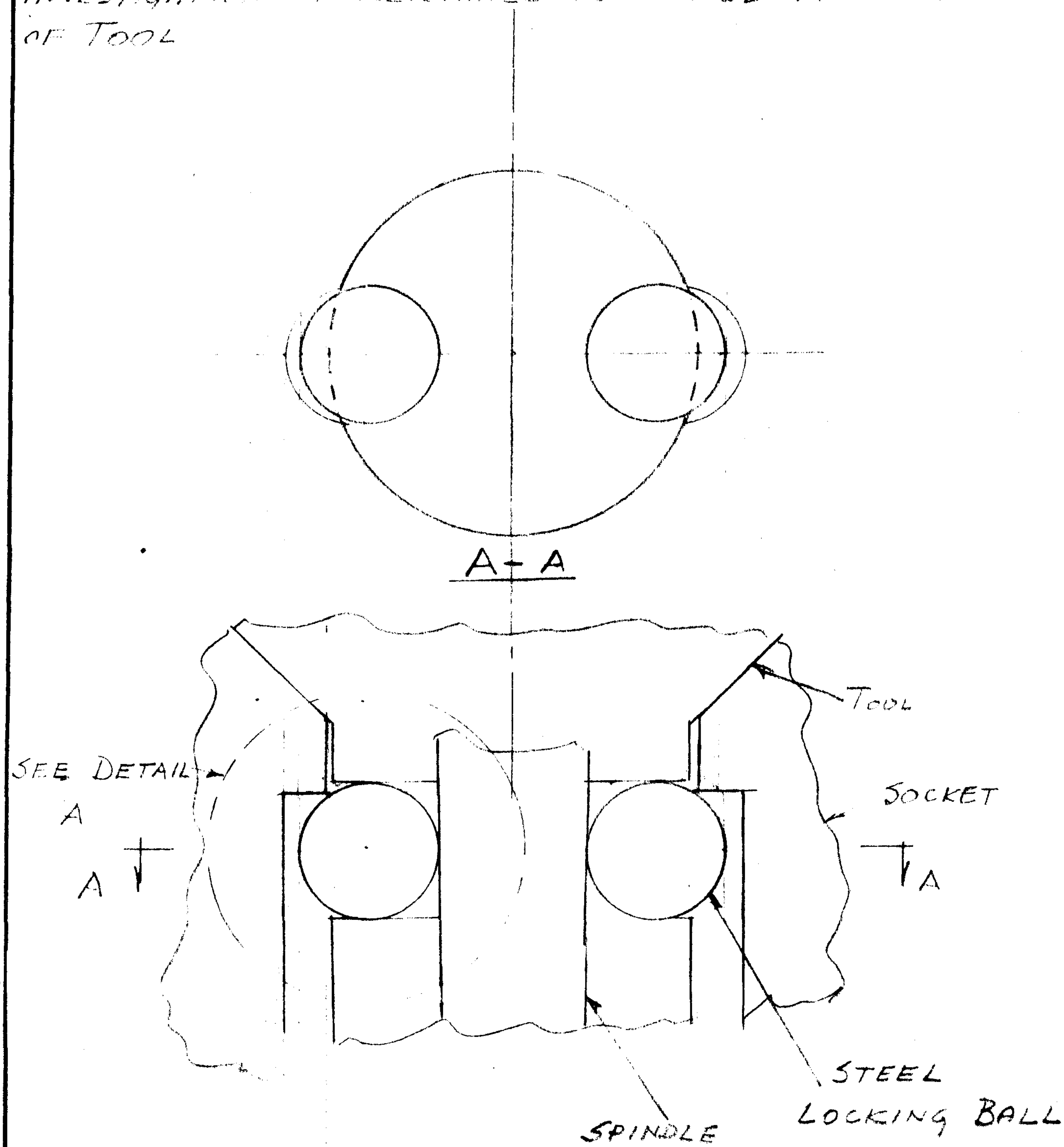
PER BOLT $\frac{900}{2} = 450\#$

OBVIOUSLY SATISFACTORY
IF SCREWS OR BOLTS ARE USED.

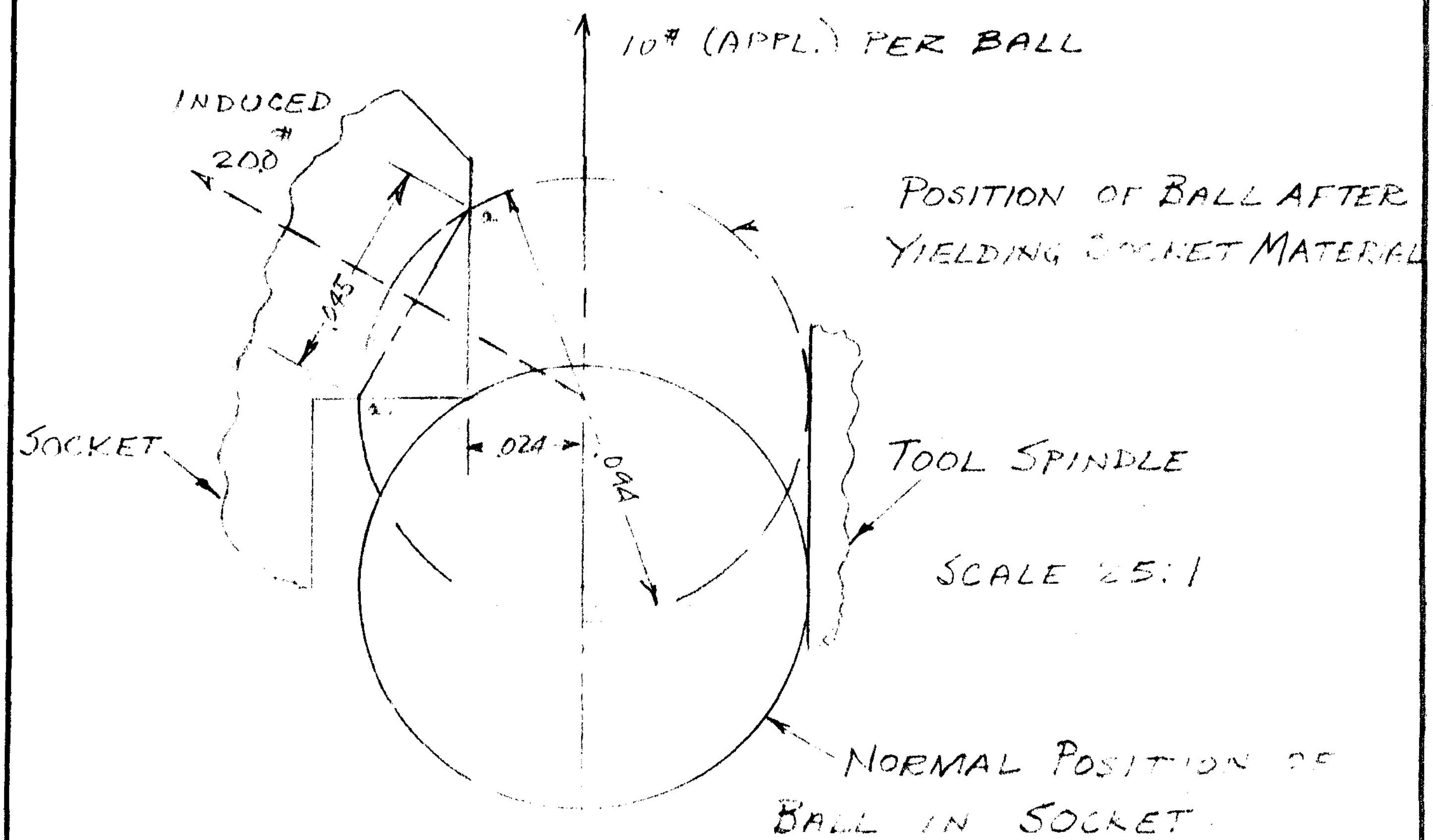
FINAL ANALYSIS ~ LRRR STRUCTURE

HANDLING SOCKET ASSEMBLY ~ DWG. 2345734

INVESTIGATION OF REISTANCE TO FORCED WITHDRAWAL OF TOOL



FINAL ANALYSIS ~ LRRR STRUCTURE
HANDLING SOCKET ASSEMBLY DWG. 2345734
INVESTIGATION OF RESISTANCE TO FORCED WITHDRAWAL OF TOOL



DETAIL "A"

SOCKET MATERIAL 17-4PH $F_{cy} = 170000$ PSI REF MIL HDBK5A
YIELD AREA OF 20.0# FORCE = 20/170000 = .118 X 10^{-3}

MAX BEARING AREA a-a = $\overline{.0225}^2$ X 3.14 = 15.9 X 10^{-4}

P_{MAX} = 15.9 X 10^{-4} X 17 X 10^{4} = 270#

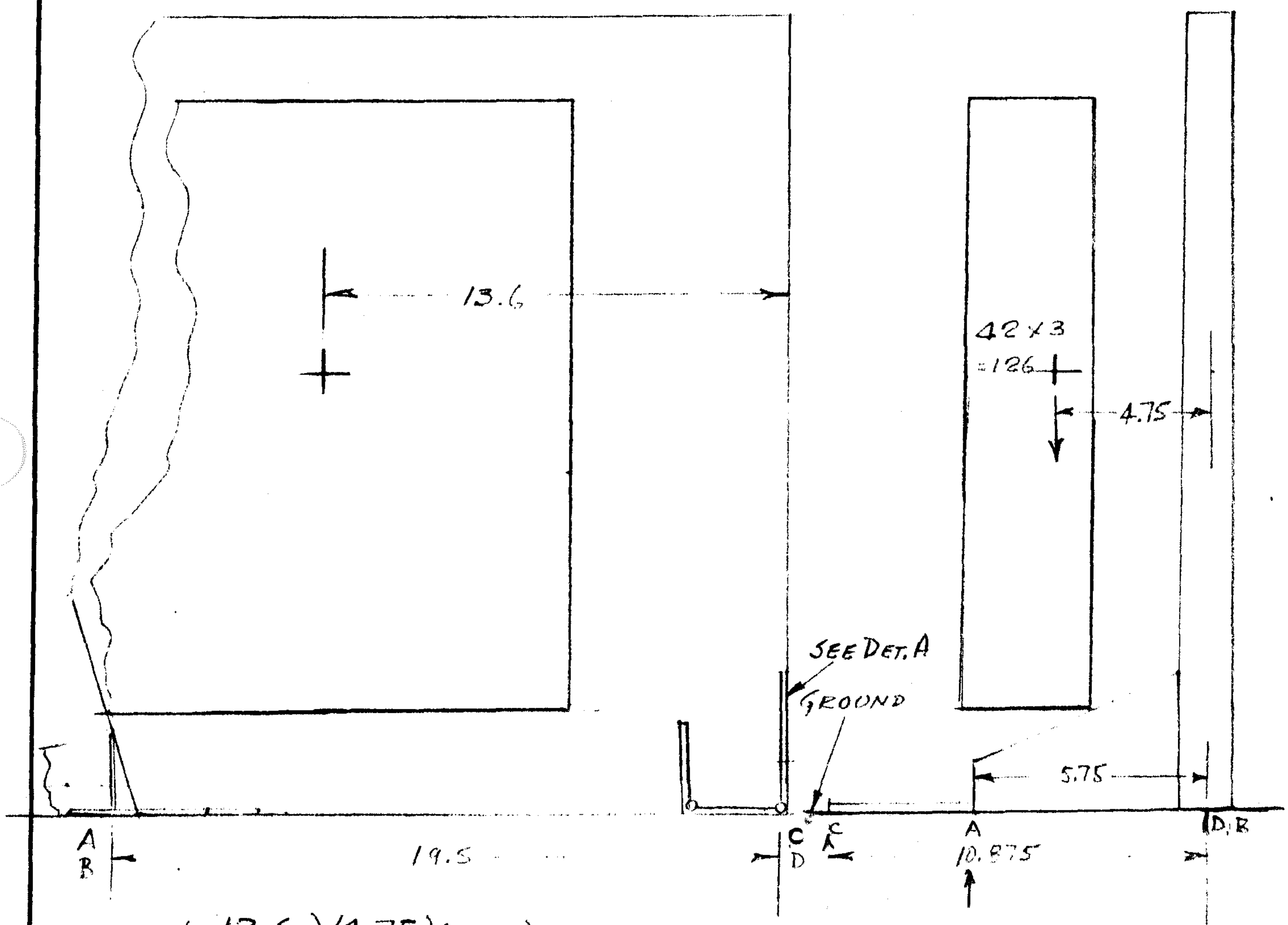
TOTAL APPL. FORCE TO WITHDRAW TOOL = $\frac{270}{20}$ X 10 X 2 = 270#

MAX FORCE ASTRONAUT IS CAPABLE OF APPLYING = 20#

FINAL ANALYSIS ~ LRRR STRUCTURE

GROUND SUPPORT STRUCTURE

CONSERVATIVELY ASSUME AN ULTIMATE LOAD OF 3 X 42 = 126#



$$R_A = \left(\frac{13.6}{19.5}\right)\left(\frac{4.75}{5.75}\right)(126) = 72.6$$

$$R_B = \left(\frac{13.6}{19.5}\right)\left(\frac{1}{5.75}\right)126 = 15.4$$

$$R_C = \left(\frac{5.9}{19.5}\right)\left(\frac{4.75}{10.875}\right)126 = 16.6$$

$$R_D = \left(\frac{5.9}{19.5}\right)\left(\frac{6.125}{10.875}\right)126 = 21.4$$

FINAL ANALYSIS ~ LRRR STRUCTURE

GROUND SUPPORT STRUCTURE

DET. A ~ REAR SUPP'T. L.H. ~ DWG. 2345740

$M_A = 16.6 \times 4.63 = 77$ "# $\qquad F_{tu} = 62000$

$\sigma_A = \frac{77 \times 32}{\pi \times .313^3} = 25700$ #/□" $\qquad$ REF: MIL HDBK 5A

$M.S. = \frac{62000}{25700} - 1 = 1.41$

$\delta_{MOON} = \frac{77}{3 \times 6} \times 4.63^2 \times \frac{1 \times 64}{3 \times 10^7 \times \pi \times .313^4} = .0064$ SMALL

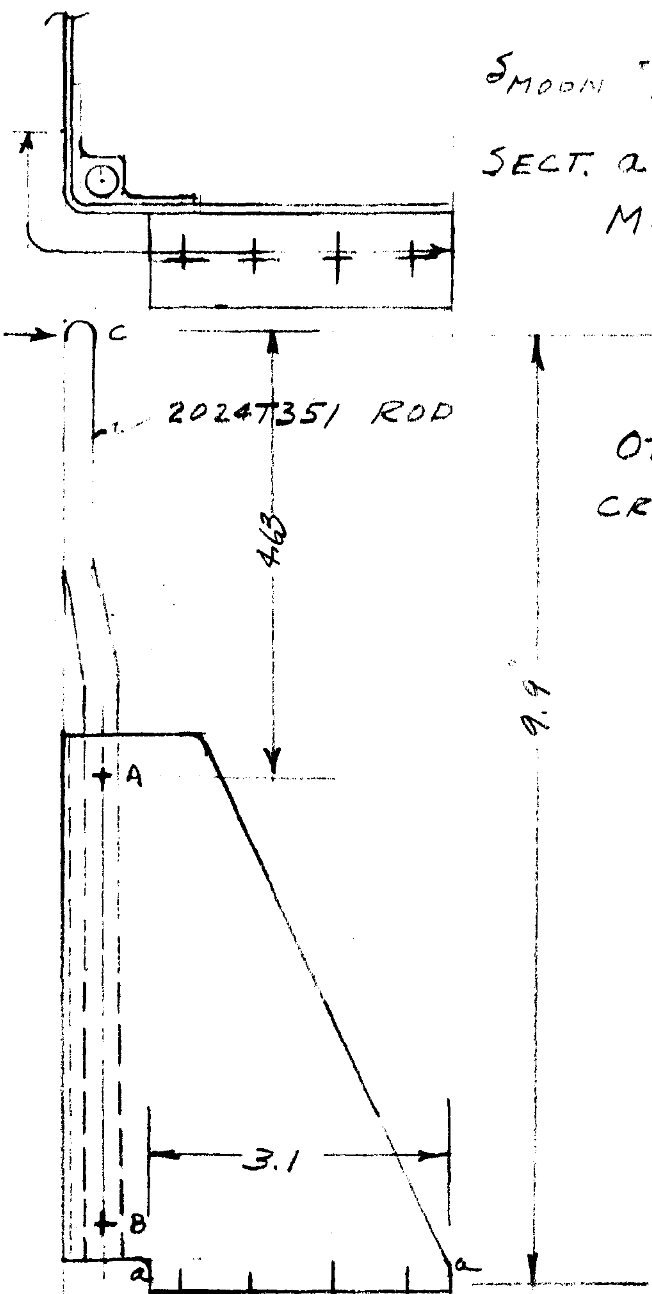
SECT. a-a:-

$M = 16.6 \times 9.9 = 164.5$ "#

$\sigma_{a\text{-}a} = \frac{164.5 \times 6}{3.1^2 \times .050} = 2050$ #/□"

M.S. AMPLE

OTHER AREAS OBVIOUSLY NOT CRITICAL.



STRUCTURAL/DYNAMICS ANALYSIS

REPORT - LRRR

SECTION 2

VIBRATION AND DYNAMIC LOADS ANALYSIS

SECTION 2.0 VIBRATION AND DYNAMIC LOADS ANALYSIS

2.1.0 Introduction and Summary

A dynamics analysis has been performed for the array and support structure system being designed for the Apollo 14 LRRR. The objectives here are to determine the effects on the dynamics environment as seen by the array and to determine the dynamic loads within the structure since the support structure is changed considerably, i.e., from a honeycomb pallet to a beam grid work. In addition, the applied environment from the LM attachment points is decreased from the Apollo 11 LRRR levels.

Results of the calculations indicate that the vibration specifications for the array structure remain adequate and need not be re-defined.

The acceleration responses were also used to determine the dynamic loads resulting from the random and sine environments. Loads from the random environment are the largest and are presented in this section.

Finally, a brief discussion of Apollo 11 LRRR measured vibration data is given.

2.2.0 Dynamics Analysis Model

The dynamics analysis model is similar to the Apollo 11 case; however, the support structure is of a different type. Incorporation of this support structure into the dynamics model is still in the form of influence coefficients at the four attachment points which are developed in another computer program. Details of that portion are given in Section 3.

The objectives of the dynamics analysis are to compute the accelerations at selected locations throughout the structure and to determine the resulting dynamic loads associated with these accelerations. When these loads are determined for the generalized coordinate locations, they can then be applied to the support frame for calculation of internal loads, stresses and displacements.

The method of dynamics analysis used is the normal mode method with refinements to account for both sine and random inputs. Details and results of the application to the previous LRRR structural system are given EATM 19, dated 7 Jan 1969 and EATM 53, dated 26 March 1969. Application to a lunar vehicle analysis is discussed in BSR 2835, dated November 1969.

The dynamics analysis model is shown in Figure 1.

Input levels are shown in Figure 2 for the random input and in Figure 3 for the sine input.

The mass matrix for the present configuration is shown in Figure 4 and the stiffness matrix is shown in Figure 5. Derivation of the stiffness matrix is discussed in Section 2.4.0.

The mass matrix is derived from the six degree of freedom, 32 lb array mass (as before) transformed from the array c.g. to the attachment coordinates. The lower structure is added in as four (unequal) lumped masses which are derived from dynamic deflection considerations. One flexible mode is also considered in the array deflections.

Generalized coordinates for which the response calculations were made are defined as relative to the input base motion coordinates. Specific locations of the coordinates are as follows:

u_1, u_2, u_3 — X-direction at array/bracket interface

u_c — X-direction at center of array.

v_1, v_2 — Y-direction at array/bracket interface

w_1 — Z-direction at array/bracket interface

x_1, x_2, x_3, x_4 — X-direction at bottom of bracket

Subscript number refers to location shown on Figure 1.

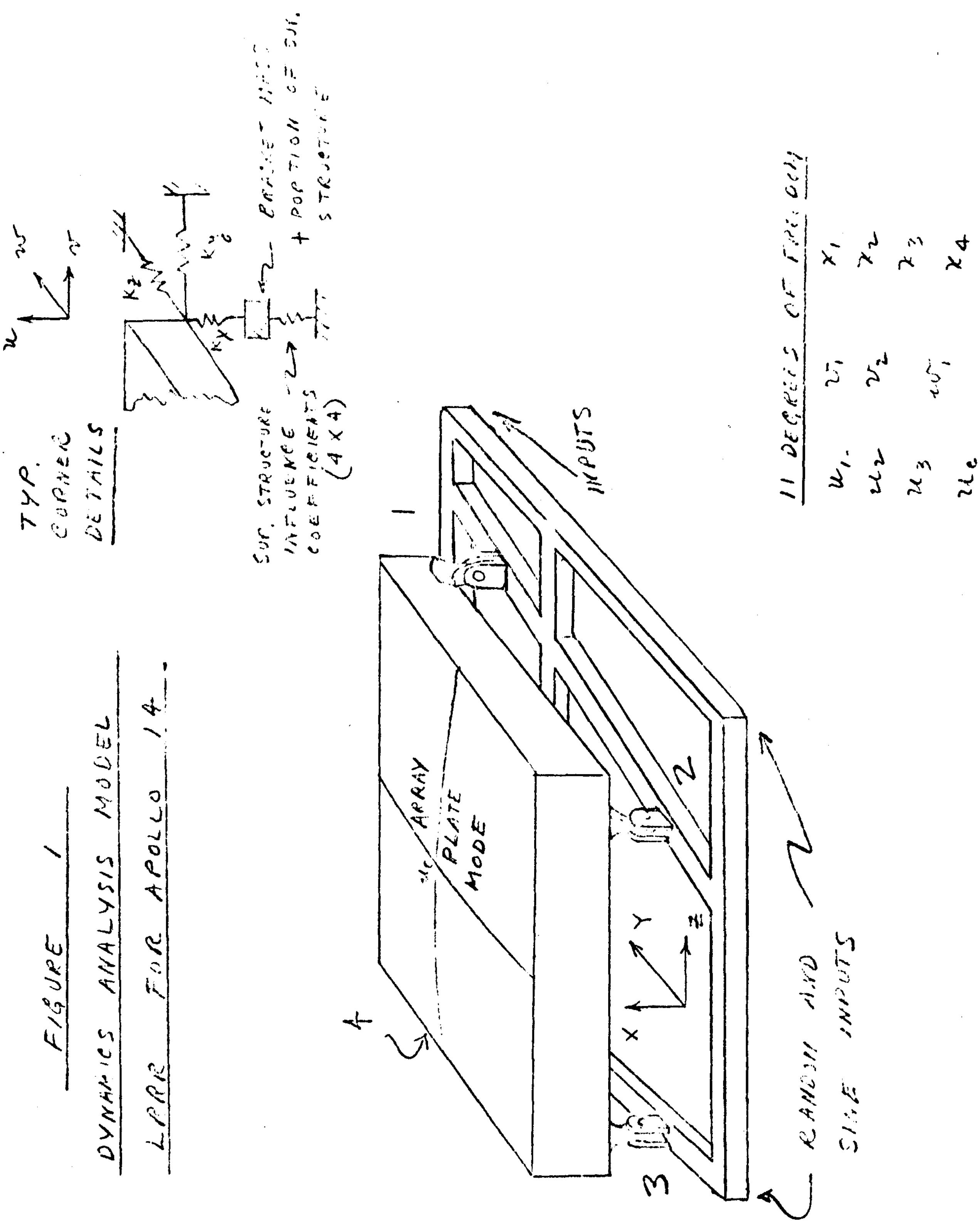


FIGURE 1
DYNAMICS ANALYSIS MODEL
LRRR FOR APOLLO 14

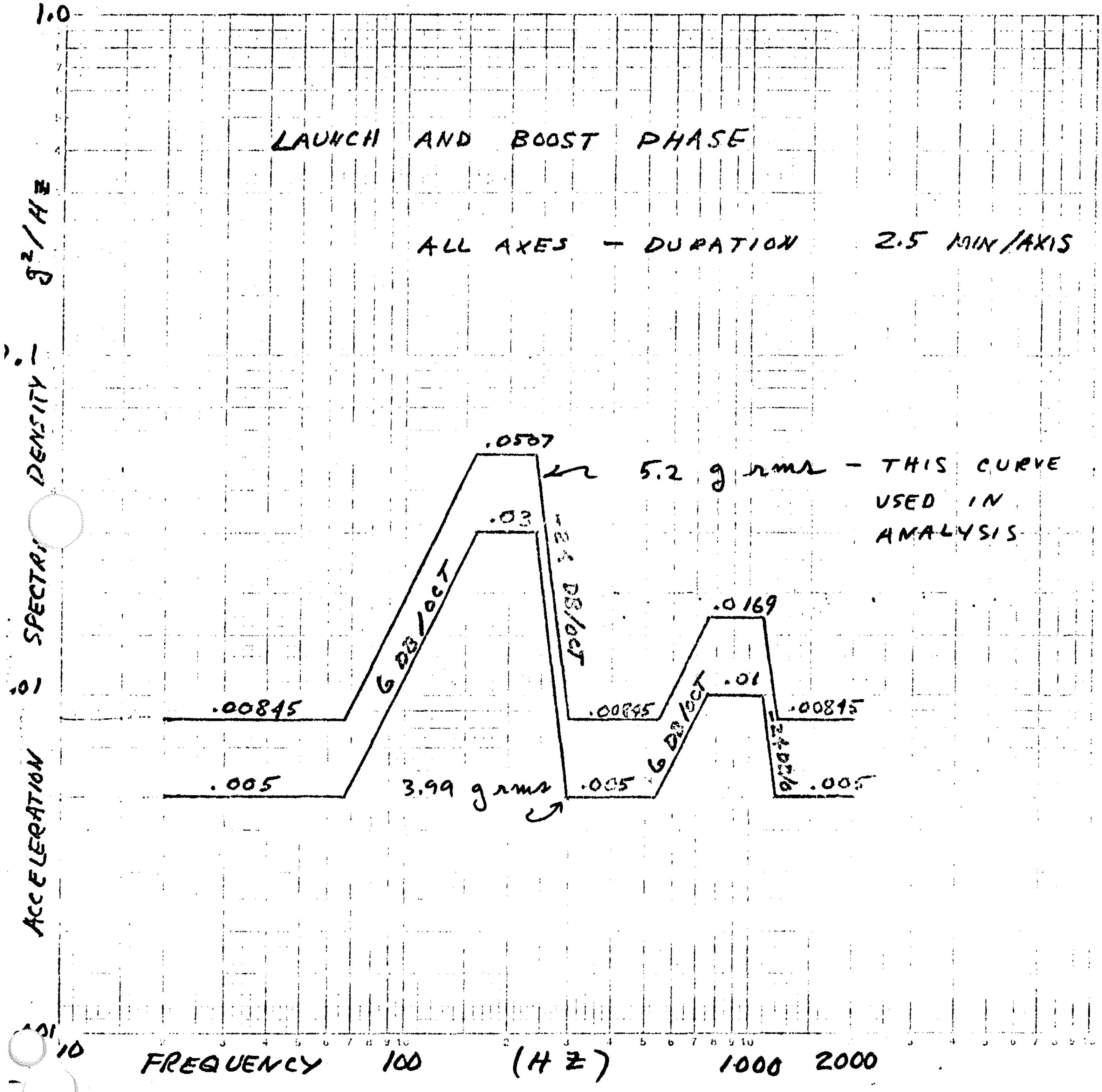


FIGURE 2. RANDOM INPUT

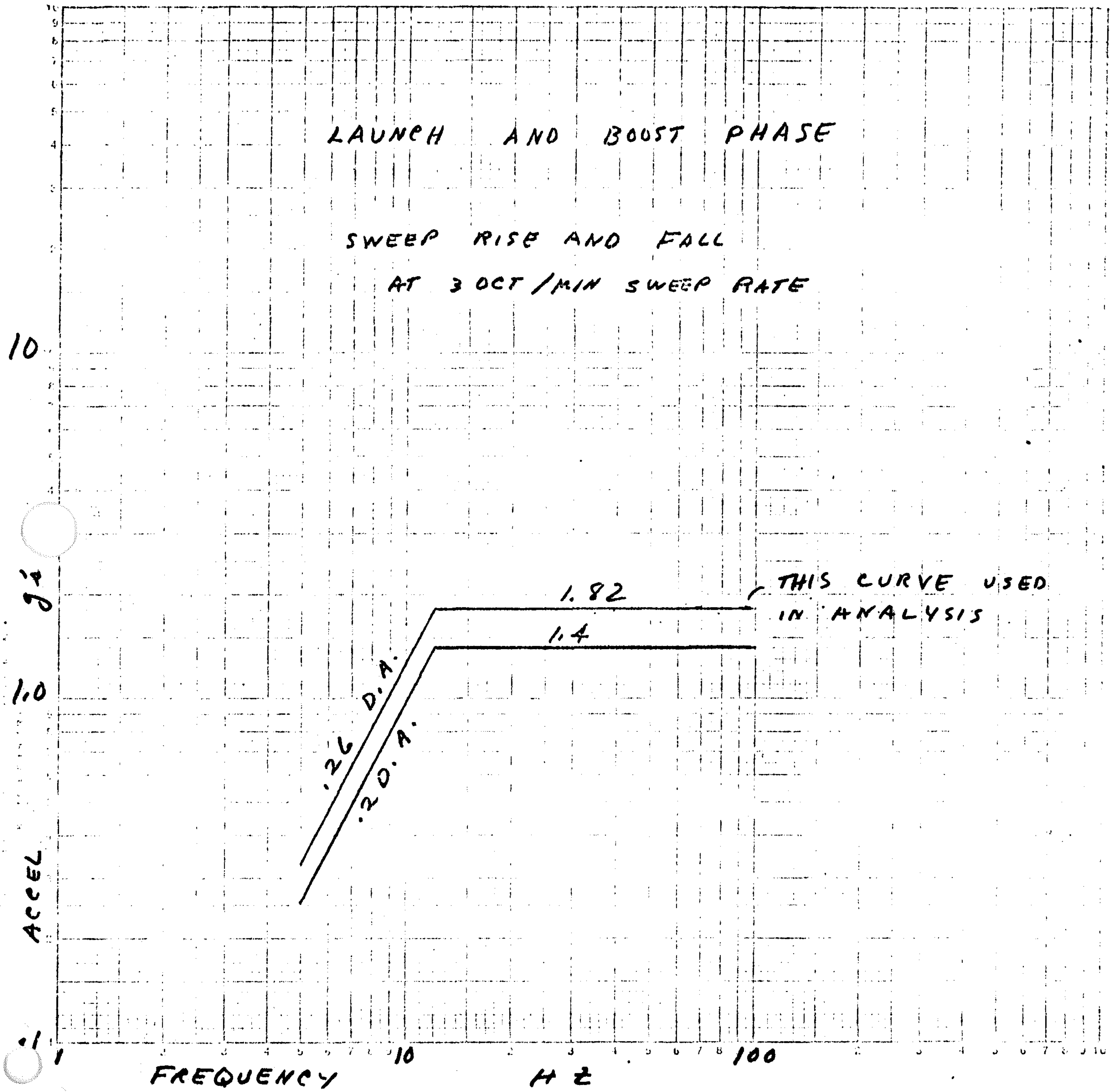


FIGURE 3. SINE INPUT

MASS MATRIX

FIGURE 4

1	0.734000D-02	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.480000D-02	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	
3	0.0	0.0	0.462000D-02	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	
4	0.0	0.0	0.0	0.665000D-02	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	
5	0.0	0.0	0.0	0.0	0.403400D-01	-0.428200D-01
	0.234400D-01	-0.232900D-01	0.232900D-01	-0.330800D-01	0.726000D-02	
6	0.0	0.0	0.0	0.0	-0.428200D-01	0.894800D-01
	-0.563100D-01	0.853000D-02	-0.468200D-01	0.436700D-01	-0.340000D-02	
7	0.0	0.0	0.0	0.0	0.234400D-01	-0.563100D-01
	0.577700D-01	0.147600D-01	0.235300D-01	-0.105900D-01	0.878000D-02	
8	0.0	0.0	0.0	0.0	-0.232900D-01	0.853000D-02
	0.147600D-01	0.969000D-01	-0.489400D-01	0.582200D-01	0.0	
9	0.0	0.0	0.0	0.0	0.232900D-01	-0.468200D-01
	0.235300D-01	-0.489400D-01	0.836700D-01	-0.582200D-01	0.0	
10	0.0	0.0	0.0	0.0	-0.330800D-01	0.436700D-01
	-0.105900D-01	0.582200D-01	-0.582200D-01	0.827000D-01	0.0	
11	0.0	0.0	0.0	0.0	0.726000D-02	-0.340000D-02
	0.878000D-02	0.0	0.0	0.0	0.207000D-01	

FIGURE 5

APOLLO 14 LRRR APRIL 1970

STIFFNESS MATRIX* 0.10000000D-05

1	0.10164D 01	-0.46164D-02	-0.25824D-03	-0.24220D-03	-0.10080D 01	0.0
	0.0	0.0	0.0	0.0	0.0	
2	-0.46164D-02	0.10154D 01	0.82900D-05	-0.32220D-03	0.0	-0.10080D 01
	0.0	0.0	0.0	0.0	0.0	
3	-0.25824D-03	0.82900D-05	0.10213D 01	-0.90450D-02	0.0	0.0
	-0.10080D 01	0.0	0.0	0.0	0.0	
4	-0.24220D-03	-0.32220D-03	-0.90450D-02	0.10196D 01	-0.10020D 01	0.16955D 01
	-0.16934D 01	0.0	0.0	0.0	0.0	
5	-0.10080D 01	0.0	0.0	-0.10020D 01	0.20741D 01	-0.17175D 01
	0.17667D 01	0.0	0.0	0.0	-0.12093D 00	
6	0.0	-0.10080D 01	0.0	0.16955D 01	-0.17175D 01	0.38745D 01
	-0.28866D 01	0.0	0.0	0.0	0.55461D-01	
7	0.0	0.0	-0.10080D 01	-0.16934D 01	0.17667D 01	-0.28866D 01
	0.39522D 01	0.0	0.0	0.0	-0.14387D 00	
8	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.45855D-01	-0.16085D-01	0.17810D-01	0.0	
9	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	-0.16085D-01	0.16085D-01	-0.17810D-01	0.0	
10	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.17810D-01	-0.17810D-01	0.28220D-01	0.0	
11	0.0	0.0	0.0	0.0	-0.12093D 00	0.55461D-01
	-0.14387D 00	0.0	0.0	0.0	0.20850D 00	

2.3.0 Computed Accelerations

Responses at all 11 coordinate locations were calculated for excitation in each of the three axes. A summary of all these values except X_1, X_2, X_3, and X_4 is shown in Table 1 wherein the maximum sinusoidal acceleration is given along with the rms value of acceleration.

The natural frequencies and mode shapes of the 11 degree of freedom system are given in Table 2.

Plotted response curves in selected locations and directions of excitation are shown in Figures 6 through 14 where each set is in three parts.

In Figure 8c the QUAL random level specified to ADL is shown along with the computed curve at that point which is typical of the acceleration values in the X direction at the corners of the array. As before, the curve exceeds the 0.1 g^2/cps specified level at a low frequency peak, but the overall level is still much less, i.e., 3.739 G-rms compared to 16.1 G-rms specified and is therefore no problem since there are no natural frequencies for the array structure down in the 40-50 Hz range. Similar observations can be made regarding the computed responses for the Y-direction, Figures 10c and 11c and the z-direction Figure 14c.

TABLE 1

COMPUTED ACCELERATION RESPONSES

LOCATION NUMBER	RESPONSE COORDINATE	MAX. SINE RESPONSE G's			RANDOM RESPONSE G - RMS		
	EXC. -	X	Y	Z	X	Y	Z
5	u_1	12.6	2.51	4.02	3.73	3.44	1.87
6	u_2	11.2	1.40	4.42	3.68	1.66	3.20
7	u_3	11.1	1.76	3.56	3.74	2.37	2.80
11	u_c	16.5	.18	.54	8.98	.05	.22
8	v_1	.1	2.69	.47	.1	5.50	.49
9	v_2	.54	8.21	4.02	.17	2.58	1.07
10	w_1	.88	4.12	7.64	.54	2.31	3.64

MAX "Q" = 5 FOR ANY ONE MODE

TABLE 2 …TURAL FREQUENCIES

MODE 1

EIGENVALUE= 0.11817D-04
FREQUENCY= 0.46299D 02

EIGENVECTORS
-0.29019D 00
-0.16061D 00
0.21984D 00
0.34693D 00
-0.29182D 00
-0.16051D 00
0.21962D 00
0.16221D 00
0.10000D 01
0.50989D 00
0.25336D-01

MODE 2

EIGENVALUE= 0.92751D-05
FREQUENCY= 0.52259D 02

EIGENVECTORS
0.99697D 00
0.87171D 00
0.85957D 00
0.97107D 00
0.10000D 01
0.87282D 00
0.86154D 00
-0.90953D-02
-0.47319D-01
-0.45668D-01
0.95869D 00

MODE 3

EIGENVALUE= 0.48599D-05
FREQUENCY= 0.72195D 02

EIGENVECTORS
0.99413D 00
0.27761D 00
-0.79717D 00
-0.81117D 00
0.10000D 01
0.27509D 00
-0.79992D 00
-0.12739D 00
0.83045D 00
0.26717D 00
-0.46763D-01

MODE 4

EIGENVALUE= 0.37208D-05
FREQUENCY= 0.82509D 02

EIGENVECTORS
0.34169D 00
0.66160D 00
0.47893D-01
-0.67954D 00
0.34098D 00
0.66429D 00
0.54483D-01
-0.40470D-01
0.59913D 00
0.10000D 01
0.61188D-01

MODE 5

EIGENVALUE= 0.11490D-05
FREQUENCY= 0.14843D 03

EIGENVECTORS
0.66849D 00
0.20467D 00
-0.49293D 00
-0.50544D 00
0.66910D 00
0.20262D 00
-0.49311D 00
0.10000D 01
0.37101D 00
-0.31198D 00
-0.73723D-02

MODE 6

EIGENVALUE= 0.86346D-06
FREQUENCY= 0.17128D 03

EIGENVECTORS
-0.48971D 00
0.99565D 00
0.82731D 00
-0.75034D 00
-0.49423D 00
0.10000D 01
0.84072D 00
0.20331D 00
0.45333D-01
-0.99229D 00
0.33481D-01

MODE 7

EIGENVALUE= 0.49755D-07
FREQUENCY= 0.71351D 03

EIGENVECTORS
-0.50073D 00
-0.50173D 00
-0.51137D 00
-0.51142D 00
-0.42905D 00
-0.45496D 00
-0.46630D 00
0.53860D-02
0.52940D-02
0.90040D-02
0.10000D 01

MODE 8

EIGENVALUE= 0.54017D-08
FREQUENCY= 0.21655D 04

EIGENVECTORS
-0.95374D 00
0.10000D 01
-0.83435D 00
0.71345D 00
0.31958D 00
0.12994D 00
-0.14363D 00
0.12708D 00
0.12671D 00
0.40634D-01
-0.34506D-01

MODE 9

EIGENVALUE= 0.43539D-08
FREQUENCY= 0.24120D 04

EIGENVECTORS
0.76508D 00
-0.24536D 00
-0.78875D 00
0.10000D 01
-0.50717D 00
0.17430D-01
0.21695D-01
-0.20613D-02
-0.20853D-02
-0.20959D 00
0.19232D 00

MODE 10

EIGENVALUE= 0.36699D-08
FREQUENCY= 0.26272D 04

EIGENVECTORS
0.39131D 00
0.10000D 01
-0.61156D 00
-0.54640D 00
-0.38612D 00
-0.29180D 00
0.19608D 00
-0.22643D 00
-0.22592D 00
0.25136D-01
0.49131D-02

MODE 11

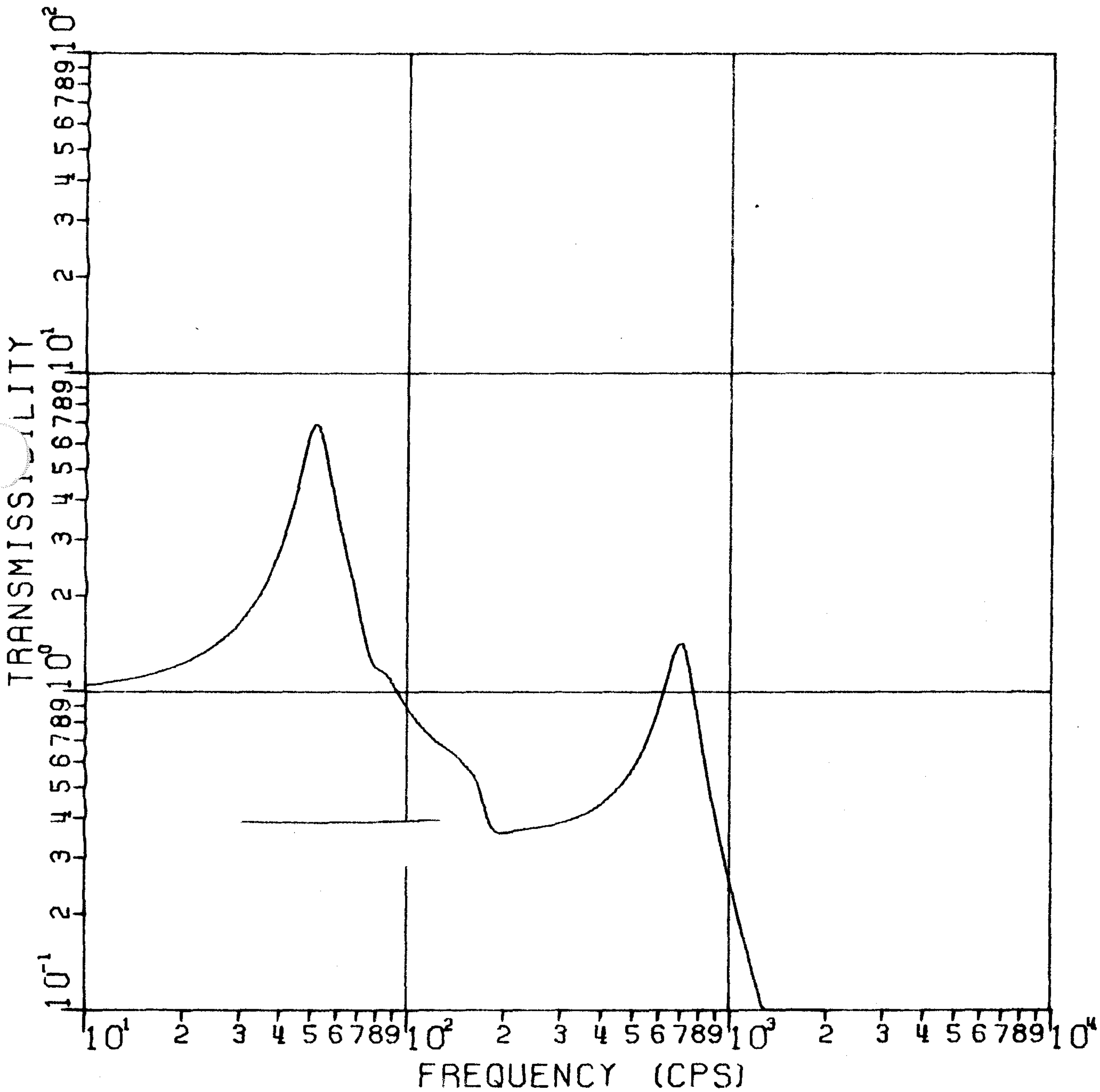
EIGENVALUE= 0.28424D-08
FREQUENCY= 0.29852D 04

EIGENVECTORS
0.20152D 00
0.85255D 00
0.10000D 01
0.27306D 00
-0.31730D 00
-0.57046D 00
-0.60178D 00
0.14527D-01
0.14503D-01
0.97328D-01
0.29406D 00

1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 6a TRANSMISSIBILITY

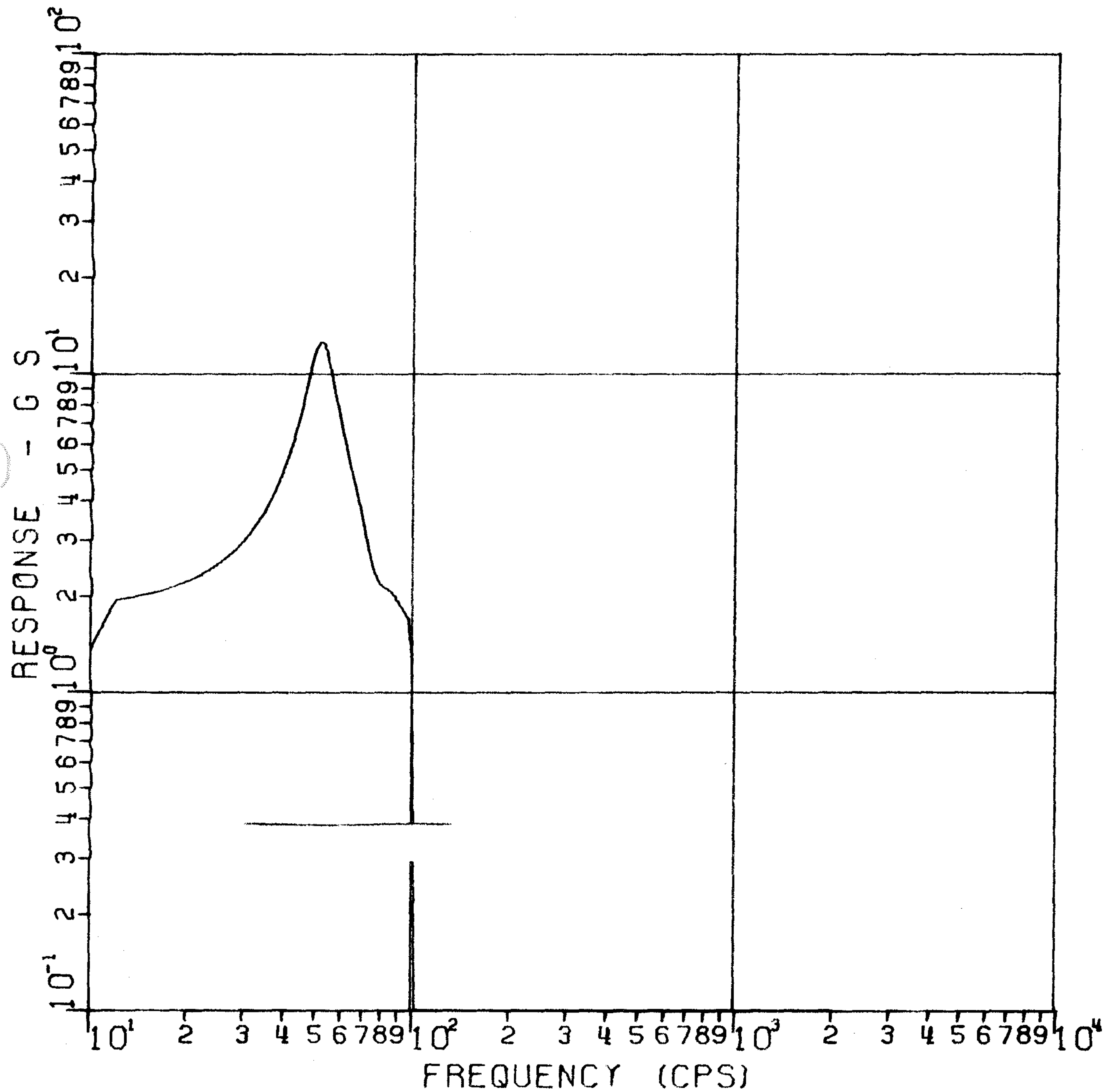
LOCATION 5



1 X AXIS APOLLO 14 LRRR APRIL 197

FIGURE 6b SINE RESPONSE

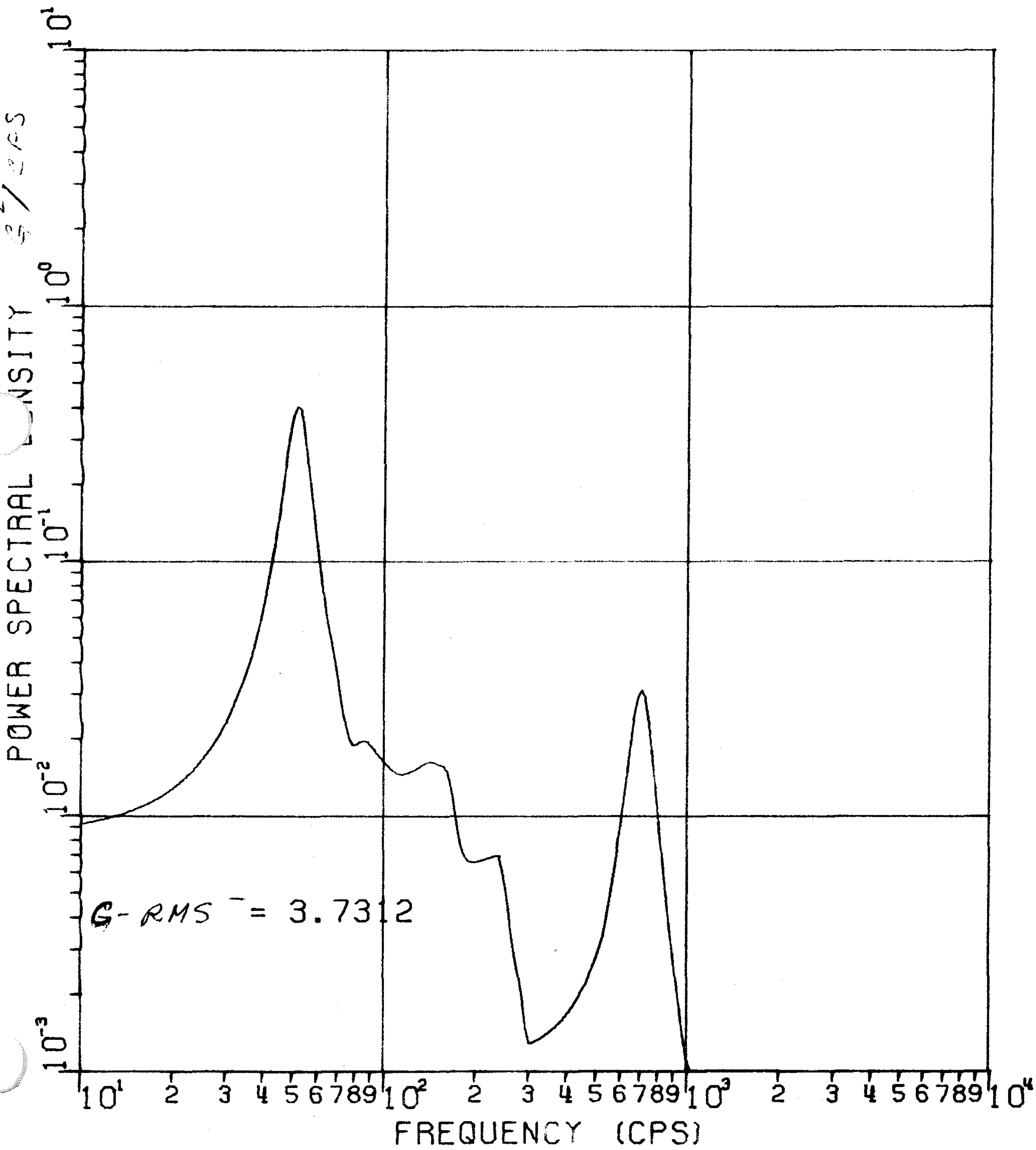
LOCATION 5, 11,



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 6 c RANDOM VIBRATION SPECTRUM

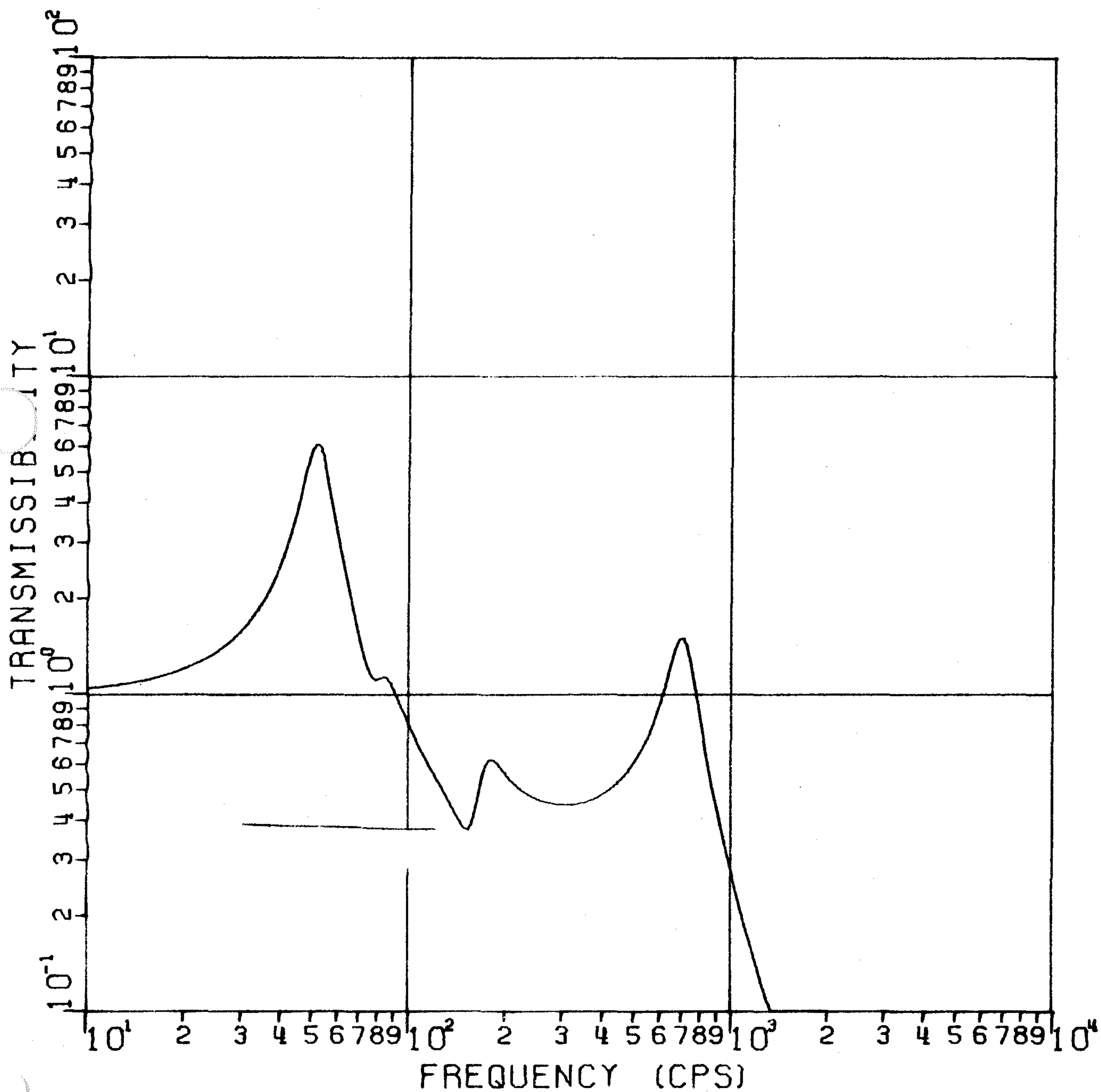
LOCATION 5 , u,



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 7a TRANSMISSIBILITY

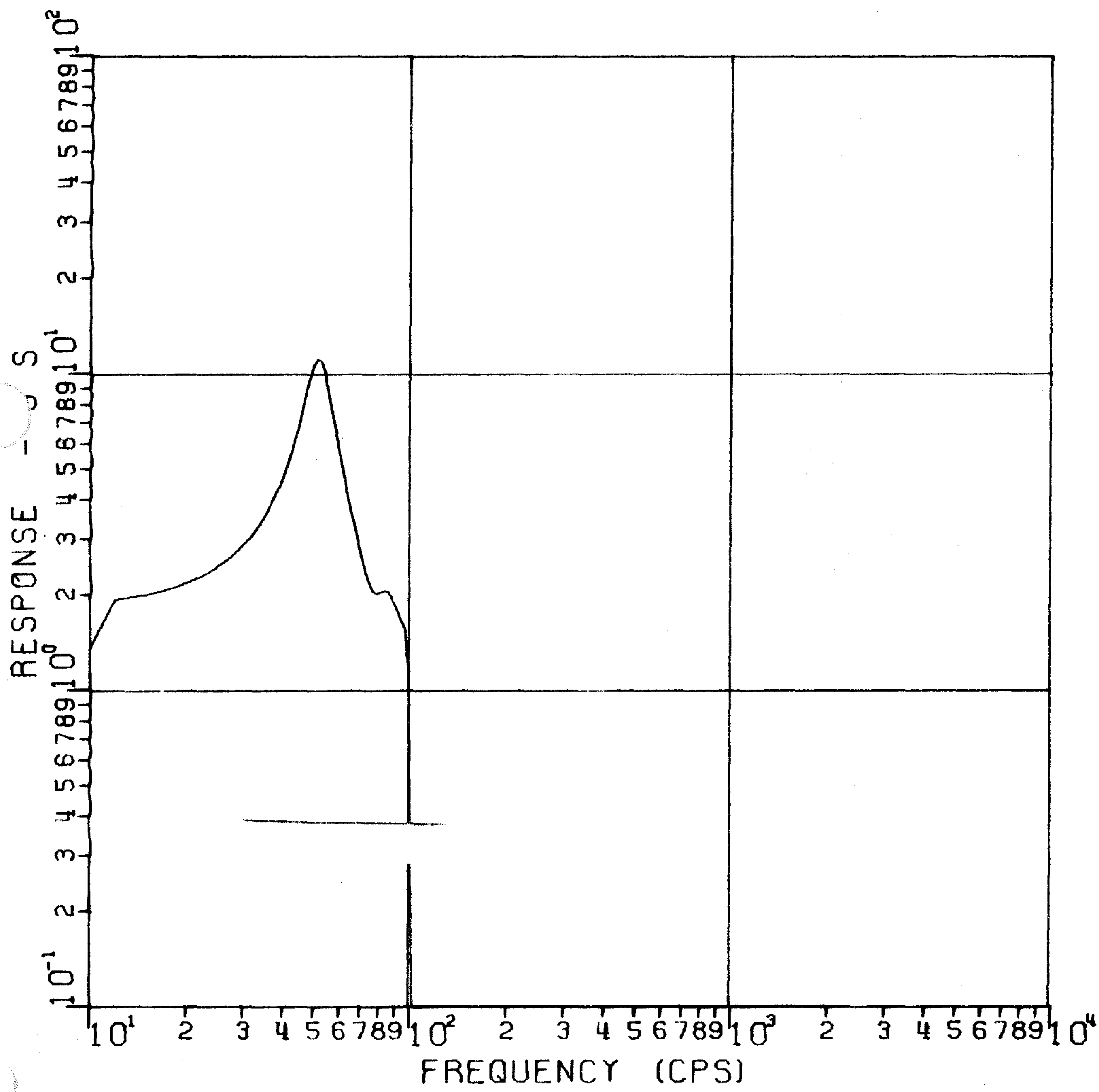
LOCATION 6, u_z



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 7b SINE RESPONSE

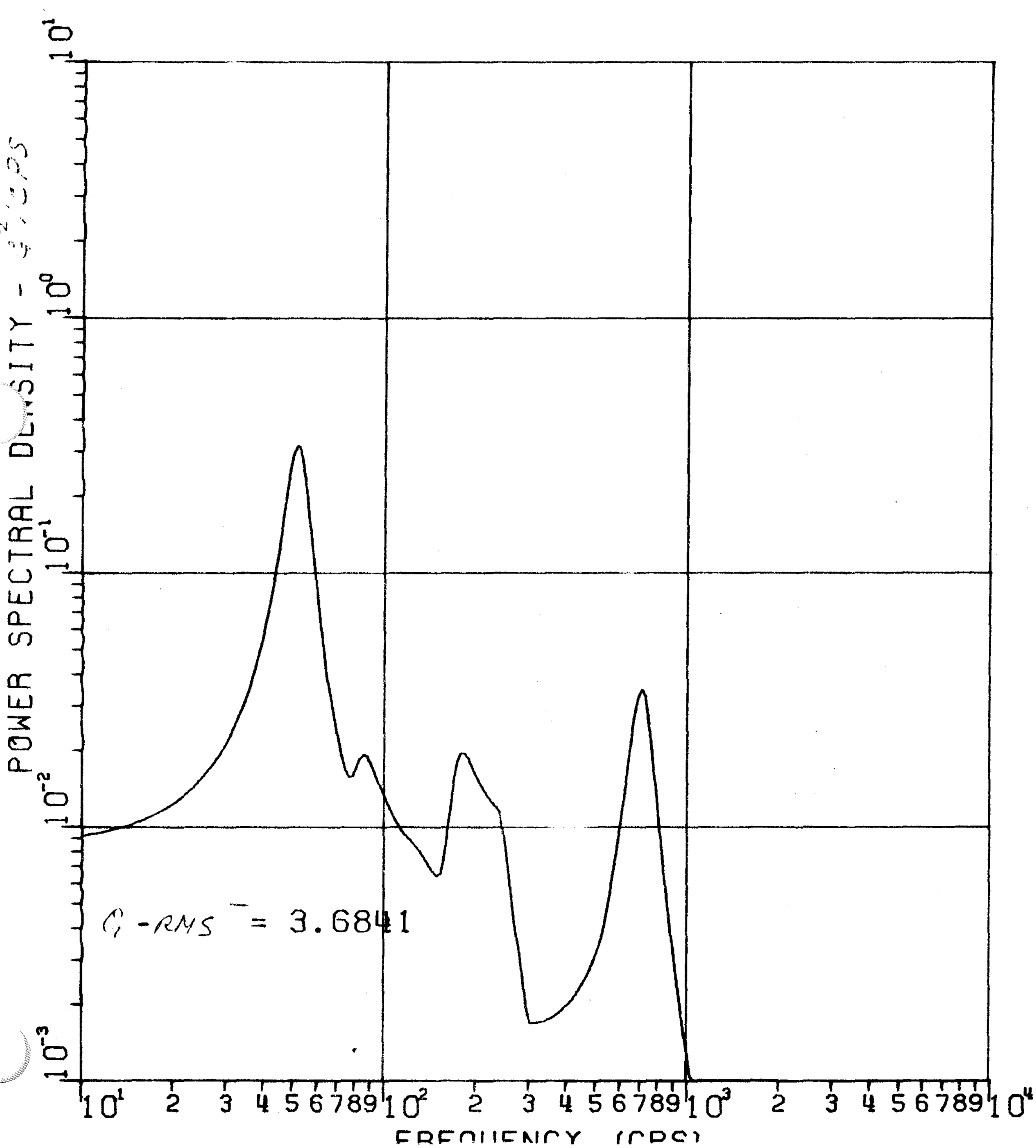
LOCATION 6, u2



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 7c RANDOM VIBRATION SPECTRUM

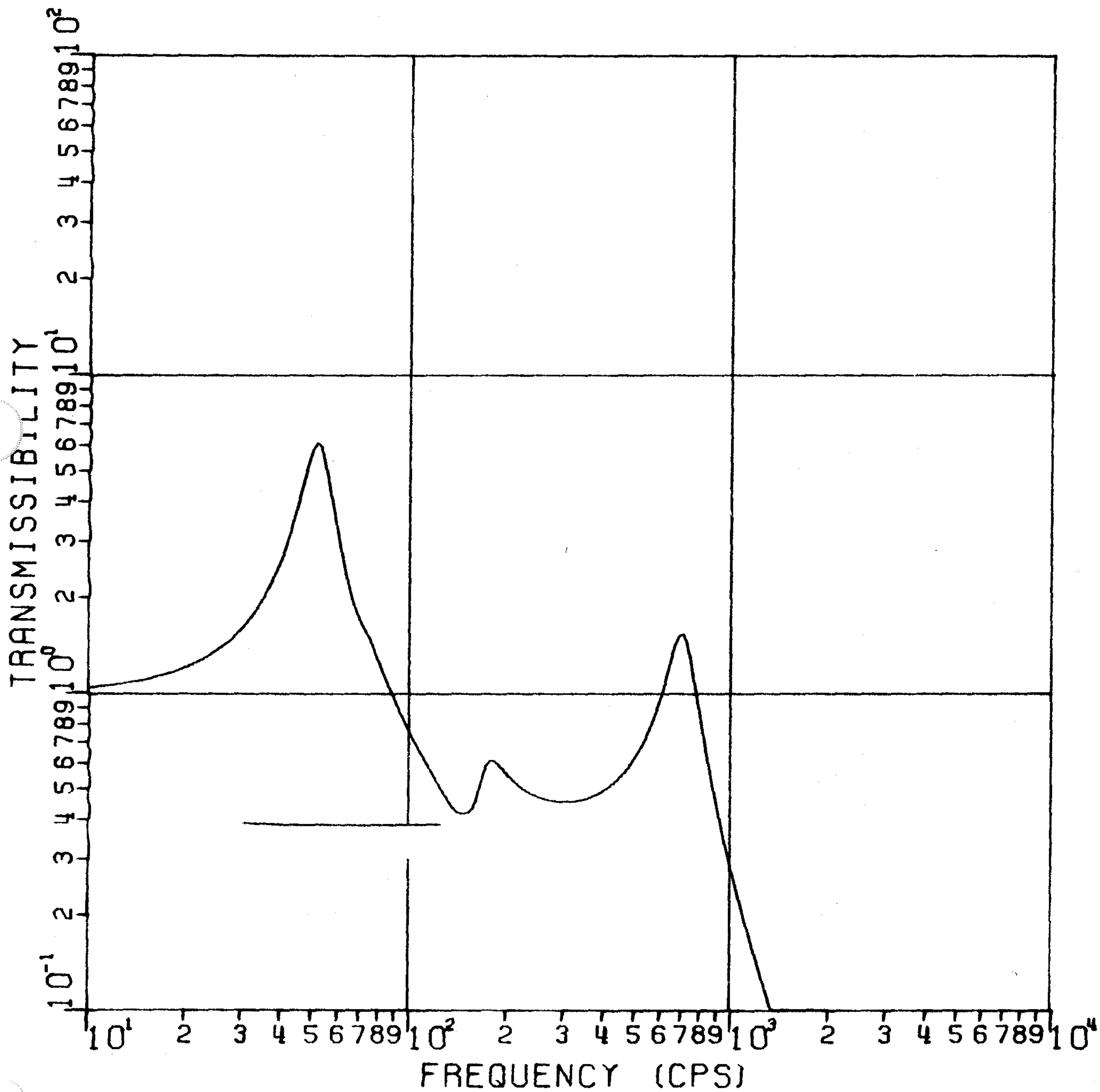
LOCATION 6, x2



1 X AXIS APOLLO 14 LRRR APRIL 1971

FIGURE 8a TRANSMISSIBILITY

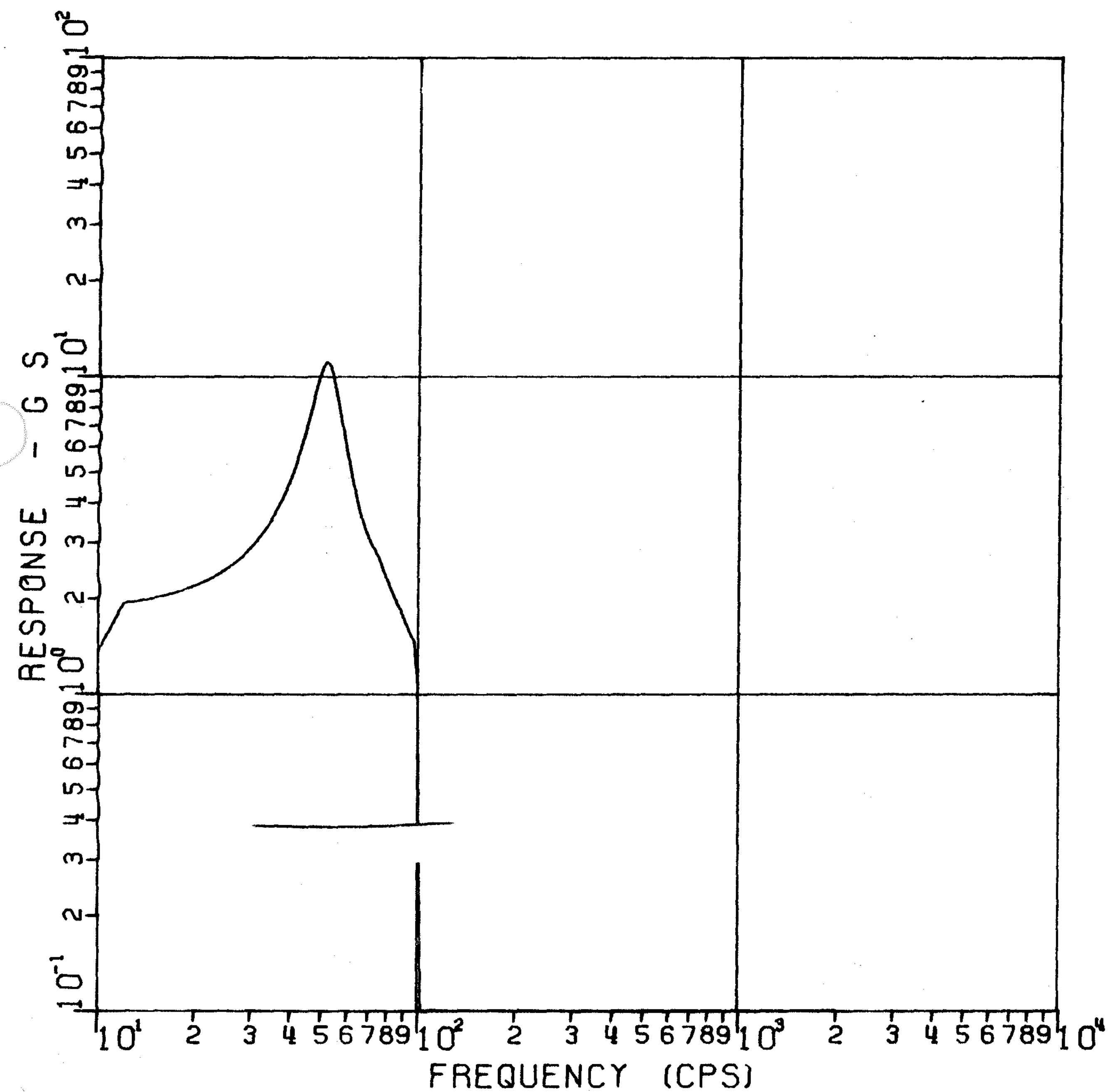
LOCATION 7, u3



1 X AXIS APOLLO 14 LRRR APRIL 197

FIGURE 8 b SINE RESPONSE

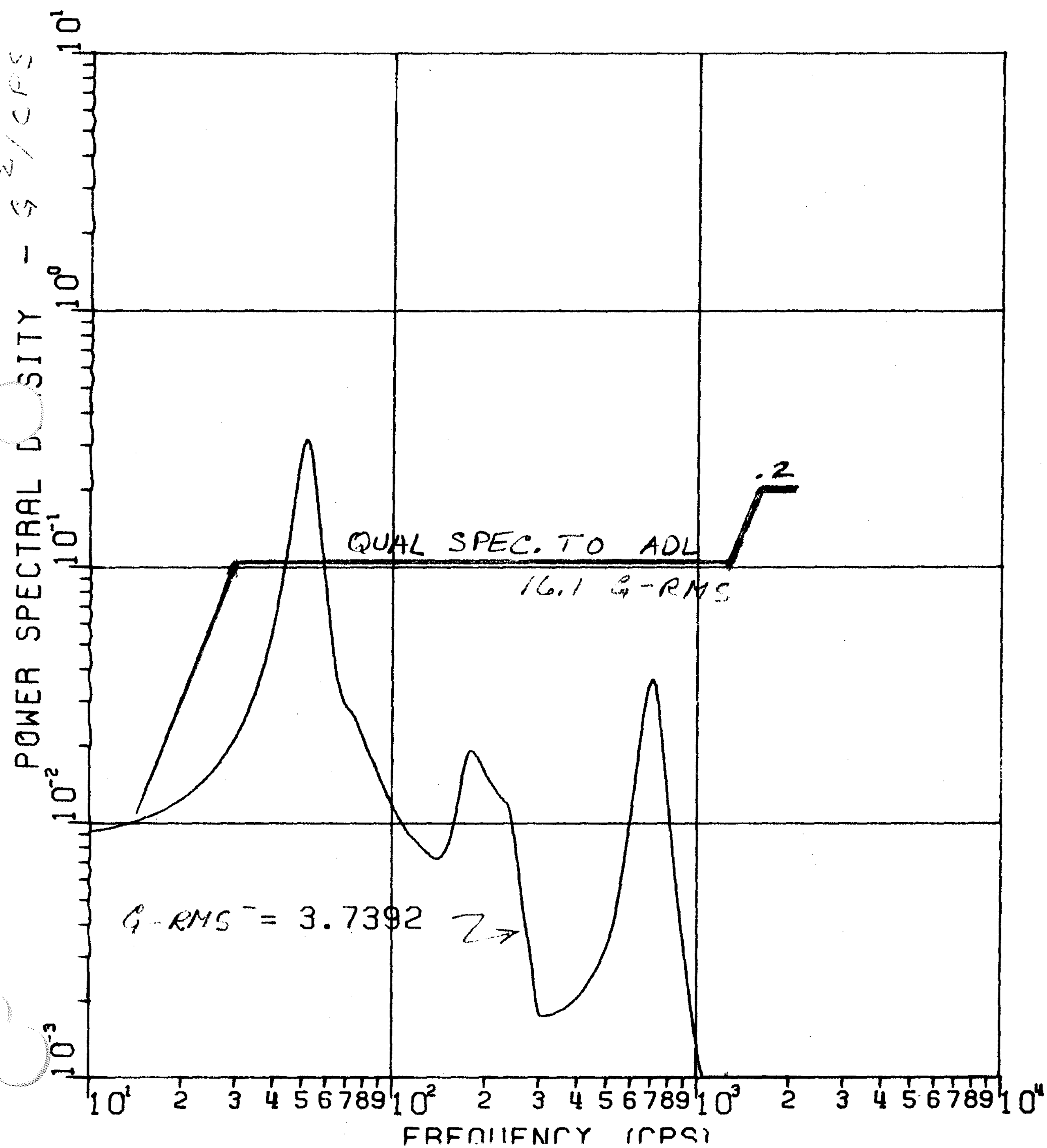
LOCATION 7, 2b3



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 8c RANDOM VIBRATION SPECTRUM

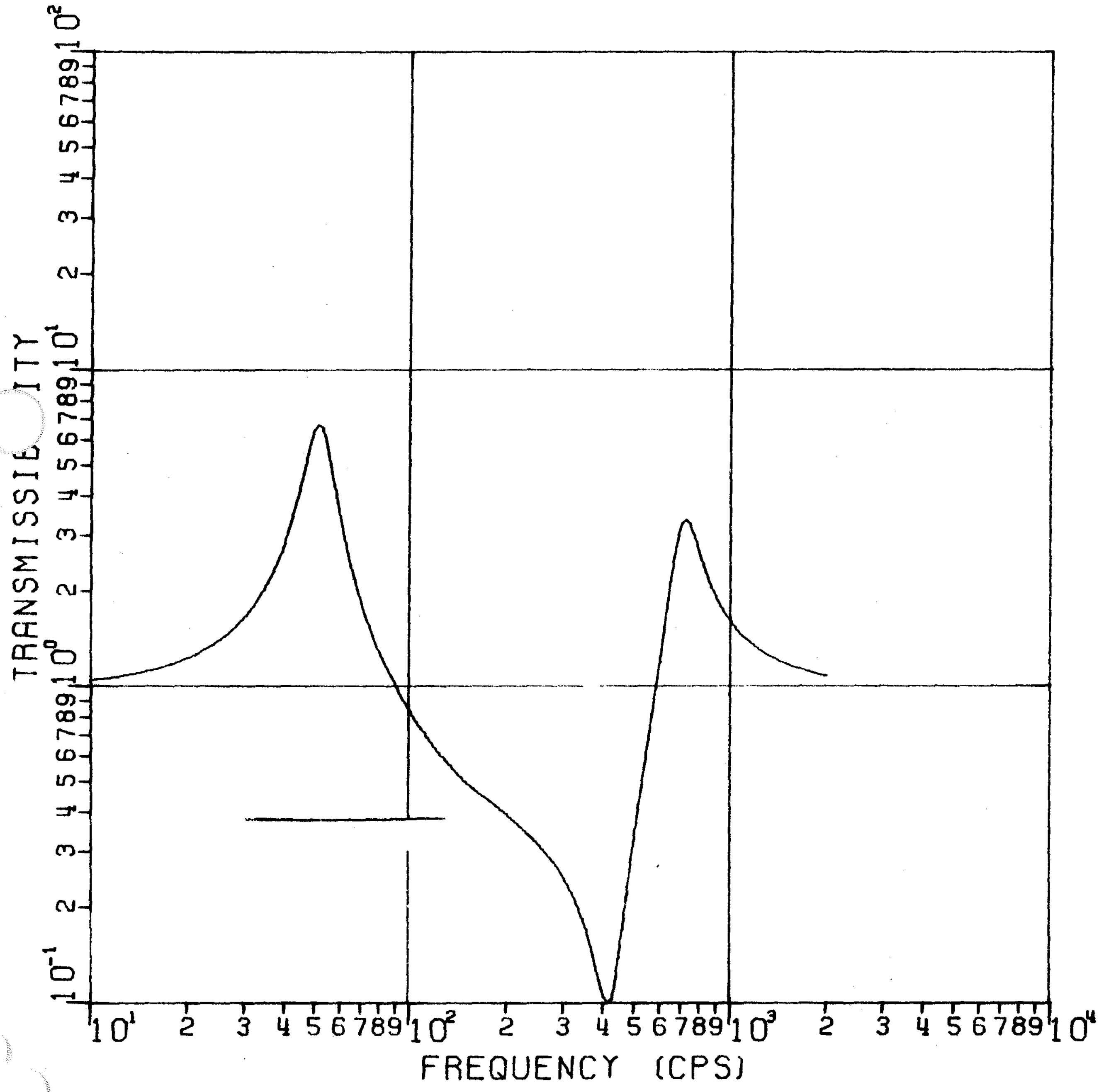
LOCATION 7 , u3



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 9a TRANSMISSIBILITY

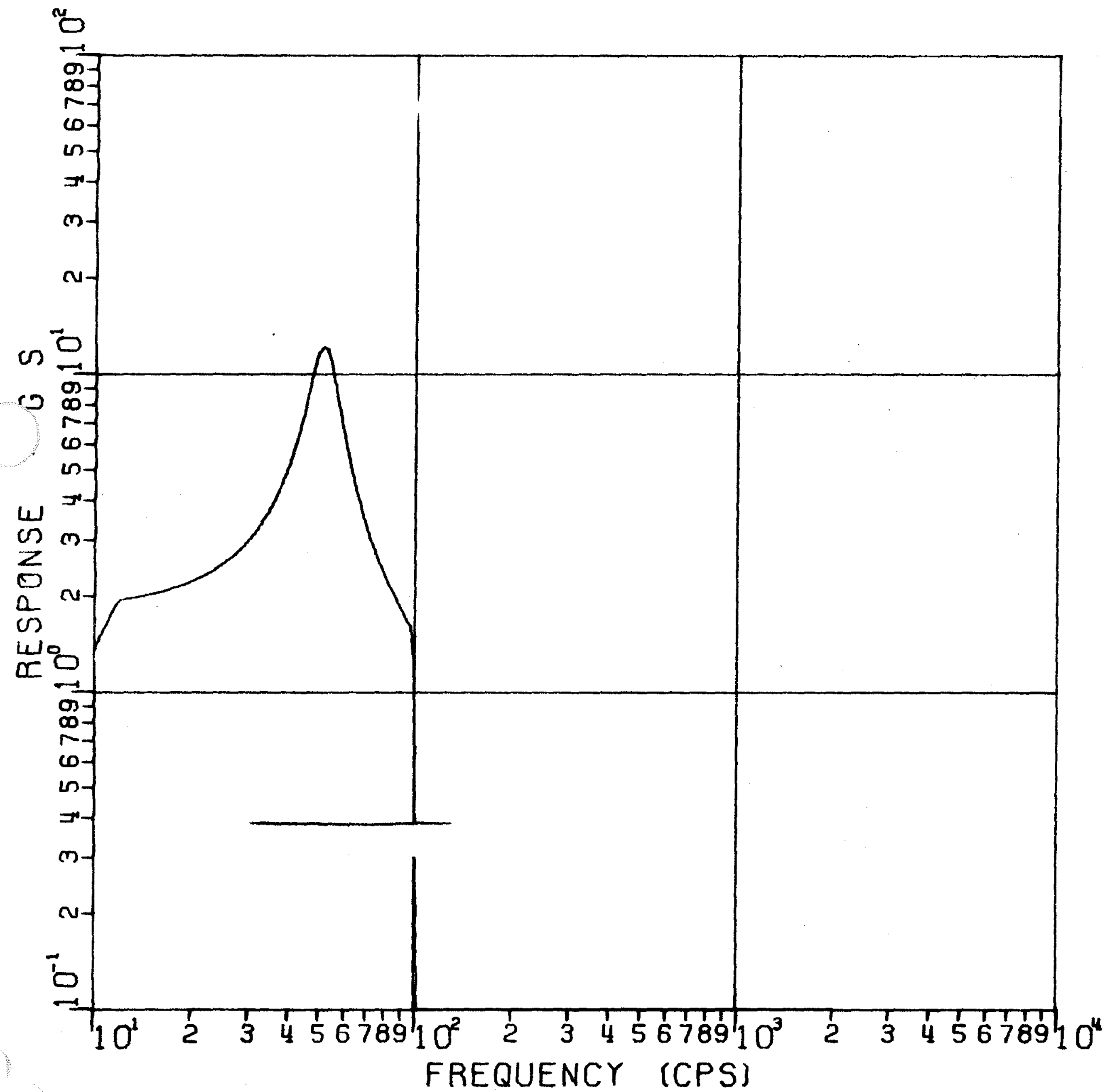
LOCATION 11



1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 9b SINE RESPONSE

LOCATION 11

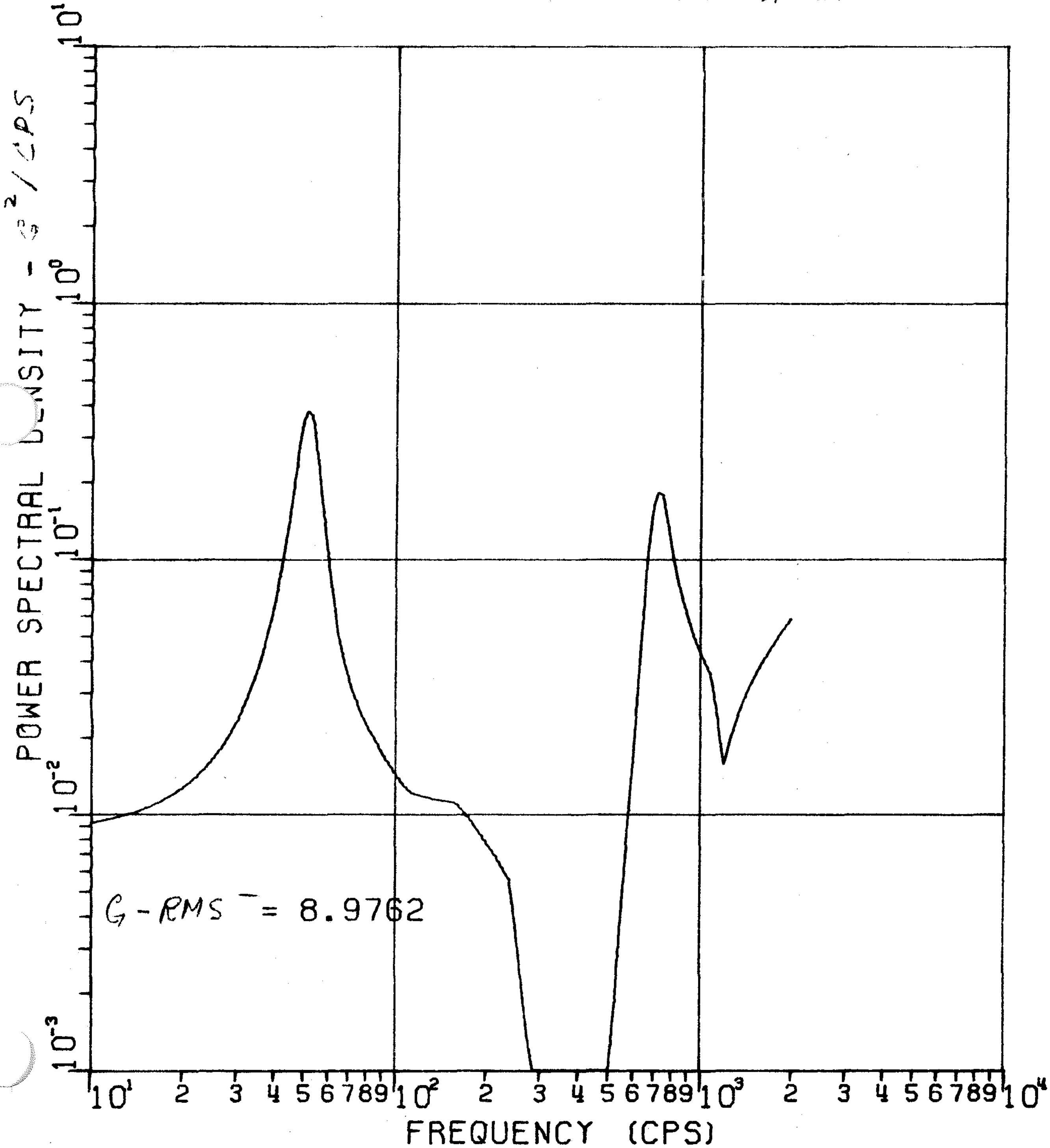


1 X AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 9c RANDOM VIBRATION SPECTRUM

LOCATION 11 , u_c

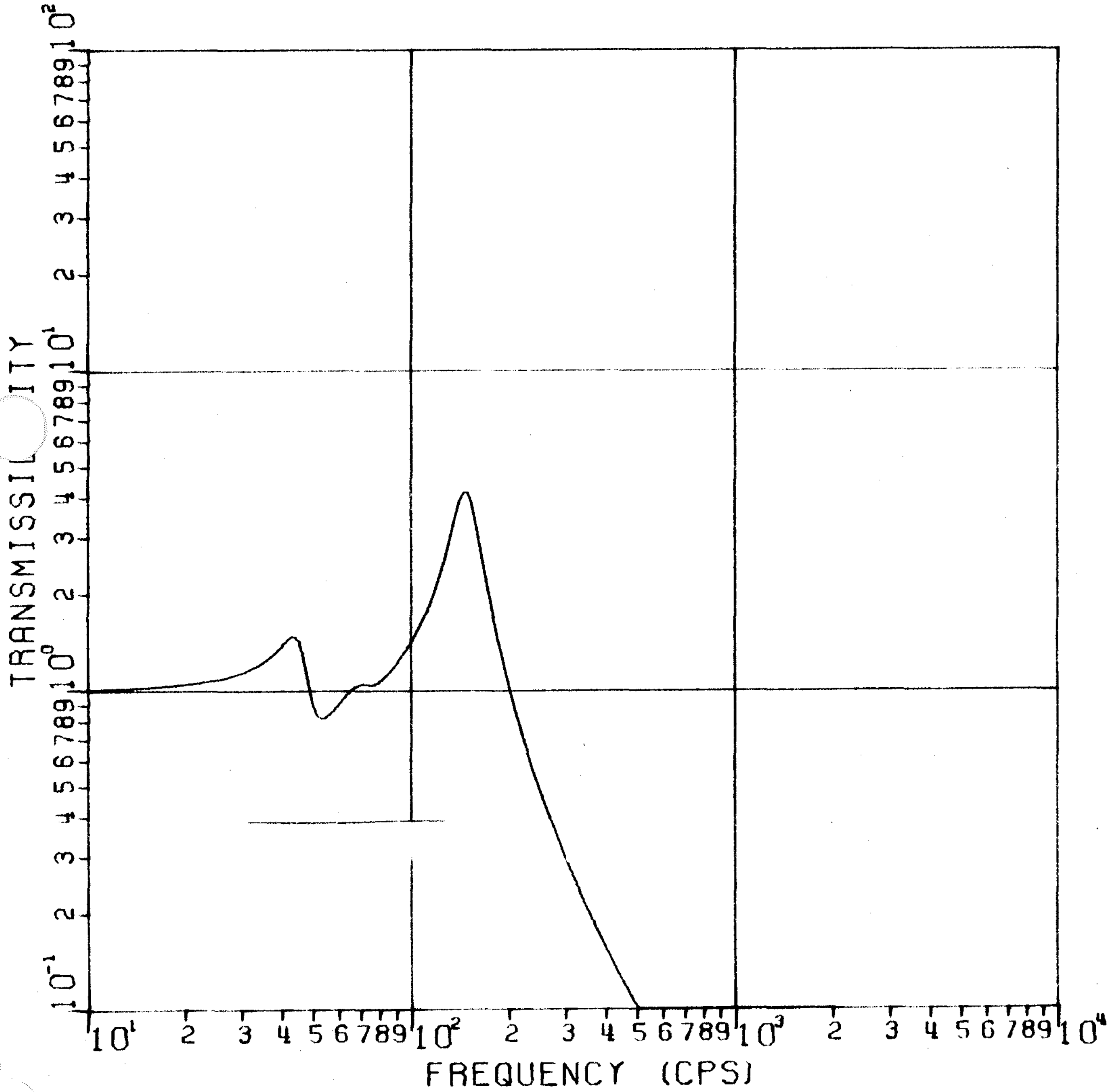
CENTER OF THE ARRAY



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 10a TRANSMISSIBILITY

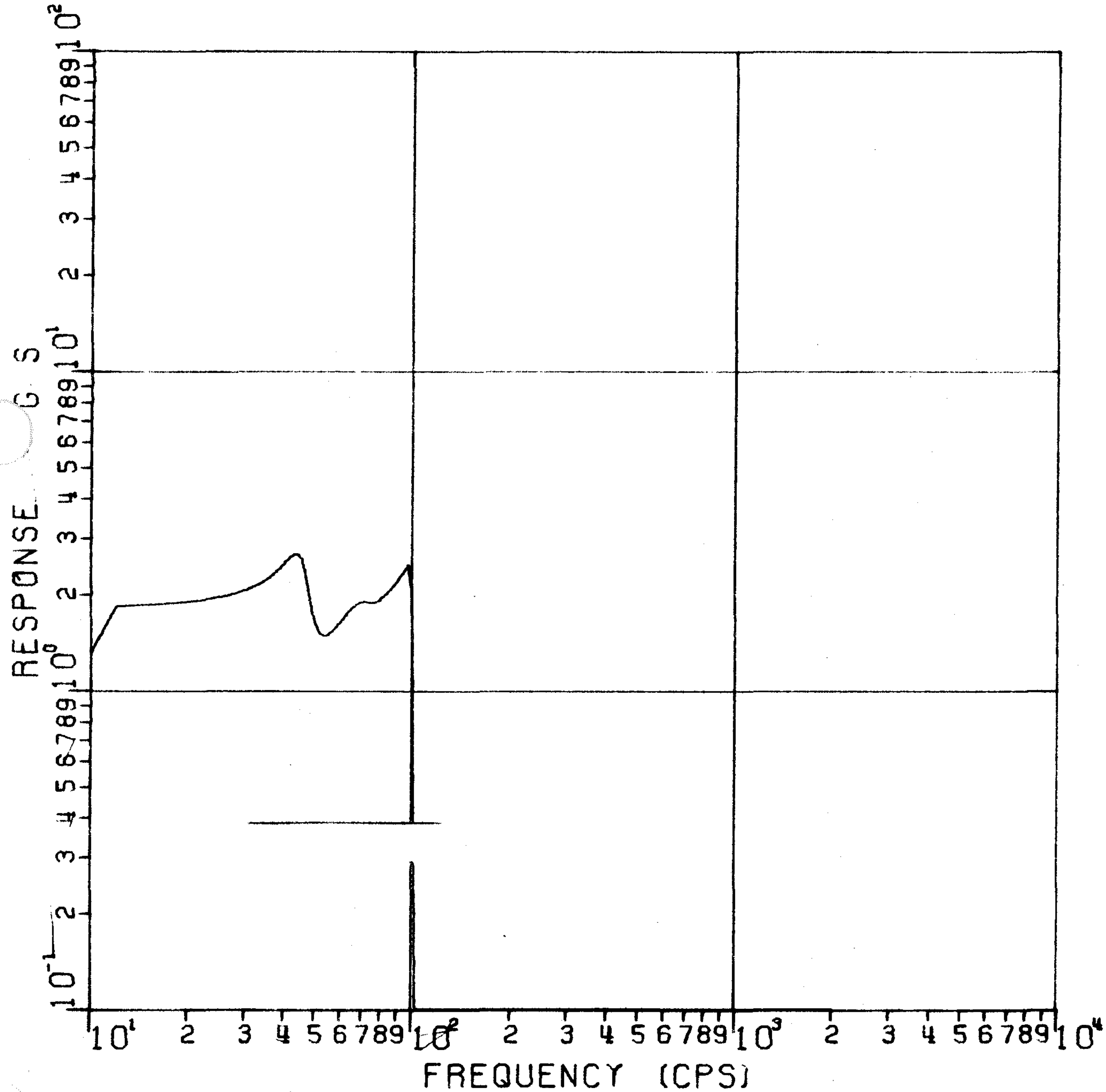
LOCATION 8



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 10b SINE RESPONSE

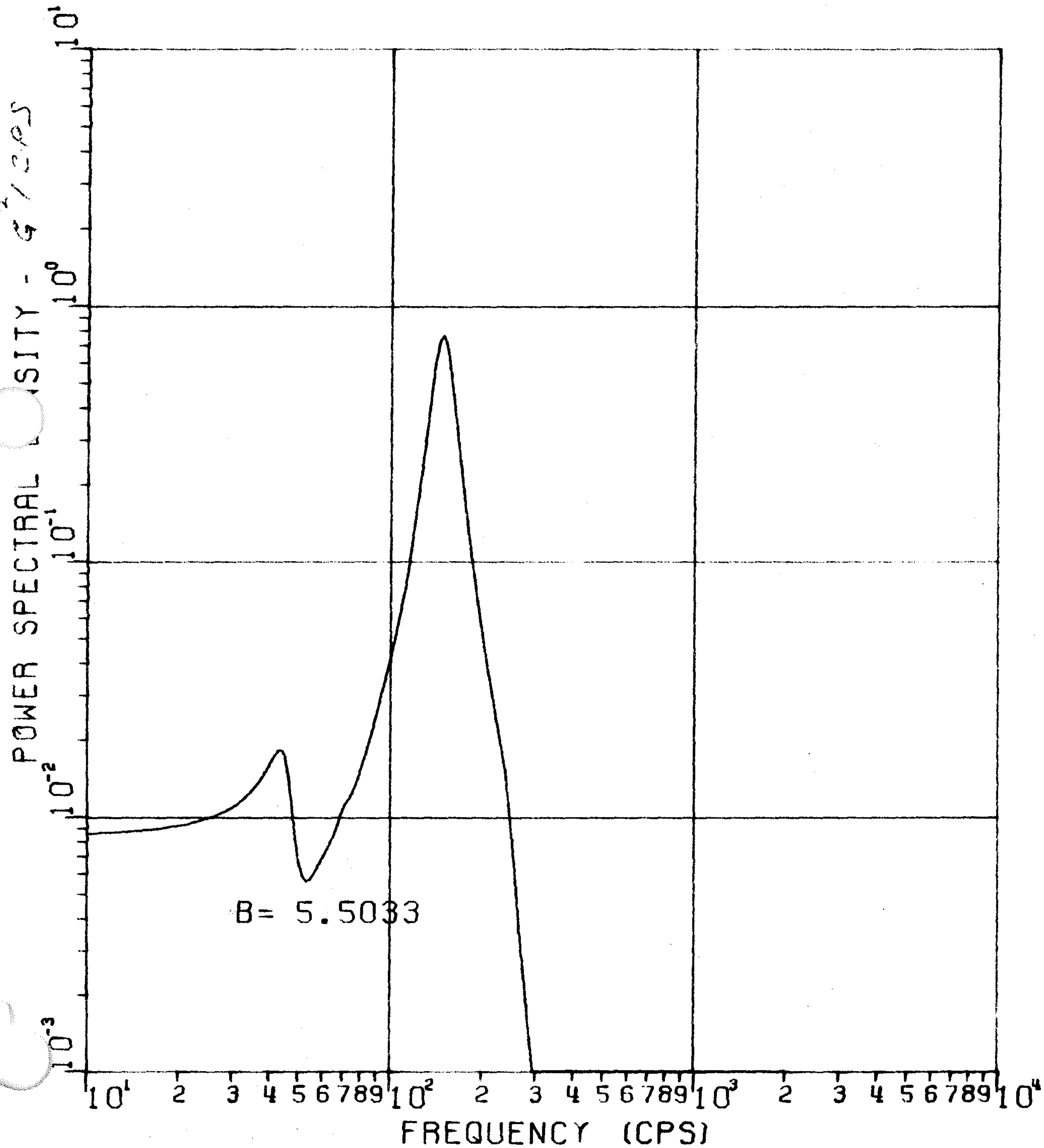
LOCATION 8 , 5,



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 10c RANDOM VIBRATION SPECTRUM

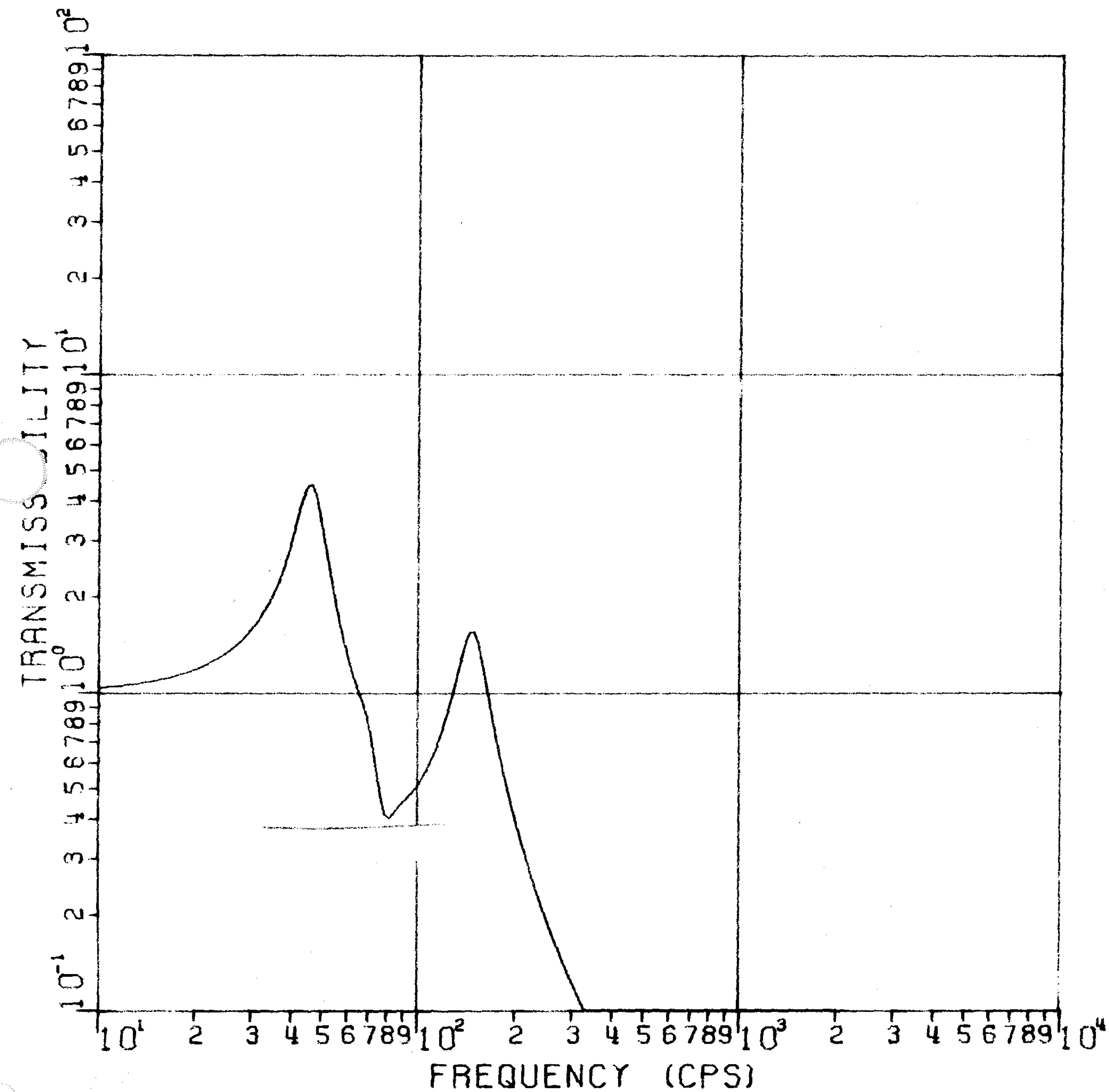
LOCATION 8 , V1



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 11a TRANSMISSIBILITY

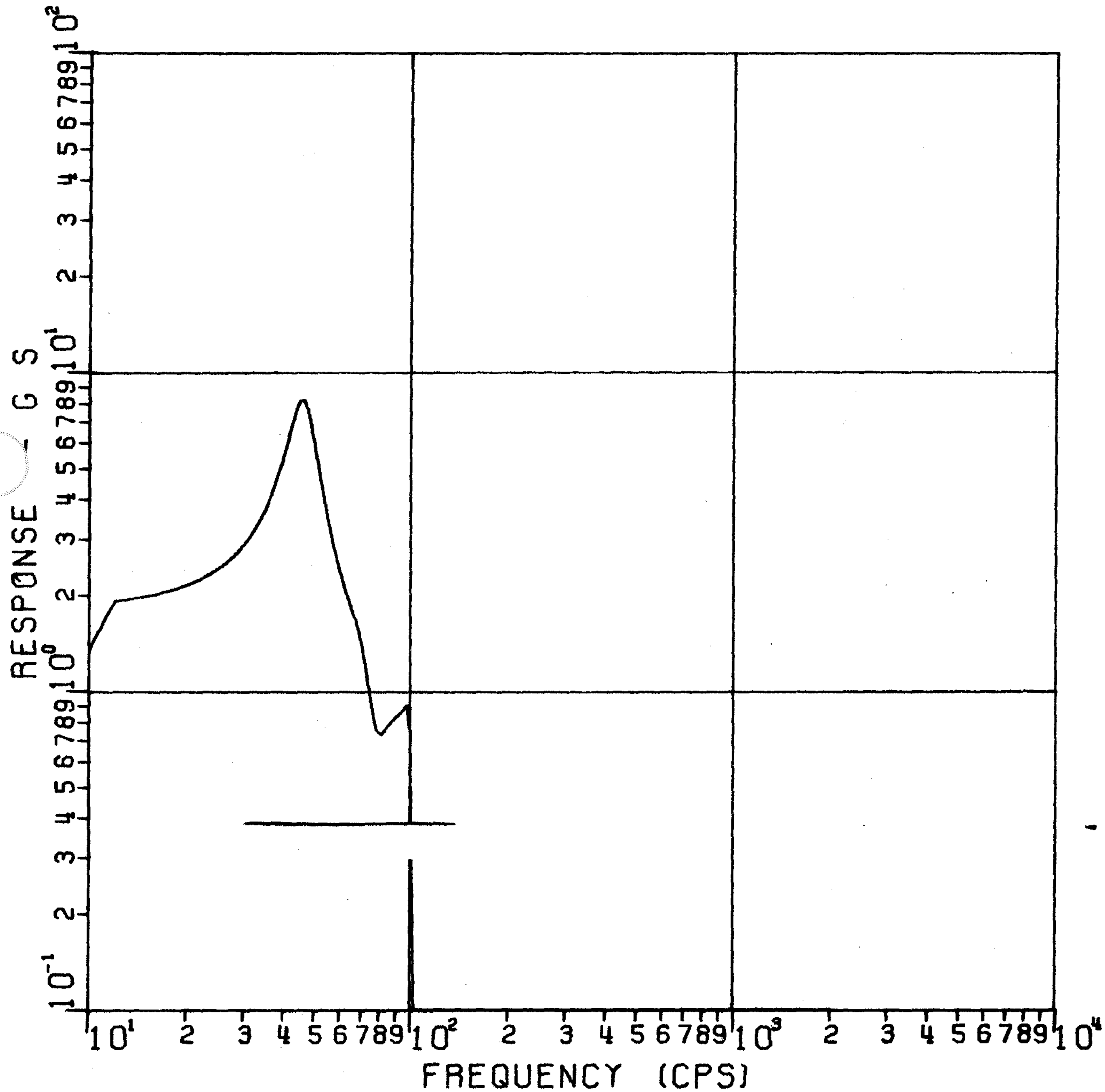
LOCATION 9



1 Y AXIS APOLLO 14 LRRR APRIL 1971

FIGURE 11b SINE RESPONSE

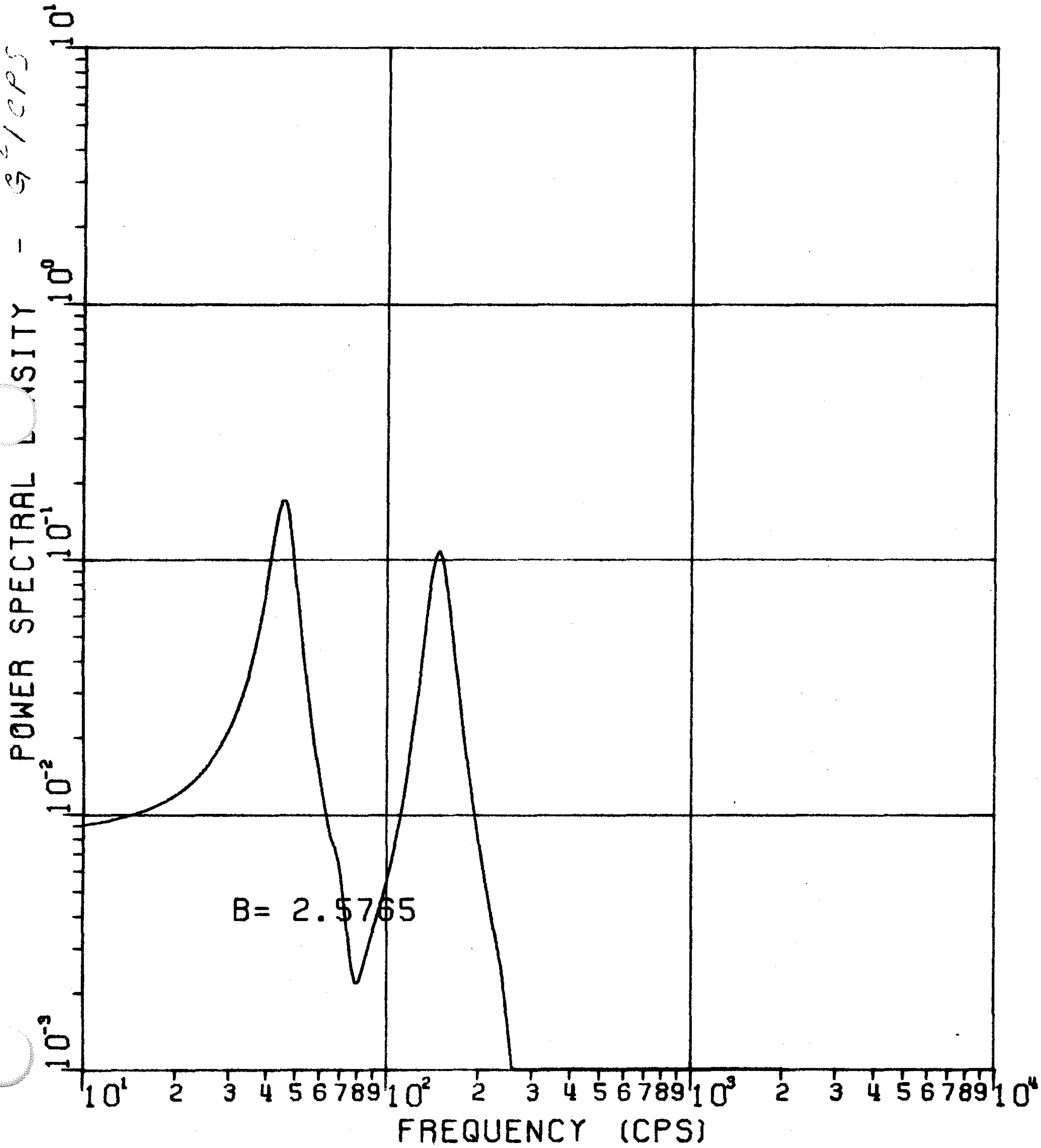
LOCATION 9 , v_2



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 11c RANDOM VIBRATION SPECTRUM

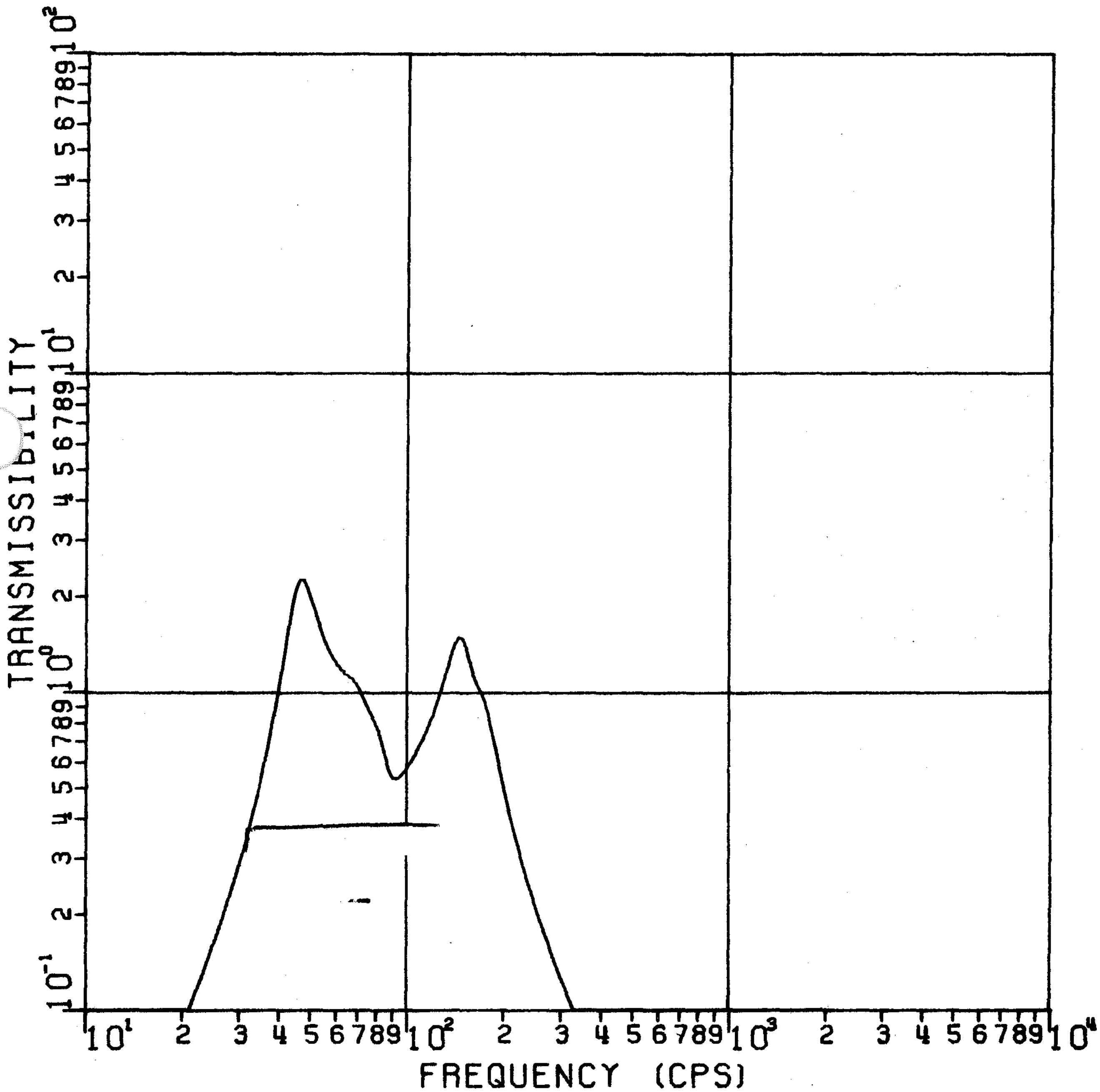
LOCATION 9 , v_2



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 12a TRANSMISSIBILITY

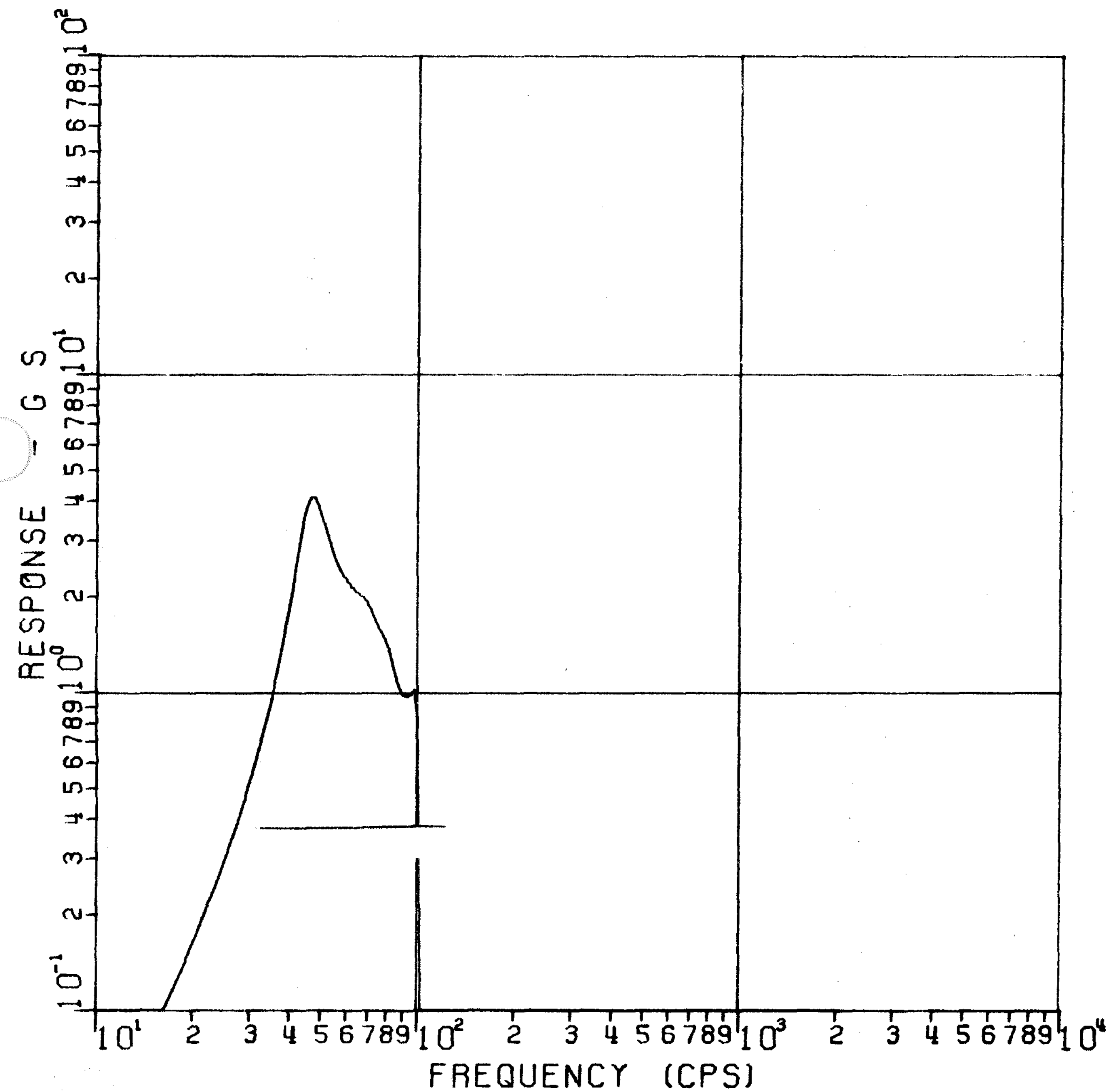
LOCATION 10 , w,



1 Y AXIS APOLLO 14 LRRR APRIL 197

FIGURE 12 b SINE RESPONSE

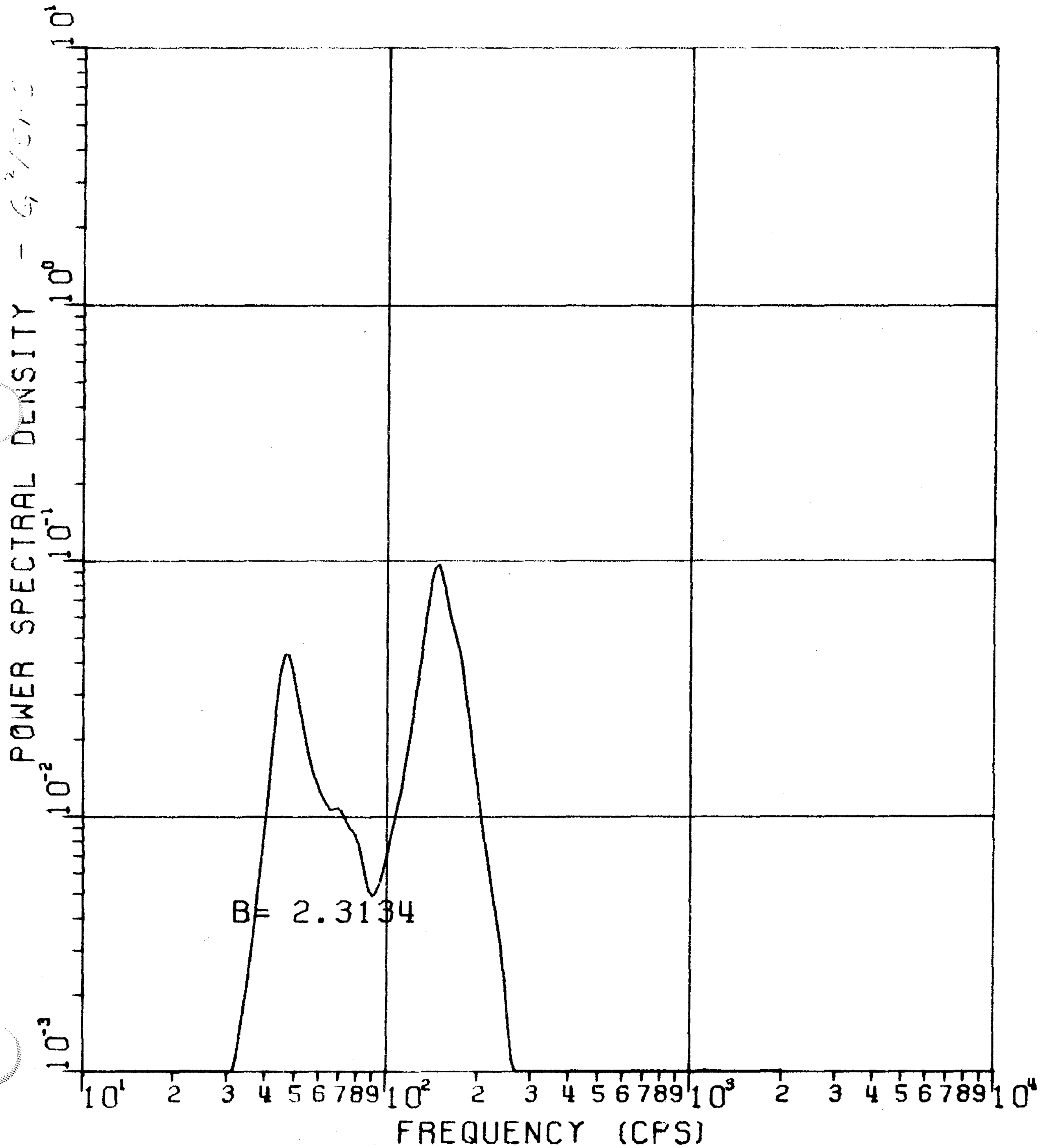
LOCATION 10



1 Y AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 12 c RANDOM VIBRATION SPECTRUM

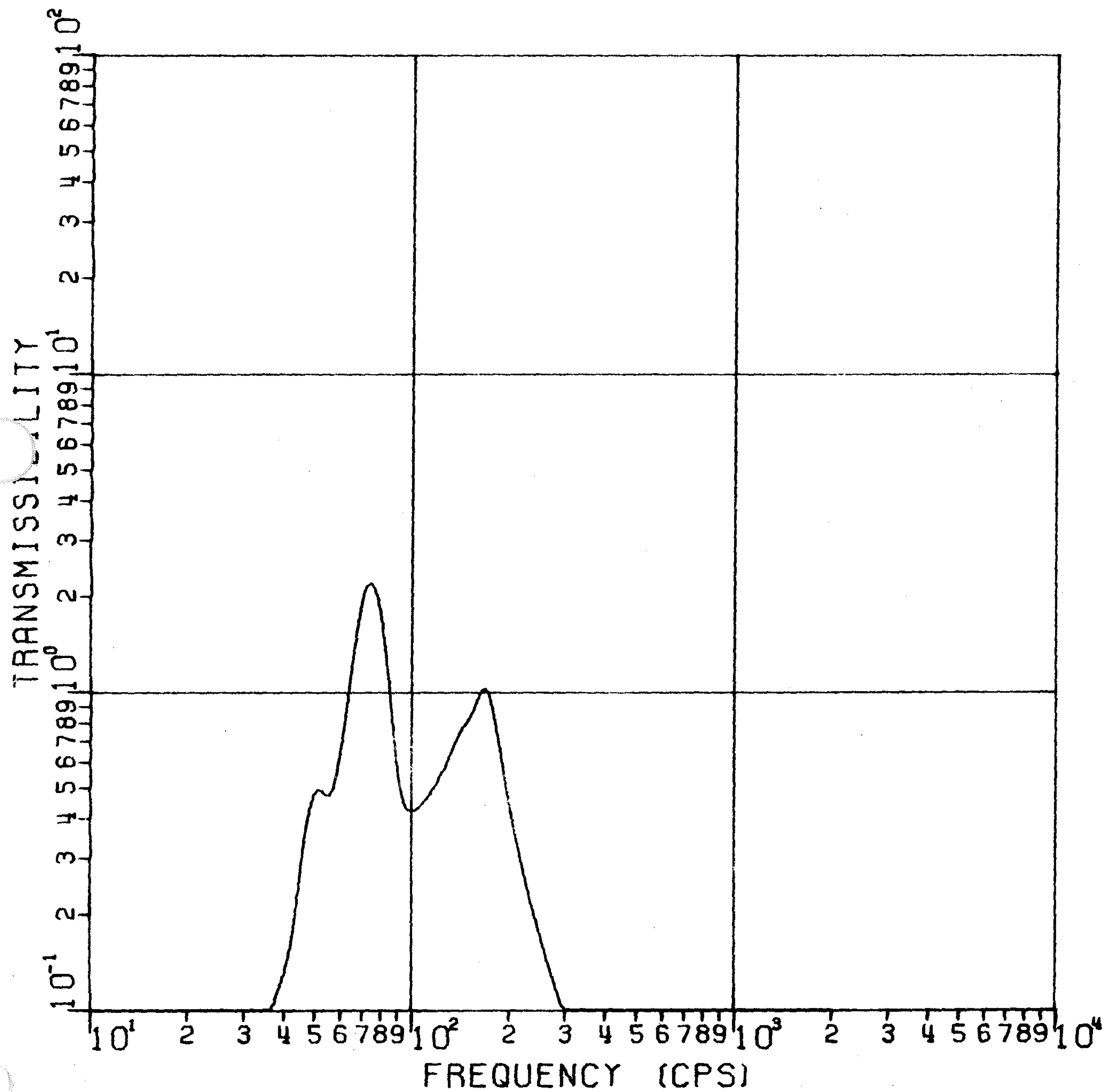
LOCATION 10 , 105,



1 Z AXIS APOLLO 14 LRRR APRIL 1971

FIGURE 12 a TRANSMISSIBILITY

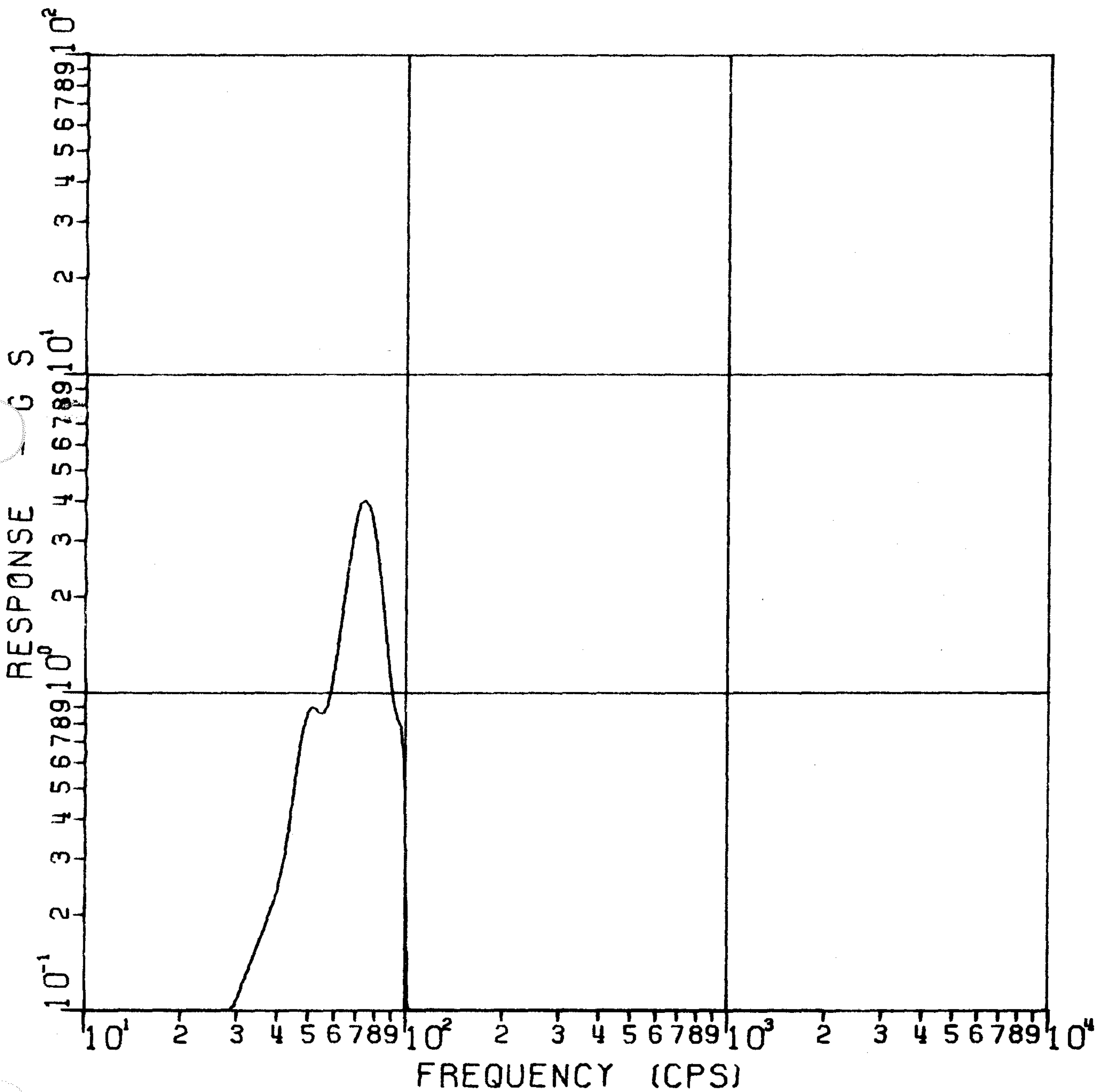
LOCATION 5 , ...



1 Z AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 12 b SINE RESPONSE

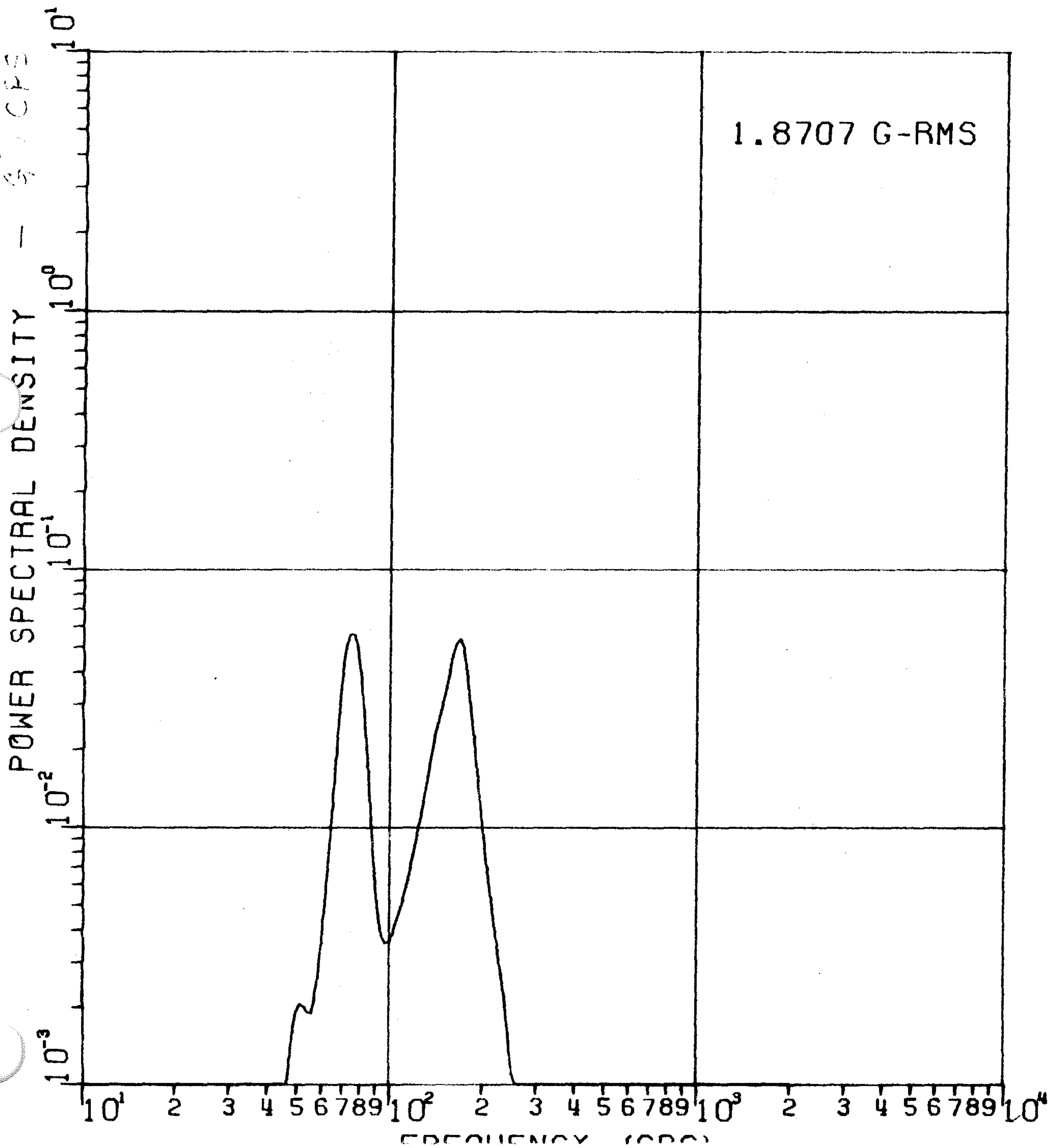
LOCATION 5 , 2L,



1 Z AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 12c RANDOM VIBRATION SPECTRUM

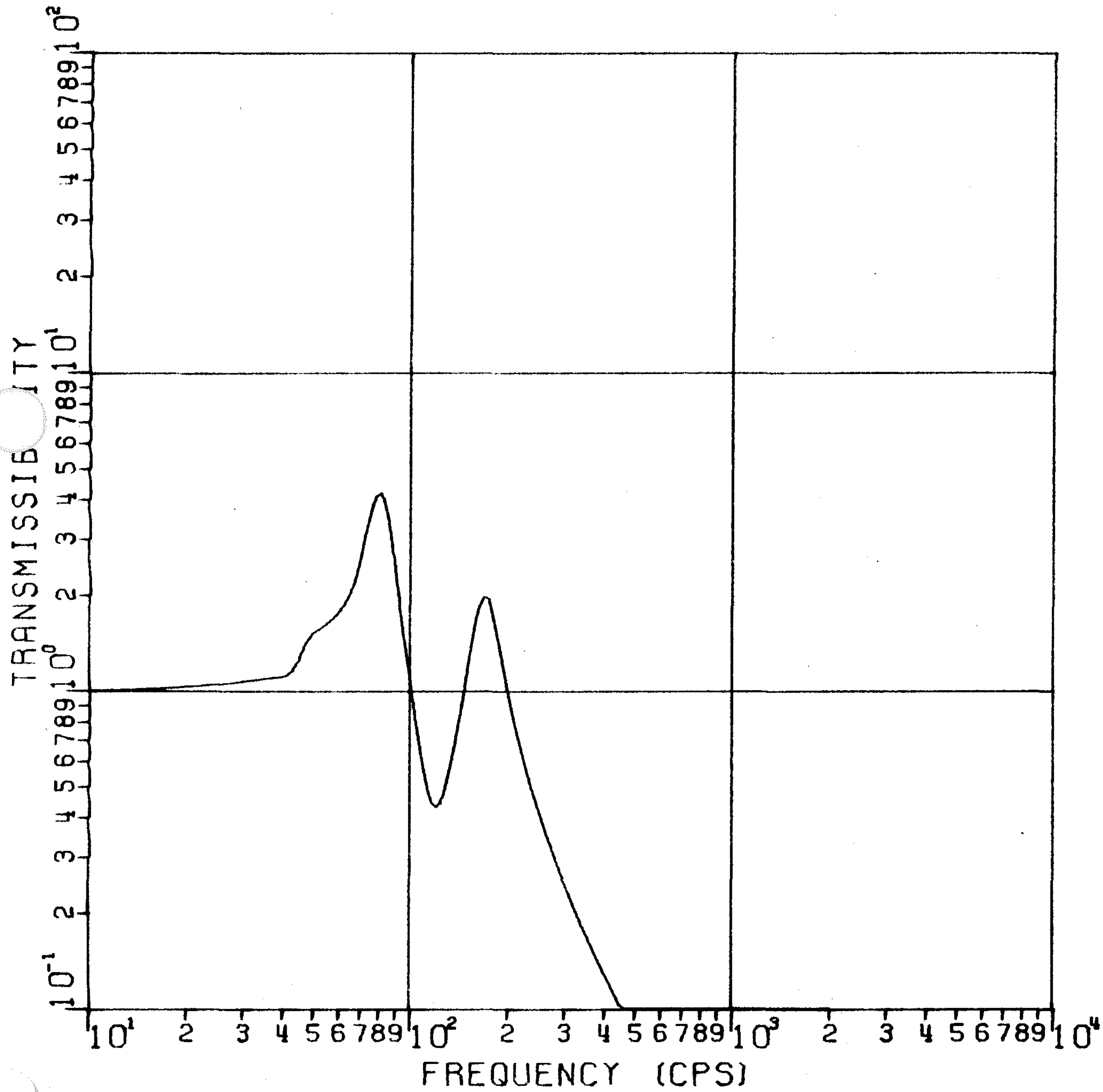
LOCATION 5



1 Z AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 14 a TRANSMISSIBILITY

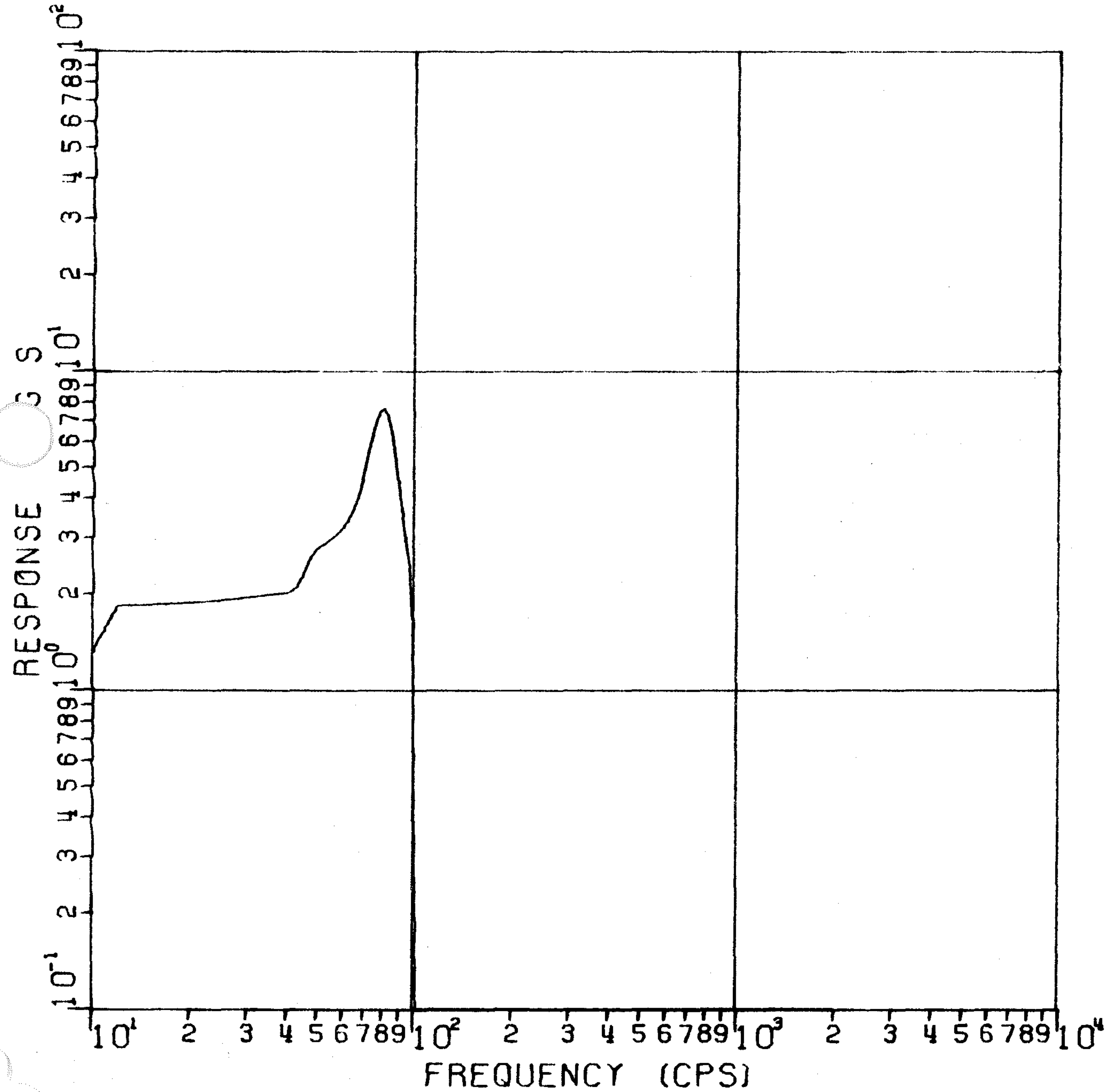
LOCATION 10



1 Z AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 14b SINE RESPONSE

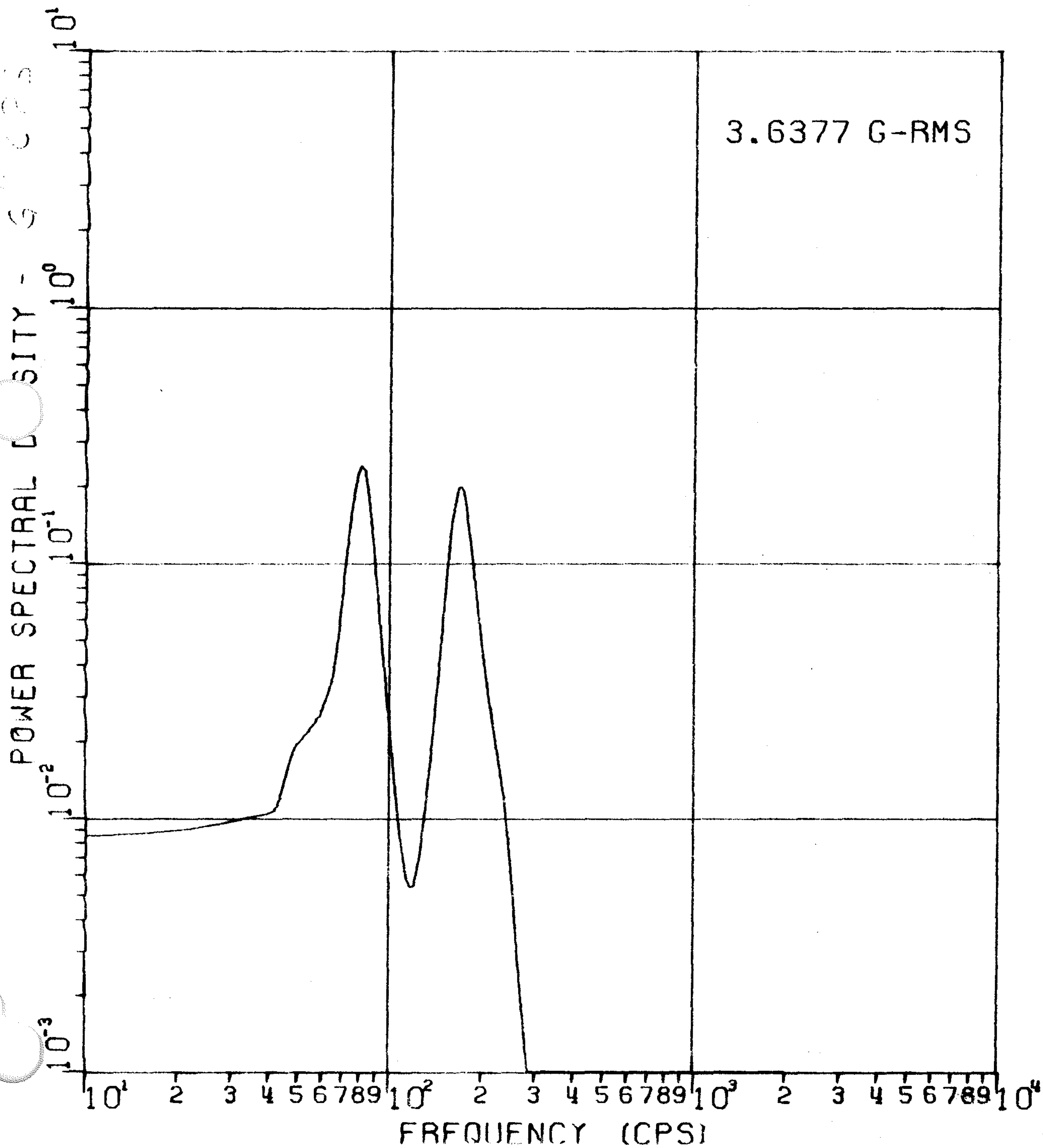
LOCATION 10



1 Z AXIS APOLLO 14 LRRR APRIL 1970

FIGURE 14c RANDOM VIBRATION SPECTRUM

LOCATION 10



2.4.0 Dynamics Loads

As discussed in Section 3.0 the flexibility and stiffness influence coefficients were developed for the support structure in the three axes of loading. These results were then incorporated into the three-dimensional program from which the reduced stiffness matrix is determined for use in the dynamics analysis program discussed previously.

The computed accelerations and the redundant frame stiffness matrix provide all the necessary information for computing the dynamic loads at the array attachment points and on the array.

The three-dimensional stiffness matrix for the structural system is shown in Figure 15. This is a 20 x 20 matrix with the displacement coordinates shown along the top. The forces associated with these coordinates are in the corresponding direction and location in the 20 vertical locations.

This stiffness matrix is reduced in size to correspond to the selected 11 generalized coordinates by the transformation

$$[k] = [B]^T [K] [B] \qquad (1)$$

where [B] is a 20 x 11 matrix relating the coordinates of Figure 15 to the 11 generalized coordinates. This is given in Figure 16.

The internal loads on the structure and the associated displacements can be determined from the following relations:

$$\{P\} = [K] [B] [k]^{-1} \{Q\} \qquad (2)$$

and

$$\{S\} = [B] [k]^{-1} \{Q\} \qquad (3)$$

where P_n is an internal load and S_n is the displacement.

$n = 1, 2, --- 20$

FIGURE 15

[K]

UPPER RIGHT TRIANGULAR

STIFFNESSES LB / IN

	1 x_{1a}	2 y_{1b}	3 x_{1b}
1	1,008,000.		-1,008,000
2		28,000.	
3			1,008,000.

	4 x_{2a}	5 y_{2b}	6 z_{2b}	7 x_{2b}
4	1,008,000.			-1,008,000.
5		0.0		
6			16,760.	
7				1,008,000.

	8 x_{3a}	9 y_{3b}	10 z_{3b}	11 x_{3b}
9	1,008,000.			-1,008,000.
		0.0		
10			11520.	
11				1,008,000.

	12 x_{4a}	13 y_{4b}	14 x_{4b}
12	1,008,000.		-1,008,000.
13		1770.	
14			1,008,000.

	15 x_1	16 x_2	17 x_3	18 x_4
15	8346.6	-1616.4	-258.24	-242.17
16		7440.9	8.29	-322.16
17			13,324.2	-9045.3
18				11585.

	19 u_c	20 u
19	208,500.	-208,500.
20		208,500.

SUBSCRIPT a REFERS TO BOTTOM OF BRACKET
" b " " TOP " "

FIGURE 16

THE MATRIX [B]

		q_1	q_2	q_3	q_4	q_5 (u_1)	q_6 (u_2)	q_7 (u_3)	q_8 (v_1)	q_9 (v_2)	q_{10} (w_1)	q_{11} (w_c)
1	x1a	1.0										
2	y1b								1.0			
3	x1b					1.0						
4	x2a		1.0									
5	y2b									1.0		
6	z2b								.287	-.287	1.0	
7	x2b						1.0					
8	x3a			1.0								
9	y3b									1.0		
10	z3b								1.13	-1.13	1.0	
11	x3b							1.0				
12	x4a				1.0							
13	y4b								1.0			
14	x4b					.994	-1.682	1.68				
15	x_1	1.0										
16	x_2		1.0									
17	x_3			1.0								
18	x_4				1.0							
19	u_c											1.0
20	u					.58	-.266	.69				

$$\{S\} = [B]\{q\}$$

The next step is to compute the load vectors, $\{Q\}$, resulting in this case from the dynamics environment.

Calculation of Load Vectors

Random Loading

The expression for the load vectors, $\{Q\}$, for the random loading case is

$$[Q]^T = [m] \lceil A \rfloor \qquad (4)$$

where

$[m]$ = mass matrix (Figure 4)

$\lceil A \rfloor$ = a diagonal matrix composed of the local rms acceleration computed with the dynamics analysis program, i.e., Table 1 type values multiplied by the acceleration of gravity.

When the $\{Q\}$ column vectors have been determined, they are applied to equations (2) and (3) to compute the internal loads and displacements at the attachment points and on the array. For the random case the rms internal loads and displacements are computed for each modal equation giving 11 sets of rms values at the 20 coordinate locations. Then for each location the 11-modal rms values are combined by taking the square root of the sum of the squares of the 11 values, thus reducing the number to 20 load and 20 displacement values.

Sinusoidal Loading

The load vectors, $\{Q\}$, are again formed by Equation (4), but real and imaginary steps are computed separately and combined into one load vector for each frequency where a maximum sine response occurs.

For the sinusoidal loading case there is only one Q vector per frequency selected and each one will produce a set of internal loads and displacements.

Application of the foregoing procedure to the present structure and array gives the results shown in Table 3 for the 8 attachment point loads due to random excitation. There are two forces in the y direction, two in the z direction and four in the x direction perpendicular to the plane of the support structure. The y and z forces also cause moments in the support structure due to the bracket height. These forces in turn induce further forces and moments in the structure. This is discussed further in Section 3.0. The loads are unequally distributed due to the asymmetries in the attachment structure and combined translational and rotational acceleration forces being reacted.

TABLE 3

LOADS AT ATTACHMENT POINTS DUE TO RANDOM EXCITATION

	FORCE LB - RMS		
EXCIT. —	X	Y	Z
FORCE DIRECTION & LOCATION			
y_{1b}	7.3	173.3	34.1
z_{2b}	33.7	47.8	185.4
z_{3b}	10.6	112.8	19.4
y_{4b}	.5	11.0	2.2
x_1	62.2	66.8	39.1
x_2	32.4	12.8	28.2
x_3	57.7	21.6	52.9
x_4	109.7	50.0	81.9

REFER TO FIGURES 1 & 15 FOR COORDINATE DEFINITIONS

2.5.0 Apollo 11 LRRR Vibration Test and Analysis Comparison

Some vibration measurements were obtained during the QUAL Model vibration testing to verify original assumptions and calculations regarding acceleration input levels to the array. Accelerations were measured on the array sides half way between the corners. While these were not at the exact locations as the computed accelerations, the two should agree fairly well, and this holds true as indicated in Figures 17, 18 and 19 which are of similar shape. The test curve, Figure 19 falls in between the two computed curves which are for a corner and for the center of the array.

Accelerations were also measured in the other axes and at the top of the support brackets. Again the responses agreed reasonably well with computed values for the array inputs; however, the measured accelerations at the tops of the brackets agreed with computed values only up to about 500 Hz after which the measurements tended to rise. This is attributed to the tops of the brackets having their own small systems responding at these higher frequencies but not being representative of the acceleration level at the array input side where the mass is much larger.

The assumed value of 0.1 critical viscous damping in each mode appears reasonable and has been used in the present analysis.

FIGURE 17 X AXIS FORCING 12 MARCH 1969

FIGURE 4c RANDOM VIBRATION SPECTRUM

LOCATION 5 , u,

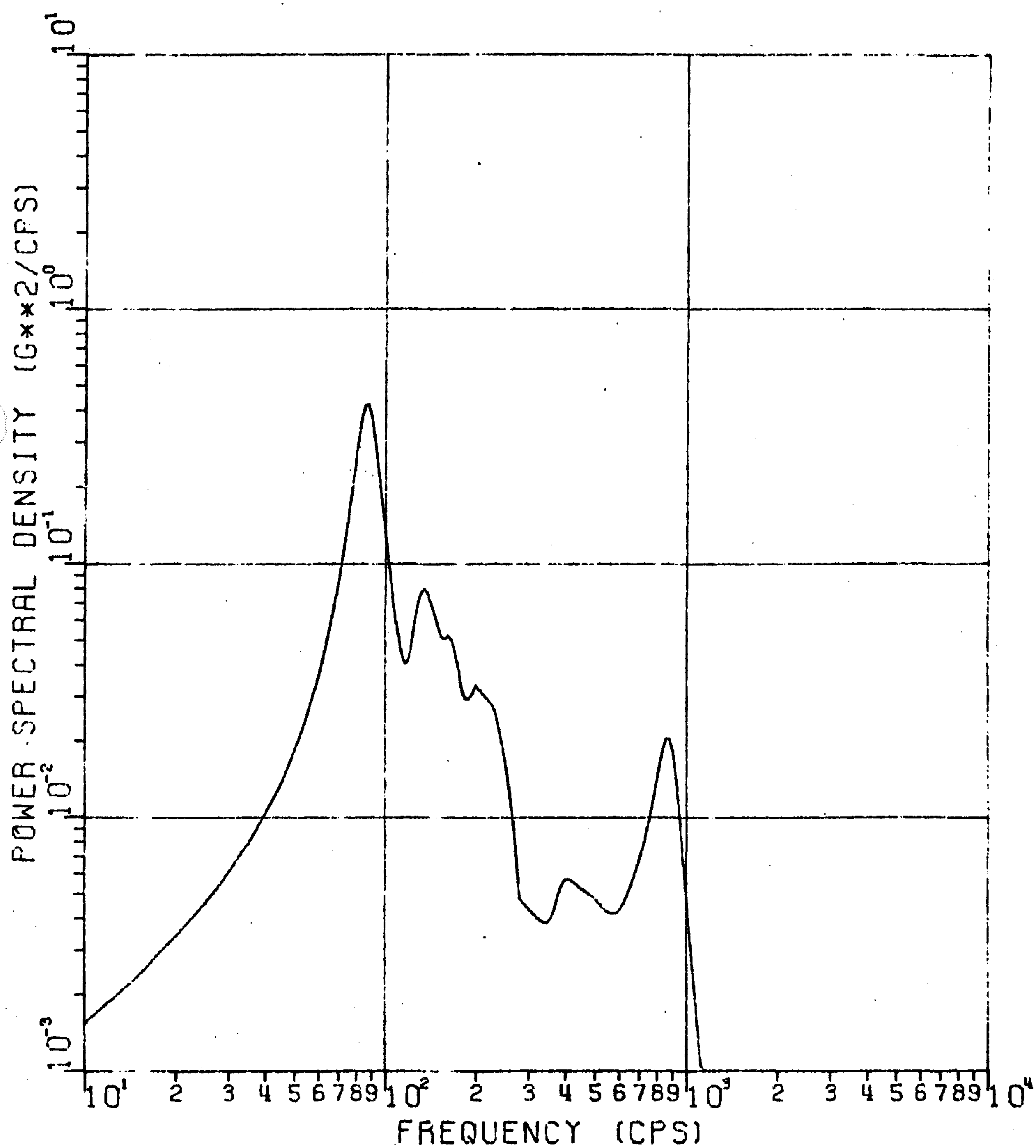
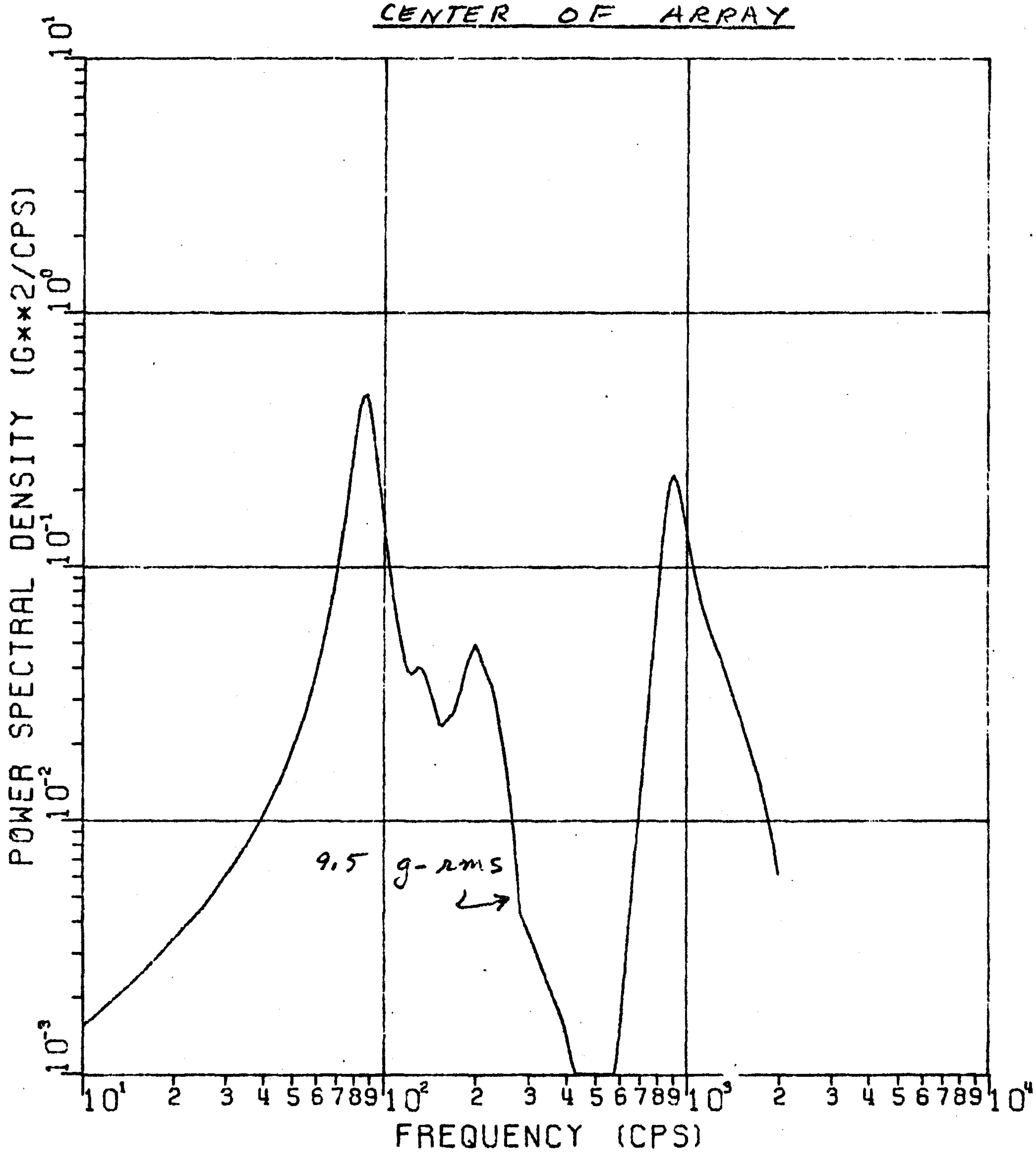


FIGURE 18 X AXIS FORCING 12 MARCH 1969

FIGURE 7c RANDOM VIBRATION SPECTRUM

LOCATION 11 , uc

CENTER OF ARRAY

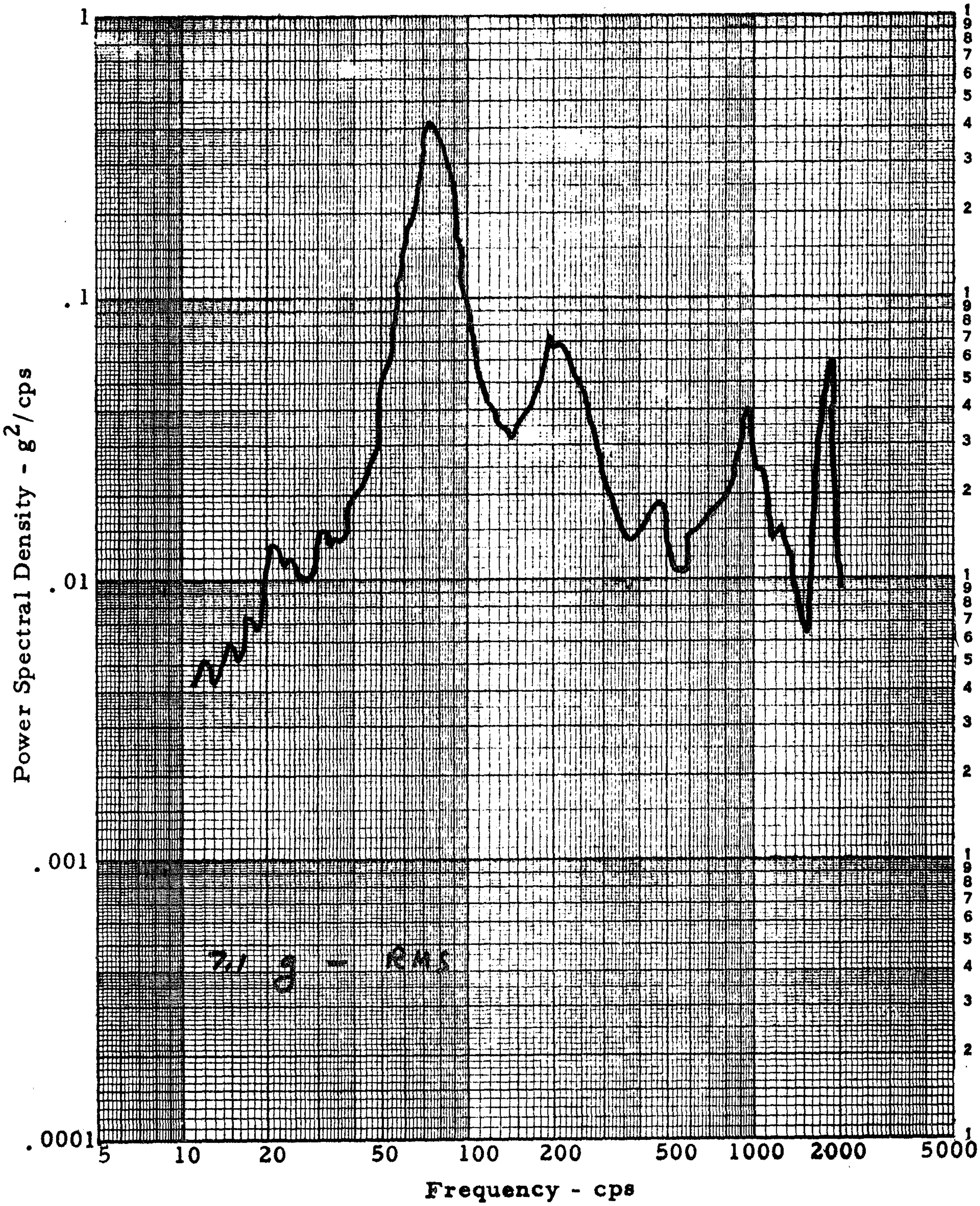


RANDOM VIBRATION SPECTRUM - APOLLO 11 LRRR

MEASURED ON ARRAY EDGE HALF-WAY BETWEEN CORNERS OF ARRAY PANEL

Test:
Test Item:
Test Date: FIGURE 19

SN:
Axis: X - EXCITATION
X - ORIENTATION



STRUCTURAL/DYNAMICS ANALYSIS

REPORT - LRRR

SECTION 3

LRRR ASSEMBLY FRAME/GRID ANALYSIS

SECTION 3

1.0 INTRODUCTION

This Section of the stress report contains the analysis of the LR^3 assembly frame. The results include the evaluation of the stiffness matrix (influence coefficients) of the four experiment support attachment points on the frame and the computation of the stress and displacement components due to various loads obtained from the dynamic analysis (see Section 2).

The analysis was performed using Bendix computer programs. The LRRR assembly frame (Bendix Drawing 2345727 - LRRR Structure Assembly) is idealized as a plane frame or grid composed of straight beam members connected at rigid joints. The primary beam members are channel sections with gusset plates added at joints and corners for local reinforcement. The equivalent stiffnesses are calculated for members stiffened by the gusset plates. The frame model, the nodes and member numbers are shown in Figure 1.

The two front support points (Nodal points 12 and 16) of the assembly frame are restrained from movements in all three global axis directions and the two back support points (Nodal points 5 and 7) are restrained only in the direction normal to the plane of the frame. These assumptions have been chosen based on the study of attachment details (see Section 1). The four experiment support point fittings are attached to the assembly frame at nodal points 1, 2, 3 and 4.

The assembly frame supports both the in-plane and the out-of-plane loads. The in-plane load components were studied by the Program DEFRAME and the out-of-plane load components were analyzed by the Program DEGRID. The analysis indicates that the stresses and displacements under all three dynamic loading conditions are structurally satisfactory.

LR^3 Assembly Frame Computer Analysis

LRRR Frame Model

Length unit: inch

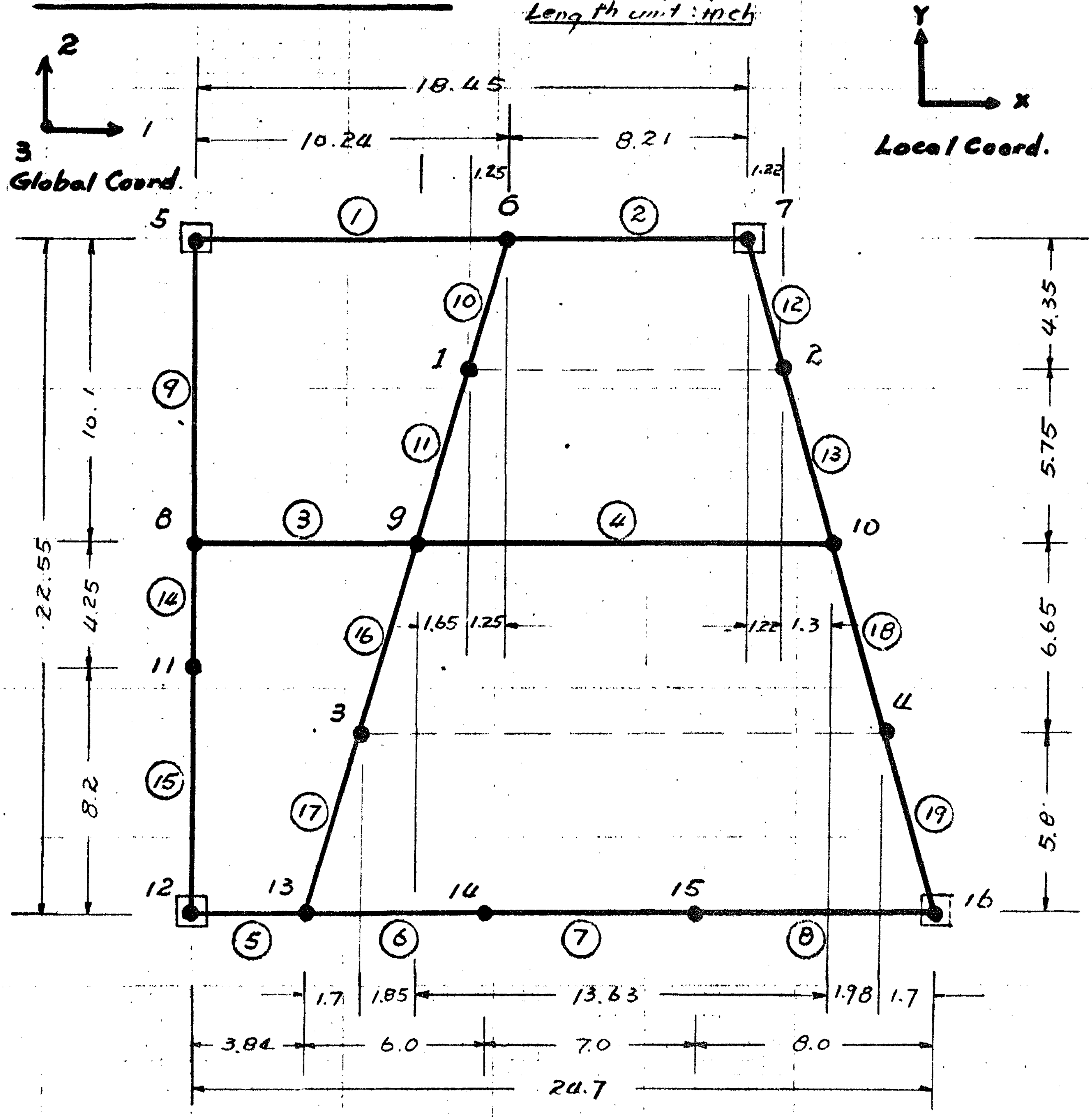
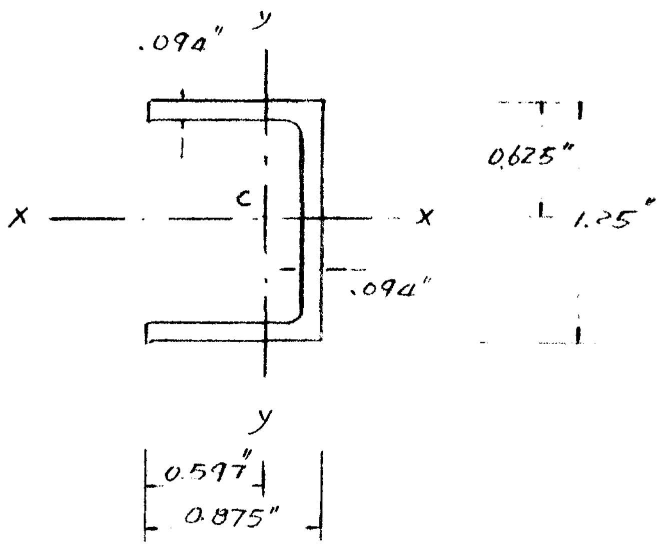
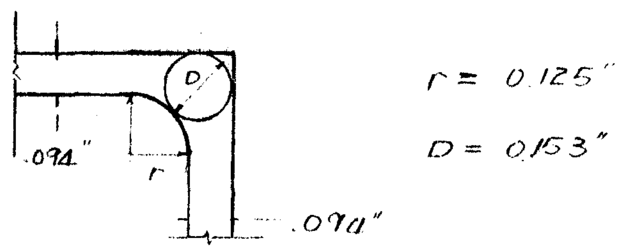


FIGURE 1

LR^3 Assembly Frame Analysis

Primary Member Section Properties





<u>Material</u> : 2024 T3511 Al Alloy

$F_t = 61{,}000$ psi

$E = 10.6 \times 10^6$ psi

$\nu = 0.33$

(Ref. MIL HDBK 5A)

$A = 0.267 \ in^2$

$I_{xx} = 0.065 \ in^4$ $\quad C_x = 0.625 \ in$ $\quad \left(f_{bx} = \frac{M_x C_x}{I_{xx}} \right)$

$I_{yy} = 0.019 \ in^4$ $\quad C_y = 0.597 \ in$ $\quad \left(f_{by} = \frac{M_y C_y}{I_{yy}} \right)$

J & Q Ref Roark's Formulas For Stress and Strain

$$K_1 = ab^3 \left[\frac{1}{3} - 0.21 \frac{b}{a} \left(1 - \frac{b^4}{12a^4}\right) \right] \qquad \begin{cases} a = 0.875 \\ b = 0.094 \end{cases}$$

$$= 225 \times 10^{-6}$$

$$K_2 = cd^3 \left[\frac{1}{3} - 0.105 \frac{d}{c} \left(1 - \frac{d^4}{192c^4}\right) \right] \qquad \begin{cases} c = 0.531 \\ d = 0.094 \end{cases}$$

$$= 138.5 \times 10^{-6}$$

$$\alpha = \frac{d}{b} \left(0.07 + 0.076 \frac{r}{b} \right) \qquad r = 0.125$$

$$D = 0.138$$

$$= 0.171$$

$$J = 2 \left(K_1 + K_2 + \alpha D^4 \right) = 2 \left(225 \times 10^{-6} + 138.5 \times 10^{-6} + 93.7 \times 10^{-6} \right)$$

$$= 915 \times 10^{-6} \ in^4$$

$$Q = \frac{D}{1 + \frac{\pi^2 D^4}{16A^2}} \left[1 + 0.15 \left(\frac{\pi^2 D^4}{16A^2} - \frac{D}{2r} \right) \right] \qquad A = .267 \ in^2$$

$$= 0.139 \ in \qquad \left(f_s = \frac{TQ}{J} \right)$$

Remarks: The cross-section properties calculated above will be used for members 1, 2, 3, 4, 7, 9, 10, 11, 12, 13, 14, 16, and 18. Note that for members 3 and 4, the xx-axis and yy-axes are reversed.

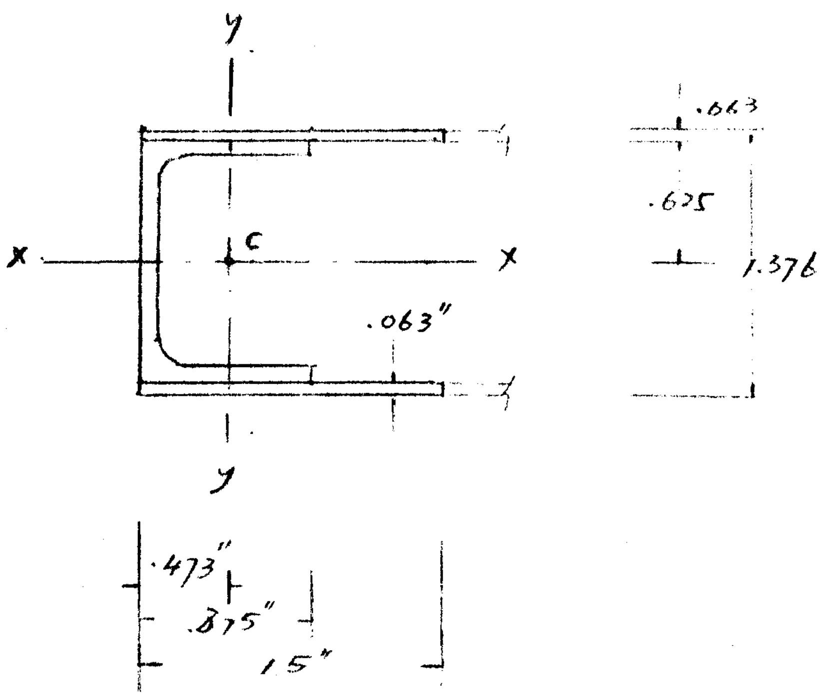
LR³ Assembly Frame Analysis

Special Member Section Properties

Considering the stiffness of gussets

I & A

(1) Members 5, 6, 8, 15 and 19



$\underline{A} = 0.267 + 0.189 = \underline{0.456 \ in^2}$

$I_{xx} = .019 + .267 \cdot .195^2 + 2\left(\frac{1.5^3 \cdot .063}{12} + 1.5 \cdot .063 \cdot .277^2\right)$

$\underline{= 0.079 \ in^4}$

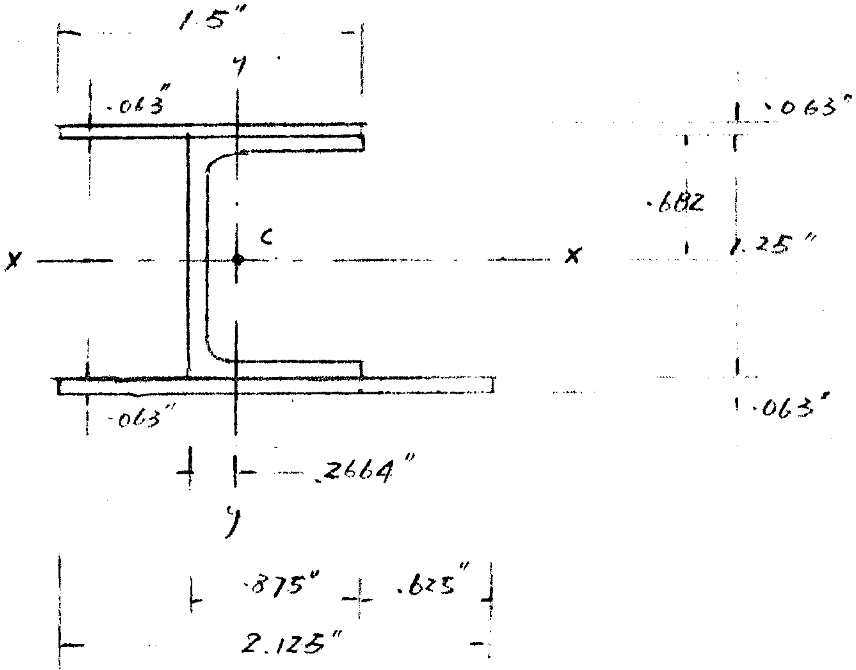
$I_{yy} = .065 + 1.5 \cdot .063 \cdot .656^2$

$= \underline{0.147 \ in^4}$

$c_x = 0.686$ in

$c_y = 1.027$ in

(2) Member 17



$A = 0.456 + .0393 = 0.495\ in^2$

$I_{xx} = .017 + 267 \times 0.0116^2 + 1.5 \times .063 \times 0.1646^2 + 2.125 \times 0.063 \times .1479^2 + \frac{1.5^3 \times .063}{12} + \frac{2.125^3 \times .063}{12}$

$= 0.0724\ in^4$

$I_{yy} = .1465 + .625 \times .063 \times .597^2 + .456 \times .0567^2$

$= 0.162\ in^4$

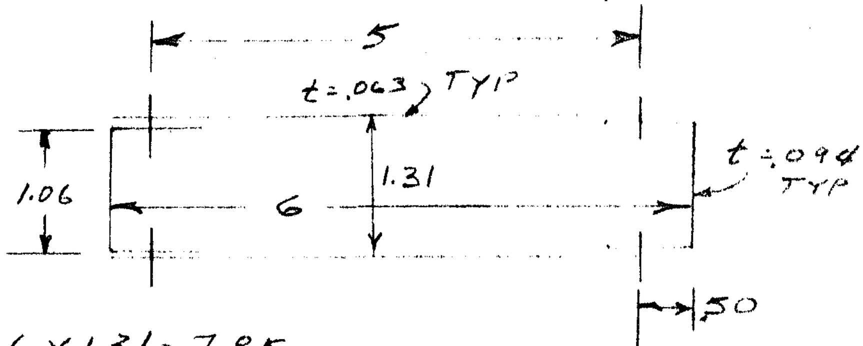
$c_x = 0.092$ in

$c_y = 1.234$ in

LRRR ASSEMBLY FRAME INVESTIGATION

TORSIONAL STIFFNESSES OF CORNER GUSSETS

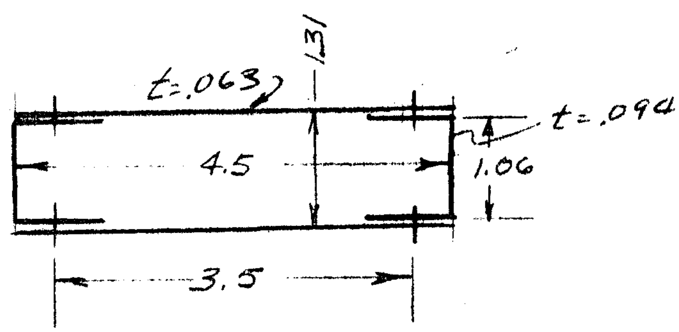
LEFT FRONT Member 15 and 17



$A = 6 \times 1.31 = 7.85$

$$\oint \frac{ds}{t} = \frac{5}{.063} \times 2 + \frac{.50}{.094} \times 4 + \frac{1.06}{.094} \times 2 = 159 + 21.3 + 22.6 = 202.9$$

$$J = \frac{4A^2}{\oint ds/t} = \frac{4 \times \overline{7.85}^2}{202.9} = 1.21$$



$A = 4.5 \times 1.31 = 5.90 \text{ IN}^2$

$$\oint \frac{ds}{t} = \frac{3.5}{.063} \times 2 + \frac{.50}{.094} \times 4 + \frac{1.06}{.094} \times 4$$

$$= 111 + 21.3 + 22.6 = 154.9$$

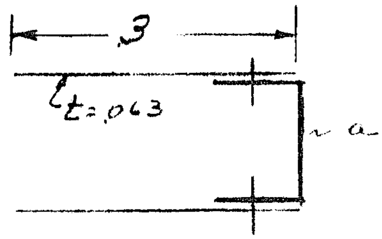
$$J = \frac{4A^2}{\oint ds/t} = \frac{4 \times 5.90^2}{154.9} = .90$$

$$AV = \frac{1.21 + .90}{2} = \frac{2.11}{2} = 1.05$$

LRRR ASSEMBLY FRAME INVESTIGATION

TORSIONAL STIFFNESS OF CORNER GUSSETS

RIGHT FRONT Member 8 and 19



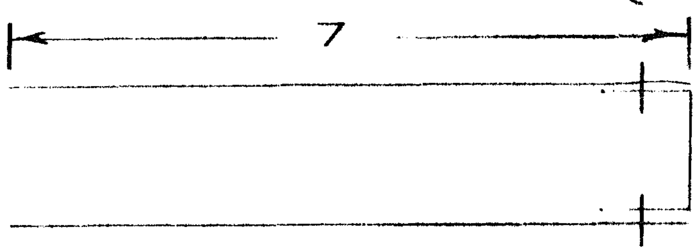
$J_a = 915 \times 10^{-6}$

$J_b = \left\{1.5 \times .031^3 \left[\frac{16}{3} - 3.36 \frac{.031}{1.5}\left(1 - \frac{.031^4}{12 \times 1.5^4}\right)\right]\right\} 2$

$= \left\{44.7 \times 10^{-6} \left[5.33 - .07\right]\right\} 2 = 470 \times 10^{-6}$

=

$J = (915 + 470) 10^{-6} = 1385 \times 10^{-6}$



$J_b = \left\{3.5 \times .031^3 \left[\frac{16}{3} - 3.36 \times \frac{.031}{3.5}\right]\right\} 2$

$= 104 \times 10^{-6} \left[5.33 - .03\right] 2 = 1100 \times 10^{-6}$

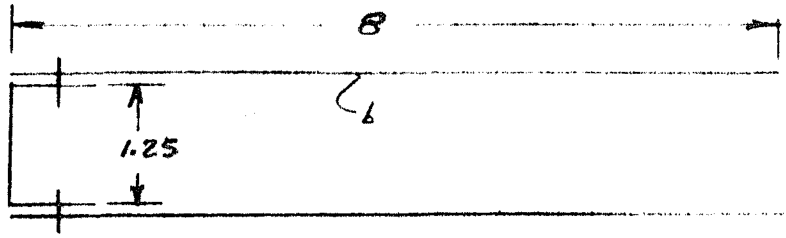
$J = \left[915 + 1100\right] 10^{-6} = 2015 \times 10^{-6}$

$AV. = \left(\frac{2015 + 1385}{2}\right) 10^{-6} = \underline{1700 \times 10^{-6}}$

LRRR ASSEMBLY FRAME INVESTIGATION

TORSIONAL STIFFNESS OF CORNER GUSSETS

LEFT FRONT - Member 5



$J_b = 2\left\{4 \times \overline{.031}^3 \left[5.33 - 3.36 \times \frac{.031}{4}\right\}2\right.$

$= 2\{119 \times 10^{-6} \times 5.3\} = 1260 \times 10^{-6}$

$J = [915 + 1260]10^{-6} = \underline{2175 \times 10^{-6}}$

LEFT FRONT Member 6

$J_b = (915 + 630)10^{-6} + 1.5 \times \overline{.031}^3 \left[5.33 - 3.36 \times \frac{.031}{1.5}\right]$

$(915 + 630 + 226)10^{-6} = \underline{1771 \times 10^{-6}}$

RIGHT FRONT e-13

LR^3 Assembly Frame Computer Analysis — TABLE 1 —

Equivalent Member's Properties $E = 10.6 \times 10^6$ psi $\nu = 0.33$ (for all members)

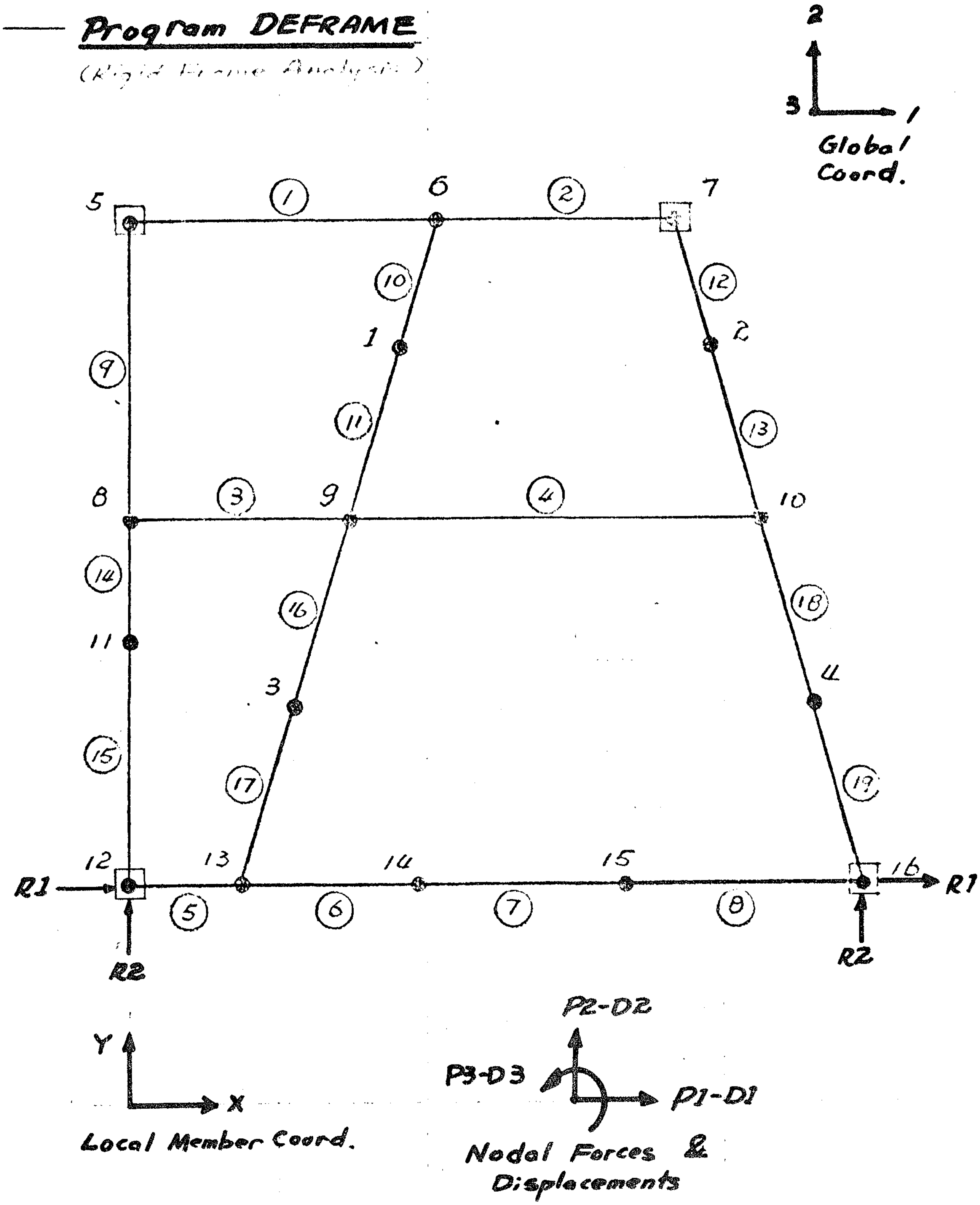
Mem	Nodes		Local Coord.		I_o out-of plane	I_i in-plane	J	C_o out-of plane	Ci in-plane	Q	A
	NI	NJ	X	Y							
1	5	6	10.24	0	.065	.019	.0009	.625	.597	.139	.267
2	6	7	8.21	0	.065	.019	.0009	.625	.597	.139	.267
3	8	9	7.37	0	.019	.065	.0009	.597	.625	.139	.267
4	9	10	13.63	0	.019	.065	.0009	.597	.625	.139	.267
5	12	13	3.84	0	.147	.079	.0022	.688	1.027	.139	.456
6	13	14	6.0	0	.147	.079	.0018	.688	1.027	.139	.456
7	14	15	7.0	0	.065	.019	.0009	.628	.597	.139	.267
8	15	16	8.0	0	.147	.079	.0017	.688	1.027	.139	.456
9	5	8	0	-10.10	.065	.019	.0009	.628	.597	.139	.267
10	1	6	1.25	4.35	.065	.019	.0009	.628	.597	.139	.267
11	1	9	-1.65	-5.75	.065	.019	.0009	.628	.597	.139	.267
12	2	7	-1.22	4.35	.065	.019	.0009	.628	.597	.139	.267
13	2	10	1.30	-5.75	.065	.019	.0009	.628	.597	.139	.267
14	8	11	0	4.25	.065	.019	.0009	.628	.597	.139	.267
15	11	12	0	-8.20	.147	.079	1.05	.688	1.027	.139	.456
16	3	9	1.85	6.65	.065	.019	.0009	.628	.597	.139	.267
17	3	13	-1.70	-5.80	.162	.092	1.05	.688	1.234	.139	.495
18	4	10	-1.98	6.65	.065	.019	.0009	.628	.597	.139	.267
19	4	16	1.70	-5.80	.147	.079	.0017	.688	1.027	.139	.456

LR³ Assembly Frame Computer Analysis

In-plane Component Study

— Program DEFRAME

(Rigid Frame Analysis)



LR^3 Assembly Frame Analysis

In-plane Component Study

— Program DEFRAME

* Number of nodes NN = 16
* Number of members NM = 19
* Number of restrained nodes NRN = 4
* Number of restraints NR = 4
* Support Conditions:

Node	I1	I2	I3
5	0	0	0
7	0	0	0
12	1	1	0
16	1	1	0

* Reference Data:

Ref $E = 10.6 \times 10^6$ psi (for all members)

Ref $I_i = 0.019$

Ref $A = 0.267$ in^2

Ref $SA = 0.267$ in^2

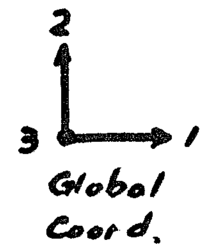
Ref $C_i = 0.625$ in

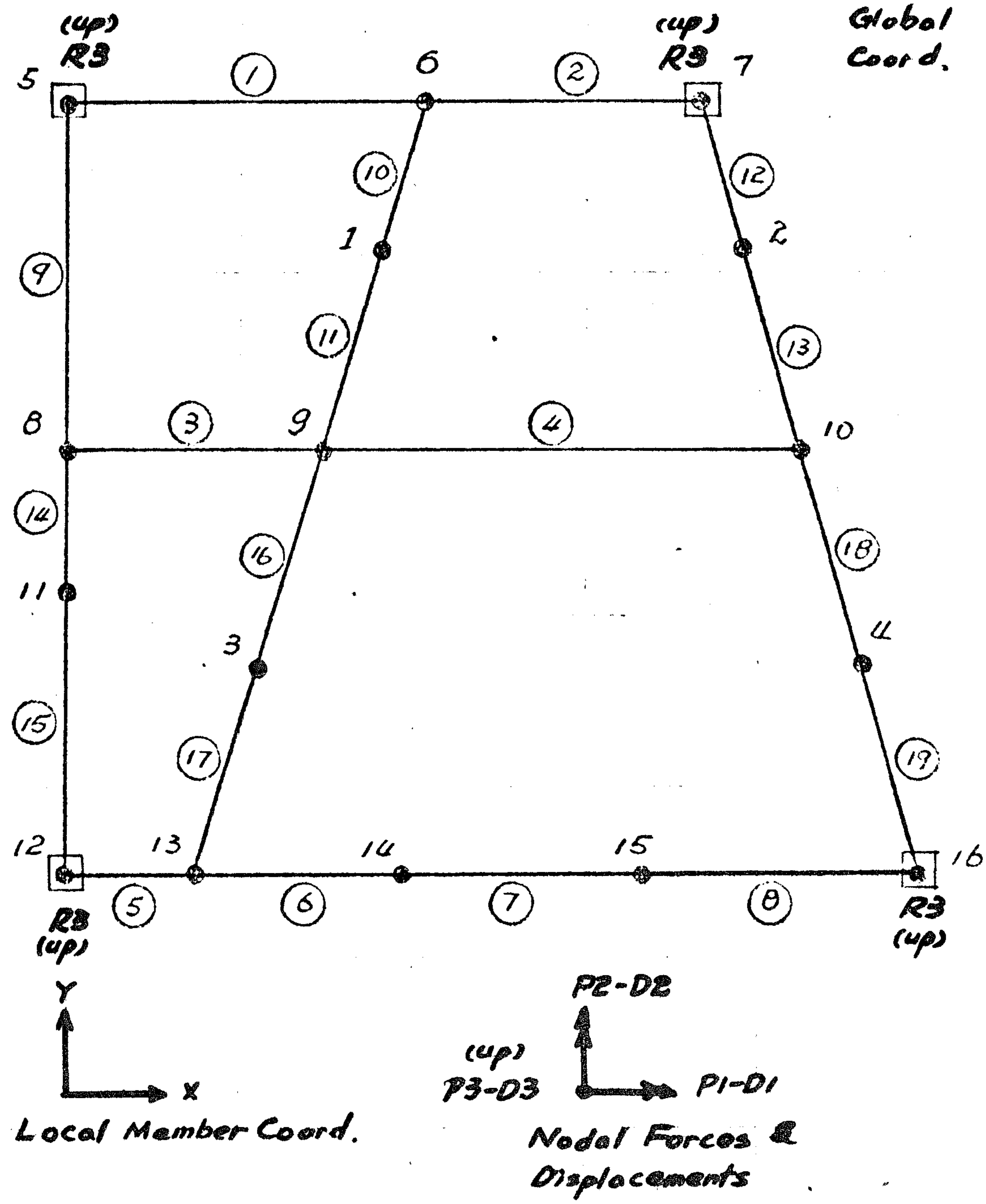
LR³ Assembly Frame Computer Analysis

Out-of-Plane Component Study

—— Program DEGRID

(Plane Grid Analysis)





LR^3 Assembly Frame Analysis

Out-of Plane Component Study

— Program DEGRID

* Number of nodes NN = 16
* Number of members NM = 19
* Number of restrained nodes NRN = 4
* Number of restraints NR = 4
* Support Conditions:

Node	I1	I2	I3
5	0	0	1
7	0	0	1
12	0	0	1
16	0	0	1

* Reference Data:

Ref. E $= 10.6 \times 10^6$ psi (for all members)

Ref. ν = 0.33 (for all members)

Ref. I_o = 0.065 in^4

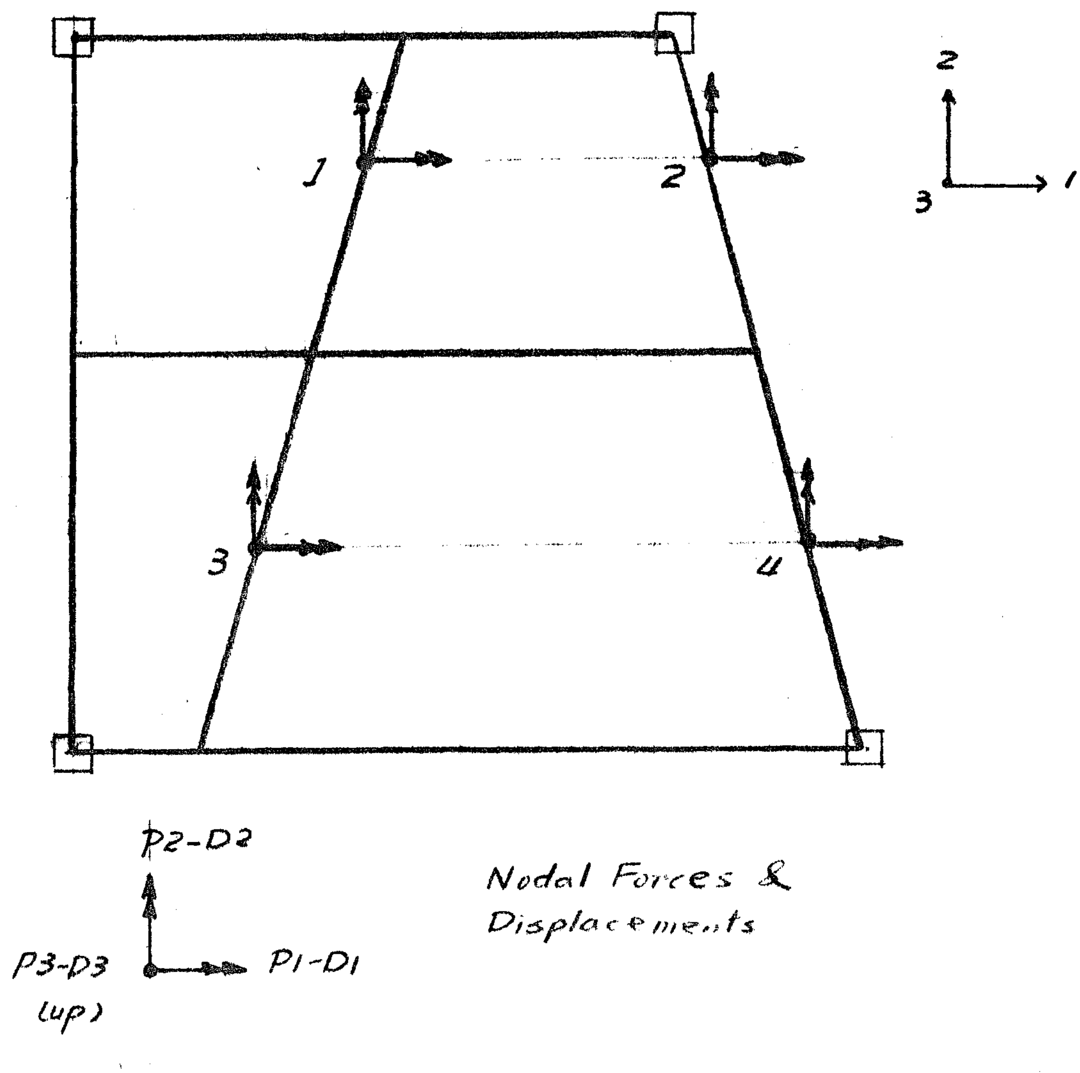
Ref. C_o = 0.625 in

Ref. Q = 0.139 in

LR[3] Assembly Frame Analysis

Calculation of Influence Coefficients of the Experiment Support Attachment Points (1, 2, 3, 4) — for dynamic analysis

The influence coefficients of the four support attachment points (1, 2, 3, 4) due to unit load normal to the plane of the frame, and unit moments about axes 1 and 2 respectively will be analyzed by means of Program DEGRID.



Nodal Forces & Displacements

LR³ Assembly Frame Analysis

The nodal forces P1 and P2 represent the applied moments about axes 1 and 2 respectively, and P3 represents the linear force applied normal to the plane of the frame. The nodal displacement components D1, D2 and D3 are the corresponding rotations and linear normal deflection. Define the nodal force and displacement relations as follows:

$$\begin{Bmatrix} D1_1 \\ D2_1 \\ D3_1 \\ D1_2 \\ D2_2 \\ D3_2 \\ D1_3 \\ D2_3 \\ D3_3 \\ D1_4 \\ D2_4 \\ D3_4 \end{Bmatrix} = \begin{bmatrix} K \end{bmatrix} \begin{Bmatrix} P1_1 \\ P2_1 \\ P3_1 \\ P1_2 \\ P2_2 \\ P3_2 \\ P1_3 \\ P2_3 \\ P3_3 \\ P1_4 \\ P2_4 \\ P3_4 \end{Bmatrix}$$

where the subscripts indicate the corresponding nodal points. The components of the [K] matrix are listed as:

PREPARED BY D. Chang
CHECKED BY
REVISED BY

ENGINEERING REPORT
Bendix Aerospace Systems Division

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REPORT No. ATM-871
MODEL LRRR

$[K] =$

10^{-3}

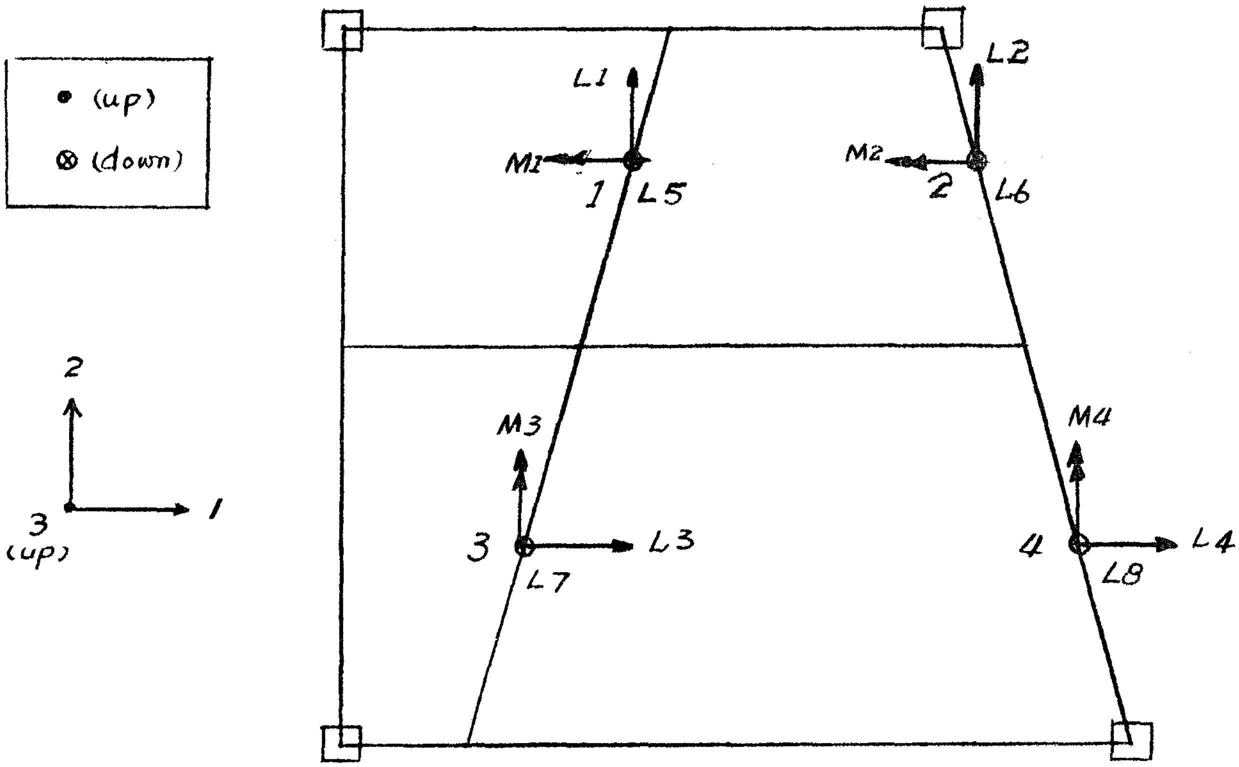
.0597					
.1882	.6556				
-.0115	-.0010	.2070			
.0006	.0006	-.0079	.0430		
.0007	.0001	.0163	-.1577	.6700	
.0037	-.0032	.0163	.0071	-.1295	.1616
-.0025	-.0003	.0173	-.0008	.0010	.0023
.0005	.0001	-.0017	.0001	-.0001	-.0004
-.0198	-.0028	.1156	-.0054	.0063	.0177
-.0002	-.0004	.0008	-.0021	-.0091	.0222
-.0015	-.0007	.0086	-.0004	.0059	-.0059
-.0040	-.0037	.0209	-.0147	-.0434	.1270

Symmetric

.0052					
.0024	.0060				
.0158	-.0095	.1849			
.0005	.0007	-.0008	.0546		
-.0003	-.0027	.0142	-.1676	.5653	
.0028	-.0005	.0209	.0303	-.0137	.1865

B-A 542

LR³ Assembly Frame Analysis
Dyamic Load Analysis



The in-plane load components were studied by means of Program DEFRAME and the out-of-plane components were analyzed by Program DEGRID.

A safety factor of 1.5 and a standard deviation factor of 3 (99.7%) were used to establish the input loads for the computer analysis.

The in-plane and out-of-plane nodal load components for all three loading conditions were listed in Tables 3 and 4. The computer analysis results of the member forces, moments and stresses, the nodal point deflections; and the support reactions are listed in Tables 5 – 11 and 13 – 18

LR^3 Assembly Frame Analysis

Dynamic Load Analysis

The equivalent dynamic loads acting at the experiment support attachment points due to the excitations in axes 1, 2 and 3 directions were obtained from the Program REFRAME as follows:

— Table 2 — Units: in-lb

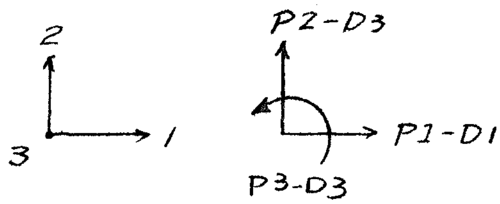
Load	Loading Condition 1	Loading Condition 2	Loading Condition 3
	Axis-1	Axis-2	Axis-3
L1	47.81	185.39	33.72
L2	112.82	19.35	10.63
L3	173.30	34.10	7.30
L4	10.95	2.15	0.46
L5	12.83	28.19	32.40
L6	21.58	52.89	57.74
L7	66.78	39.12	62.17
L8	50.01	81.89	109.71
M1	47.81	185.39	33.72
M2	112.82	19.35	10.63
M3	173.30	34.10	7.30
M4	10.95	2.15	0.46

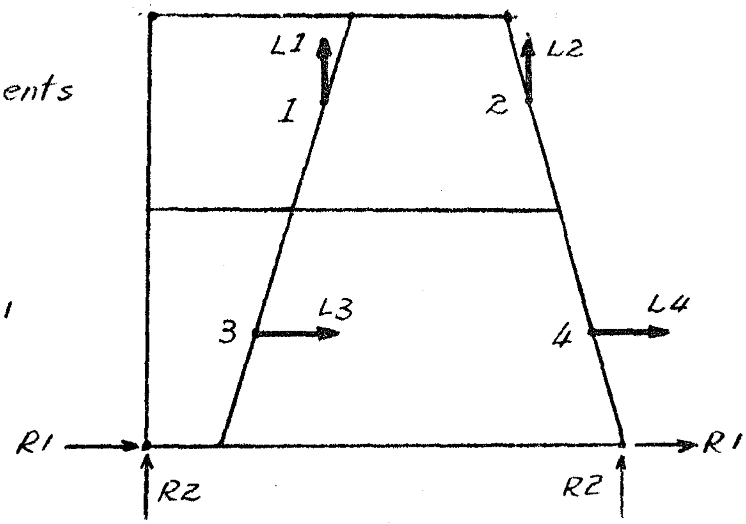
The positive directions of the dynamic loading components are shown in the Figure on next page.

LR³ Assembly Frame Analysis

Dynamic load Analysis
— in-plane component

In-put Nodal Load Components for Program DEFRAME





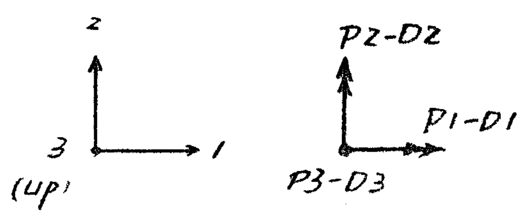
—Table 3—

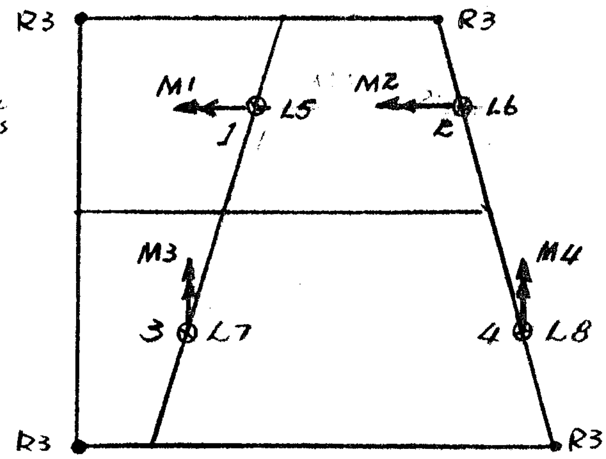
Loading Condition	Node	P1	P2	P3
1	1	0	215.15	0
	2	0	507.69	0
	3	779.85	0	0
	4	49.28	0	0
2	1	0	834.26	0
	2	0	87.08	0
	3	153.45	0	0
	4	9.68	0	0
3	1	0	151.74	0
	2	0	46.62	0
	3	32.85	0	0
	4	2.07	0	0

LR³ Assembly Frame Analysis

Dynamic load Analysis
— out-of-plane Components

In-put Nodal Load Components for Program DEGRID





— Table 4 —

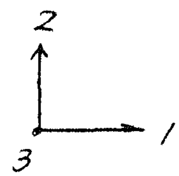
Loading Condition	Node	P1	P2	P3
1	1	- 215.15	0	- 57.74
	2	- 507.69	0	- 97.11
	3	0	779.85	-300.51
	4	0	42.28	-225.05
2	1	- 834.26	0	-126.86
	2	- 87.08	0	- 238.01
	3	0	153.45	-176.04
	4	0	9.68	-368.51
3	1	- 151.74	0	- 145.80
	2	- 46.62	0	- 259.83
	3	0	32.85	- 297.77
	4	0	2.07	- 493.70

LR^3 Assembly Frame Analysis

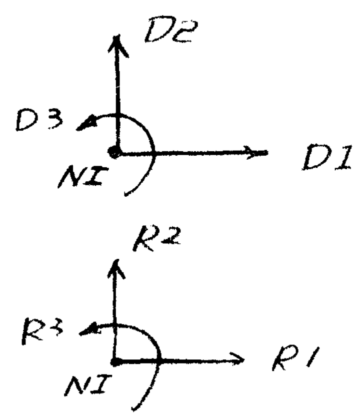
Notations Used in Tables 6-18

(1) In-plane components — Tables 6-11

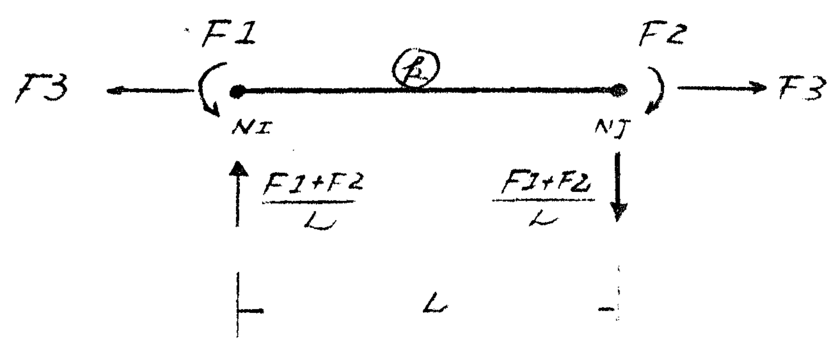
Nodal Displacements & Support Reactions



Global Coord.



Member Forces and Stresses



$$S1 = \frac{F1\, c_i}{I_i}$$

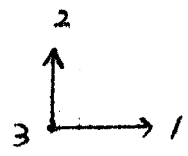
$$S2 = \frac{F2\, c_i}{I_i}$$

$$S3 = \frac{F3}{A}$$

$$S12 = \left(\frac{F1+F2}{L}\right) / SA$$

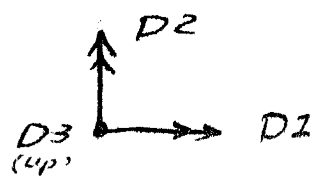
LR^3 Assembly Frame Analysis

(2) Out-of-plane components Table 13-18

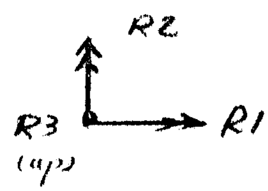


Global Coord

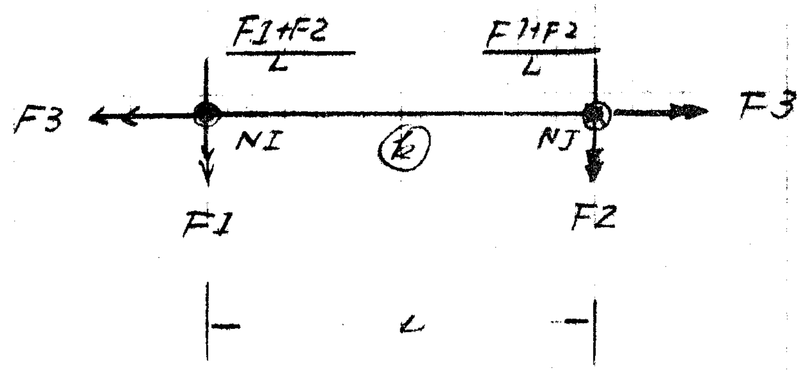
Nodal Displacements



Support Reactions



Member Forces and Stresses



$$S1 = \frac{F1\, c_o}{I_o}$$

$$S2 = \frac{F2\, c_o}{I_o}$$

$$S3 = \frac{F3\, Q}{J}$$

TABLE 5

LRRR ASSEMBLY FRAME INVESTIGATION (IN-PLANE LOADING)   APRIL 27 1970 D CHANG

UNITS USED   LENGTH - IN   FORCE - LB

DIRECT ELEMENT METHOD OF RIGID FRAME ANALYSIS - PROGRAM DEFRAME

REF.E #	0.1060E 08	DEGREES OF FREEDOM #	40
REF.SA#	0.2670	NUMBER OF MEMBERS #	19
REF.I #	0.0190	NUMBER OF JOINTS #	16
REF.A #	0.2670	NUMBER OF RESTRAINTS #	8
REF.C #	0.5970	NUMBER OF LOADINGS #	3

MEMBER	NI	NJ	X	Y	I	A	L	C	SA	E
1	5	6	10.2400	0.0	0.0190	0.2670	10.2400	0.5970	0.2670	0.1060E 08
2	6	7	8.2100	0.0	0.0190	0.2670	8.2100	0.5970	0.2670	0.1060E 08
3	8	9	7.3700	0.0	0.0650	0.2670	7.3700	0.6250	0.2670	0.1060E 08
4	9	10	13.6300	0.0	0.0650	0.2670	13.6300	0.6250	0.2670	0.1060E 08
5	12	13	3.8400	0.0	0.0790	0.4560	3.8400	1.0270	0.4560	0.1060E 08
6	13	14	6.0000	0.0	0.0790	0.4560	6.0000	1.0270	0.4560	0.1060E 08
7	14	15	7.0000	0.0	0.0190	0.2670	7.0000	0.5970	0.2670	0.1060E 08
8	15	16	8.0000	0.0	0.0790	0.4560	8.0000	1.0270	0.4560	0.1060E 08
9	5	8	0.0	-10.1000	0.0190	0.2670	10.1000	0.5970	0.2670	0.1060E 08
10	1	6	1.2500	4.3500	0.0190	0.2670	4.5260	0.5970	0.2670	0.1060E 08
11	1	9	-1.6500	-5.7500	0.0190	0.2670	5.9821	0.5970	0.2670	0.1060E 08
12	2	7	-1.2200	4.3500	0.0190	0.2670	4.5178	0.5970	0.2670	0.1060E 08
13	2	10	1.3000	-5.7500	0.0190	0.2670	5.8951	0.5970	0.2670	0.1060E 08
14	8	11	0.0	-4.2500	0.0190	0.2670	4.2500	0.5970	0.2670	0.1060E 08
15	11	12	0.0	-8.2000	0.0790	0.4560	8.2000	1.0270	0.4560	0.1060E 08
16	3	9	1.8500	6.6500	0.0190	0.2670	6.9025	0.5970	0.2670	0.1060E 08
17	3	13	-1.7000	-5.8000	0.0920	0.4950	6.0440	1.2340	0.4950	0.1060E 08
18	4	10	-1.9800	6.6500	0.0190	0.2670	6.9385	0.5970	0.2670	0.1060E 08
19	4	16	1.7000	-5.8000	0.0790	0.4560	6.0440	1.0270	0.4560	0.1060E 08

TABLE 6
LOADING CONDITION NO. 1 (IN-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

	BENDING MOMENTS		AXIAL FORCE	BENDING STRESSES		AXIAL STRESS	SHEAR STRESS
MEMBER	F1	F2	F3	S1	S2	S3	S12
1	202.1487	222.1750	-54.7773	6351.7227	6960.9688	-205.1586	155.1980
2	-319.2212	-128.1638	13.1523	-10030.2617	-4027.0417	49.2597	-204.0926
3	144.7388	995.0276	124.0195	1391.4304	9545.3398	464.4927	578.1799
4	-606.3147	-658.7507	24.5313	-5829.9453	-6334.1406	91.8773	-347.6208
5	[illegible]	-1756.9865	650.9223	-8528.0733	-22840.7305	1427.4624	-1377.9446
6	-706.9126	306.2119	-96.3030	-9449.8555	3980.7527	-211.1908	-153.7649
7	-306.1992	-184.6451	-96.3032	-9821.0977	-5801.7422	-360.6860	-262.6240
8	184.6445	-745.6062	-96.3019	2400.3774	-9692.8984	-211.1884	-153.7729
9	-202.1476	-351.0554	-41.4377	-6351.6875	-11030.5273	-155.1974	-205.1407
10	78.3999	97.0437	110.9570	2463.4063	3049.2146	415.5693	145.1806
11	-75.4044	-44.4896	317.7227	-2453.5471	-1397.9097	1169.9727	-76.9430
12	-251.8389	128.1638	-48.8906	-7913.0391	4027.0417	-183.1110	-102.5275
13	251.8389	261.6426	444.8750	7913.0430	8221.0820	1666.1987	326.2275
14	210.3451	88.0037	-195.8118	6453.7031	2765.1675	-733.3777	259.3989
15	-37.4795	655.9009	-195.8110	-1143.7527	8526.7070	-429.4102	151.8832
16	-900.9119	-342.2224	529.3750	-28337.5977	-10752.9844	1982.6780	-674.5254
17	900.9543	2485.9810	745.9219	12084.5430	33317.7383	1506.9128	1131.4119
18	65.7690	397.1165	356.0820	2066.5317	12477.8125	1333.6406	249.8596
19	-65.7524	745.6230	342.4922	-854.7813	9693.0938	751.0793	246.6817

MAXIMUM BENDING STRESS = 33317.7383
ASSOC. MEMBER NUMBER = 17

MAXIMUM AXIAL STRESS = 1982.6780
ASSOC. MEMBER NUMBER = 16

MAXIMUM SHEAR STRESS = 1377.9446
ASSOC. MEMBER NUMBER = 5

TABLE 7
LOADING CONDITION NO. 2 (IN-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

MEMBER	BENDING MOMENTS F1	BENDING MOMENTS F2	AXIAL FORCE F3	BENDING STRESSES S1	BENDING STRESSES S2	AXIAL STRESS S3	SHEAR STRESS S12
1	-183.5647	-401.1528	35.0820	-5767.7930	-12604.6406	131.3934	-213.8627
2	342.5940	370.8740	99.3594	10754.6602	11653.2500	374.0051	325.4768
3	-367.6951	-505.5149	22.4453	-5535.5293	-4860.7188	84.0648	-443.7517
4	592.5586	636.4080	53.9683	9140.2734	6119.3047	202.2033	436.0828
5	-519.2654	-1054.0818	217.6072	-6750.4453	-13703.0547	477.2085	-898.5222
6	498.8088	-225.0030	-32.1945	6454.5078	-2925.0369	-70.6020	100.0752
7	224.9917	94.4795	-32.1944	7069.4727	2968.6458	-120.5784	170.9317
8	-94.4745	459.5920	-32.1947	-1223.1672	5974.6914	-70.6024	100.0870
9	183.5635	170.7209	57.1011	5767.7539	5364.2266	213.8619	131.3770
10	463.3066	58.5625	-120.4683	12572.3164	1840.0952	-451.2668	382.1995
11	-463.3054	-362.9915	661.3359	-12572.2773	-11405.5703	2551.8203	-479.7727
12	42.5229	-370.8735	110.6328	1336.1147	-11653.2344	414.3550	-272.2048
13	-42.5246	-305.4700	191.7209	-1336.1670	-9598.1875	718.0559	-221.0695
14	156.9690	47.5150	175.5824	6188.9727	1492.9712	657.6118	215.4520
15	-47.5249	519.2393	175.5813	-617.5232	6750.1055	385.0466	126.1539
16	-119.5154	-82.0903	464.4922	-3755.3003	-2579.3650	1739.6711	-109.3914
17	119.5061	555.2251	507.2227	1602.9492	7447.2539	1024.6921	225.5283
18	-117.1233	-330.9419	322.2515	-3680.1382	-10398.5391	1206.9343	-241.8600
19	117.1208	-459.5886	319.2458	1522.5701	-5974.6484	700.1006	-124.2597

MAXIMUM BENDING STRESS # 13703.0547
ASSOC. MEMBER NUMBER # 5

MAXIMUM AXIAL STRESS # 2551.8203
ASSOC. MEMBER NUMBER # 11

MAXIMUM SHEAR STRESS # 898.5222
ASSOC. MEMBER NUMBER # 5

Bendix
Aerospace Systems Division

Structural/Dynamics Analysis Report - LRRR
LRRR Assembly Frame/Grid Analysis

NO. ATM-871
REV. NO.

DATE 5-15-70

TABLE 8

LOADING CONDITION NO. 3 (IN-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

	BENDING MOMENTS		AXIAL FORCE	BENDING STRESSES		AXIAL STRESS	SHEAR STRESS
MEMBER	F1	F2	F3	S1	S2	S3	S12
1	-30.2823	-66.7757	5.6177	-951.5907	-2098.1624	21.0400	-35.4993
2	50.1397	61.6561	19.3425	1575.4409	1937.2993	72.4439	51.0001
3	-68.3615	-78.2363	6.7429	-657.3223	-752.2720	25.2544	-74.4936
4	146.7537	88.9617	14.0476	1411.0928	855.4011	52.6128	64.7710
5	-111.9657	-212.5757	46.9397	-1455.5530	-2763.4824	102.9380	-185.3421
6	77.6905	-36.0094	-6.9446	1009.9758	-468.1218	-15.2295	15.2343
7	36.0076	12.6256	-6.9446	1131.3960	396.7085	-26.0098	26.0210
8	-12.6244	68.2069	-6.9447	-154.1173	886.6890	-15.2295	15.2364
9	30.2821	26.4426	9.4783	951.4958	830.8545	35.4992	21.0349
10	71.9498	16.6366	-18.4041	2260.7368	522.7402	-68.9240	73.3058
11	-71.9498	-61.3695	127.4330	-2260.7373	-1928.2952	477.2959	-83.4702
12	-5.8693	-61.6561	18.3342	-184.4189	-1937.2998	68.6675	-55.9790
13	5.8690	-38.7777	63.0183	184.4090	-1218.4353	236.0238	-20.9077
14	41.9181	10.6106	29.3695	1317.1118	333.3955	109.9980	46.2910
15	-10.6116	111.9615	29.3692	-137.9506	1455.4983	64.4062	27.1047
16	-22.1664	-7.1491	93.7495	-696.4900	-224.6311	351.1216	-15.9066
17	22.1651	134.8772	102.9211	297.3020	1809.1130	207.9215	52.4913
18	-18.3505	-50.1843	83.6351	-576.5928	-1576.8433	313.9893	-36.9942
19	18.3500	-68.2060	83.2105	238.5495	-886.6772	182.4792	-18.0896

MAXIMUM BENDING STRESS = 2763.4824
ASSOC. MEMBER NUMBER = 5

MAXIMUM AXIAL STRESS = 477.2959
ASSOC. MEMBER NUMBER = 11

MAXIMUM SHEAR STRESS = 185.3421
ASSOC. MEMBER NUMBER = 5

TABLE 9

LOADING CONDITION NO. 1 (IN-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	0.0464	-0.0170	0.0003
2	0.0571	0.0188	0.0001
3	0.0477	-0.0195	-0.0088
4	0.0253	0.0079	-0.0054
5	0.0465	-0.0008	-0.0000
6	0.0463	-0.0168	0.0005
7	0.0463	0.0157	0.0044
8	0.0537	-0.0006	-0.0038
9	0.0510	-0.0191	0.0008
10	0.0512	0.0165	0.0003
11	0.0299	-0.0003	-0.0050
12	0.0	0.0	-0.0014
13	0.0005	-0.0065	-0.0039
14	0.0004	-0.0173	-0.0002
15	0.0002	-0.0012	0.0019
16	0.0	0.0	-0.0025

NODAL REACTIONS

NODE	R1	R2	R3
12	-720.1816	-432.5320	0.0
16	-107.9141	-290.1833	0.0

TABLE 10
LOADING CONDITION NO. 2 (IN-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	-0.0444	0.0311	0.0014
2	-0.0335	-0.0076	0.0027
3	-0.0094	0.0185	0.0014
4	-0.0102	-0.0026	0.0026
5	-0.0385	0.0008	0.0031
6	-0.0384	0.0291	-0.0025
7	-0.0381	-0.0087	-0.0019
8	-0.0242	0.0006	0.0027
9	-0.0241	0.0238	0.0020
10	-0.0239	-0.0056	-0.0011
11	-0.0177	0.0003	0.0012
12	0.0	0.0	0.0039
13	0.0002	0.0151	0.0027
14	0.0001	0.0226	0.0001
15	0.0001	0.0090	-0.0022
16	0.0	0.0	0.0005

NODAL REACTIONS

NODE	R1	R2	R3
12	-275.1328	-585.3076	0.0
16	111.9745	-336.0586	0.0

TABLE 11
LOADING CONDITION NO. 3 (IN-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	-0.0064	0.0051	0.0002
2	-0.0040	-0.0007	0.0004
3	-0.0010	0.0031	0.0001
4	-0.0012	-0.0002	0.0003
5	-0.0052	0.0001	0.0005
6	-0.0052	0.0047	-0.0004
7	-0.0051	-0.0009	-0.0002
8	-0.0030	0.0001	0.0004
9	-0.0030	0.0038	0.0004
10	-0.0029	-0.0005	-0.0002
11	-0.0024	0.0000	0.0001
12	0.0	0.0	0.0007
13	0.0000	0.0026	0.0004
14	0.0000	0.0039	0.0000
15	0.0000	0.0018	-0.0004
16	0.0	0.0	0.0000

NODAL REACTIONS

NODE	R1	R2	R3
12	-59.2995	-113.8848	0.0
16	24.3758	-84.4788	0.0

TABLE 12

LRRR ASSEMBLY FRAME INVESTIGATION (OUT-OF-PLANE LOADING)   APRIL 27 70   D CHANG

UNITS USED   LENGTH -   IN   FORCE -   LB

DIRECT ELEMENT METHOD OF PLANE GRID ANALYSIS @ PROGRAM DEGRID

REF.E #	0.1060E 08	DEGREES OF FREEDOM	#	44
REF.PR#	0.3300	NUMBER OF MEMBERS	#	19
REF.I #	0.0650	NUMBER OF JOINTS	#	16
REF.J #	0.0009	NUMBER OF RESTRAINTS	#	4
REF.C #	0.6250	NUMBER OF LOADINGS	#	3
REF.C #	0.1390			

MEMBER	NI	NJ	X	Y	I	J	L	C	Q	E	PR
1	5	6	10.2400	0.0	0.0650	0.0009	10.2400	0.6250	0.1390	0.1060E 08	0.3300
2	6	7	8.2100	0.0	0.0650	0.0009	8.2100	0.6250	0.1390	0.1060E 08	0.3300
3	8	9	7.3700	0.0	0.0190	0.0009	7.3700	0.5970	0.1390	0.1060E 08	0.3300
4	9	10	13.6300	0.0	0.0190	0.0009	13.6300	0.5970	0.1390	0.1060E 08	0.3300
5	12	13	3.8400	0.0	0.1470	0.0022	3.8400	0.6880	0.1390	0.1060E 08	0.3300
6	13	14	6.0000	0.0	0.1470	0.0018	6.0000	0.6880	0.1390	0.1060E 08	0.3300
7	14	15	7.0000	0.0	0.0650	0.0009	7.0000	0.6250	0.1390	0.1060E 08	0.3300
8	15	16	8.0000	0.0	0.1470	0.0017	8.0000	0.6880	0.1390	0.1060E 08	0.3300
9	5	5	0.0	-10.1000	0.0650	0.0009	10.1000	0.6250	0.1390	0.1060E 08	0.3300
10	1	6	1.2500	4.3500	0.0650	0.0009	4.5260	0.6250	0.1390	0.1060E 08	0.3300
11	1	9	-1.6500	-5.7500	0.0650	0.0009	5.9821	0.6250	0.1390	0.1060E 08	0.3300
12	2	7	-1.2200	4.3500	0.0650	0.0009	4.5178	0.6250	0.1390	0.1060E 08	0.3300
13	2	10	1.3000	-5.7500	0.0650	0.0009	5.8951	0.6250	0.1390	0.1060E 08	0.3300
14	8	11	0.0	-4.2500	0.0650	0.0009	4.2500	0.6250	0.1390	0.1060E 08	0.3300
15	11	12	0.0	-8.2000	0.1470	1.0500	8.2000	0.6880	0.1390	0.1060E 08	0.3300
16	3	9	1.8500	6.6500	0.0650	0.0009	6.9025	0.6250	0.1390	0.1060E 08	0.3300
17	3	13	-1.7000	-5.8000	0.1620	1.0500	6.0440	0.6880	0.1390	0.1060E 08	0.3300
18	4	10	-1.9800	6.6500	0.0650	0.0009	6.9385	0.6250	0.1390	0.1060E 08	0.3300
19	4	16	1.7000	-5.8000	0.1470	0.0017	6.0440	0.6880	0.1390	0.1060E 08	0.3300

TABLE 13

LOADING CONDITION NO. 1 (OUT-OF-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

MEMBER	BENDING MOMENTS F1	BENDING MOMENTS F2	TORSIONAL MOMENT F3	BENDING STRESSES S1	BENDING STRESSES S2	TORSIONAL STRESS S3
1	-2.6541	410.7017	2.0257	-25.5197	3949.0542	307.7236
2	-377.3230	-90.1697	2.8455	-3628.1055	-867.0159	432.2708
3	4.7771	269.3247	2.0641	150.1015	8462.4648	513.5667
4	-236.2820	-35.7124	-0.7124	-7424.2266	-1122.1211	-108.2281
5	-2.0586	516.5078	-8.7444	-9.6348	2417.3975	-557.5557
6	-1315.4414	929.1992	-0.8032	-6156.6211	4348.9023	-62.0274
7	-929.1365	478.3328	-0.8032	-8934.0039	4599.3516	-122.0206
8	-478.3672	-36.8750	-0.8032	-2238.8889	-172.5851	-65.6726
9	-2.0261	211.4995	-2.6551	-19.4819	2033.6489	-403.3450
10	-429.6580	-8.4597	32.3046	-4131.3242	-81.3434	4907.4688
11	-222.8359	492.3359	-27.1959	-2142.6531	4733.9961	-4131.4023
12	-740.2915	-27.1060	-86.0468	-7118.1836	-260.6340	-13071.5898
13	-248.5195	677.3711	63.8186	-2389.6106	6513.1797	9694.8516
14	-213.5706	143.6421	2.1196	-2053.5627	1381.1738	321.9907
15	-143.6472	8.7446	2.1177	-672.3081	40.9272	0.2803
16	-1185.8164	480.5586	-0.1021	-11402.0781	4620.7539	-15.5055
17	-966.4609	-232.4609	764.6172	-4104.4766	-987.2417	101.2208
18	-1036.8242	670.6211	-16.1260	-9969.4609	6448.2773	-2449.7476
19	-1050.8567	9.5217	35.5890	-4918.2930	44.5643	2909.9221

MAXIMUM BENDING STRESS # 11402.0781
ASSOC. MEMBER NUMBER # 16

MAXIMUM TORSIONAL STRESS # 13071.5898
ASSOC. MEMBER NUMBER # 12

TABLE 14
LOADING CONDITION NO. 2 (OUT-OF-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

	BENDING MOMENTS		TORSIONAL MOMENT	BENDING STRESSES		TORSIONAL STRESS
MEMBER	F1	F2	F3	S1	S2	S3
1	-0.7488	870.1758	1.2576	-7.1998	8367.0742	191.0523
2	-738.0828	-57.3745	8.4453	-7096.9492	-551.6777	1282.9434
3	4.4490	78.9539	1.0040	139.7915	2460.8130	152.5164
4	32.0776	65.4983	-0.1581	1007.9128	2058.0249	-24.0244
5	-3.6680	355.0234	-10.4206	-17.1671	1661.6064	-664.4338
6	-523.2422	370.3945	-3.2756	-2448.9163	1733.5474	-252.9476
7	-370.3740	191.9861	-3.2756	-3561.2883	1846.0196	-497.6025
8	-192.0000	-11.8857	-3.2755	-898.6123	-55.6285	-267.8215
9	-1.2587	68.0084	-0.7565	-12.1024	653.9265	-114.9207
10	-793.2148	-29.5742	128.9423	-7627.0625	-284.3674	19587.9492
11	8.5703	320.0313	-101.4401	82.4068	3077.2234	-15410.0234
12	-1273.0913	-23.6477	-52.9464	-12241.2617	-227.3818	-8043.2266
13	-1189.1289	1478.0703	31.3350	-11433.9297	14212.2109	4760.1797
14	-69.0156	49.0103	3.6869	-663.6116	471.2522	560.0908
15	-49.0099	10.4236	3.6853	-229.3796	48.7852	0.4879
16	-696.0391	288.3203	2.6210	-6692.6797	2772.3105	398.1646
17	-652.8892	-54.2720	159.4763	-2772.7646	-230.4884	21.1116
18	-1885.2852	1495.6875	-5.0133	-18127.7383	14381.6094	-761.5803
19	-1888.2007	0.0754	12.3193	-8837.2930	0.3531	1007.2798

MAXIMUM BENDING STRESS # 18127.7383
ASSOC. MEMBER NUMBER # 18

MAXIMUM TORSIONAL STRESS # 19587.9492
ASSOC. MEMBER NUMBER # 10

TABLE 15

LOADING CONDITION NO. 3 (OUT-OF-PLANE COMPONENTS)

MEMBER FORCES AND STRESSES

	BENDING MOMENTS		TORSIONAL MOMENT	BENDING STRESSES		TORSIONAL STRESS
MEMBER	F1	F2	F3	S1	S2	S3
1	-3.1670	786.8354	3.3290	-30.6443	7565.7227	505.7153
2	-766.5015	-56.5039	8.0223	-7370.2031	-562.5374	1218.6929
3	10.9714	199.2034	2.1555	344.7339	6259.1758	327.4453
4	-163.7324	96.3923	-0.2104	-5144.6445	3028.7483	-31.9586
5	-7.7305	693.4219	-21.1789	-36.1807	3245.4036	-1350.3989
6	-761.3438	541.8906	-3.3120	-3563.2966	2536.1960	-255.7604
7	-541.8584	285.7202	-3.3120	-5210.1758	2747.3096	-503.1360
8	-285.7417	-7.0120	-3.3119	-1337.3491	-32.8179	-270.7981
9	-3.3301	169.3738	-3.1928	-32.0200	1628.5942	-485.0229
10	-800.0703	-1.1289	20.8358	-7692.9805	-10.8549	3165.2129
11	-654.1680	840.9180	-21.3149	-6290.0742	8085.7461	-3238.0005
12	-1520.2207	-23.5625	-54.1499	-14617.5039	-226.5625	-8226.0469
13	-1475.4297	1958.0742	33.8311	-14186.8203	18827.6328	5139.3633
14	-171.5352	120.2029	7.7738	-1649.3762	1155.7966	1180.9424
15	-120.2048	21.1814	7.7708	-562.5913	99.1347	1.0287
16	-1275.0781	828.9219	5.3981	-12260.3633	7970.3984	820.0383
17	-1264.1211	-36.3828	60.2705	-5368.6133	-154.5147	7.9787
18	-2517.2266	1983.6406	-5.0794	-24204.0977	19073.4648	-771.6252
19	-2518.0278	-1.3560	7.6463	-11785.0547	-6.3462	625.1968

MAXIMUM BENDING STRESS # 24204.0977
ASSOC. MEMBER NUMBER # 18

MAXIMUM TORSIONAL STRESS # 8226.0469
ASSOC. MEMBER NUMBER # 12

TABLE 16

LOADING CONDITION NO. 1 (OUT-OF-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	-0.0050	-0.0387	-0.0461
2	-0.0172	0.0598	-0.0539
3	-0.0037	0.0075	-0.0677
4	-0.0153	0.0252	-0.0544
5	0.0017	0.0025	0.0
6	0.0074	-0.0005	-0.0153
7	0.0136	-0.0023	0.0
8	0.0001	0.0099	-0.0119
9	0.0043	0.0050	-0.0731
10	0.0016	-0.0017	-0.0746
11	-0.0010	0.0074	-0.0100
12	-0.0014	0.0074	0.0
13	-0.0052	0.0068	-0.0276
14	-0.0059	0.0024	-0.0545
15	-0.0074	-0.0047	-0.0439
16	-0.0084	-0.0058	0.0

NODAL REACTIONS

NODE	R1	R2	R3
5	0.0	0.0	60.5883
7	0.0	0.0	226.8021
12	0.0	0.0	150.4258
16	0.0	0.0	236.6968

TABLE 17

LOADING CONDITION NO. 2 (OUT-OF-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	-0.0425	-0.1543	-0.0481
2	0.0014	0.0569	-0.0881
3	-0.0040	0.0026	-0.0435
4	-0.0175	0.0092	-0.1009
5	0.0006	0.0053	0.0
6	0.0041	-0.0011	-0.0325
7	0.0231	-0.0052	0.0
8	0.0001	0.0074	-0.0039
9	0.0021	0.0061	-0.0555
10	0.0015	0.0049	-0.1380
11	-0.0003	0.0031	-0.0033
12	-0.0005	0.0031	0.0
13	-0.0051	0.0027	-0.0114
14	-0.0078	0.0010	-0.0221
15	-0.0141	-0.0019	-0.0177
16	-0.0180	-0.0024	0.0

NODAL REACTIONS

NODE	R1	R2	R3
5	0.0	0.0	91.5138
7	0.0	0.0	383.9043
12	0.0	0.0	96.2019
16	0.0	0.0	337.8730

TABLE 18

LOADING CONDITION NO. 3 (OUT-OF-PLANE COMPONENTS)

NODAL DISPLACEMENTS

NODE	D1	D2	D3
1	0.0011	-0.0250	-0.0750
2	0.0060	0.0582	-0.1118
3	-0.0084	0.0034	-0.0806
4	-0.0208	0.0044	-0.1327
5	0.0014	0.0050	0.0
6	0.0107	-0.0009	-0.0311
7	0.0288	-0.0051	0.0
8	0.0001	0.0138	-0.0097
9	0.0045	0.0104	-0.1038
10	0.0037	0.0016	-0.1805
11	-0.0008	0.0048	-0.0082
12	-0.0011	0.0048	0.0
13	-0.0105	0.0039	-0.0172
14	-0.0133	0.0014	-0.0327
15	-0.0196	-0.0028	-0.0263
16	-0.0235	-0.0035	0.0

NODAL REACTIONS

NODE	R1	R2	R3
5	0.0	0.0	92.9680
7	0.0	0.0	442.1858
12	0.0	0.0	190.6406
16	0.0	0.0	453.4341

LR^3 Assembly Frame Analysis

Dynamic Load Analysis —— Margin of Safety

The combined stress resultants and the margin of safety were calculated for the member with the most critical stress level of each loading conditions:

(1) Loading Condition 1

Member 17 — Nodal Point 13

$$S_N = 33.318 - 1.01 + 1.507 = 33.838$$

$$S_S = 0.101$$

$$R_N = \frac{33.838}{61} = 0.555$$

$$R_S = \frac{0.101}{31} = 0.003$$

$$M.S. = \frac{1}{\sqrt{0.554^2 + 0.003^2}} - 1 = 0.80$$

(2) Loading Condition 2

Member 10 Nodal Point 1

$$S_N = +12.672 - 7.627 + 0.451 = 4.594$$

$$S_S = 19.588$$

$$R_N = \frac{4.594}{61} = 0.075$$

$$R_s = \frac{19.588}{31} = 0.632$$

$$M.S. = \frac{1}{\sqrt{0.075^2 + 0.632^2}} - 1 = 0.57$$

(3) Loading Condition 3

Member 18 — Nodal Point 4

$$S_N = -0.577 - 24.204 + 0.314 = 24.467$$

$$S_s = -0.772$$

$$R_n = \frac{24.467}{61} = 0.401$$

$$R_s = \frac{0.772}{31} = 0.025$$

$$M.S. = \frac{1}{\sqrt{0.401^2 + 0.025^2}} - 1 = 1.48$$

Loading Condition	1	2	3
M. S.	0.80	0.57	1.48