Bendix

Aerospace Systems Division

Analysis of #1 Rocket Motor Firing on ALSEP	NO. ATM 908
	REV. NO.
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	DATE 10 August 70

The analysis reported in this ATM was performed in response to a Question posed by NASA, chit # 2.3-2 of Flight 4 Array C, Delta CARR meeting held at Bendix Aerospace on 25 June 1970. The purpose of this analysis is to determine the structural effect on ALSEP of an inadvertent rocket motor firing before the ASE is deployed.

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Introduction and Summary

The purpose of this analysis is to determine the structural effect on ALSEP of an inadvertent rocket motor firing before the ASE is deployed. The chit specified a 5000 lb. force for 12 milliseconds simulating a #1 Rocket Motor firing. Because the force and time were based on preliminary information a review of Reference 2 was made to determine the actual worst case impulse curve. This was then approximated by the impulse curve of Figure 4, which has a peak value of 4200 lb. and a duration of 7 milliseconds.

The structural configuration was treated as a 2 degree of freedom linear elastic system, Sections 1.0 and 2.0. Transmitted forces and displacements were computed, Section 3.0. This analysis showed that a peak load of 4950 lb. would be transmitted to the ASE mortar box. This load represents an amplification rather than a attenuation of the applied load.

Based on the computed loads, Section 4.0 determines that negative margins exist in the mounting pins (dwg 2335837). Indeed, it is probable that two of these pins would fracture. However, the remaining two pins are not expected to fracture. Therefore, the ASE mortar box should be retained by the remaining two pins together with the thumper assembly. The grenade itself, will be retained by the safety pins. Therefore, although extensive damage would be done to the ALSEP, it does not appear likely that the grenade would separate from ALSEP.

A study of Ref (1) shows that firing tests were conducted on the launch assembly with restraining pins through the tubes. These pins were installed specifically to restrain the grenades and prevent them from leaving the launch tubes, in the case of inadvertent firing. Test reports show that these pins prevent the grenades from exiting from the tubes although some tube deformation is possible.

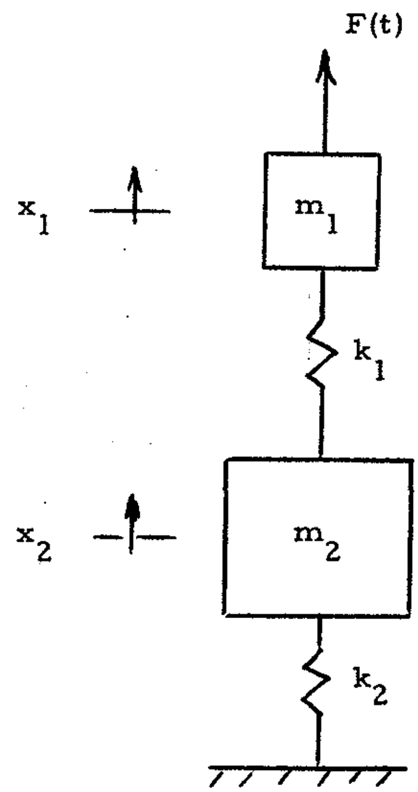

Figure 1. Dynamics Model of Active Seismic Package

Active Seismic Experiment Accidental Detonation Study

1.0 Dynamics Analysis Model

The dynamics analysis model of the active seismic experiment undergoing accidental detonation of the number one rocket is a two degree of freedom system as shown in Figure 1. In this model the following definitions apply:

m_1 = mass of firing rocket (grenade)

m_2 = mass of remainder of experiment package

k_1 = spring rate of grenade and restraining pin for firing rocket

k_2 = spring rate of mounting pin system to ALSEP pallet

$F(t)$ = thrust-time function of rocket

x_1 = absolute displacement coordinate of firing rocket mass

x_2 = absolute displacement coordinate of remainder of experiment package

It is desired to know the relative displacement $x_1 - x_2$ vs. time and the relative displacement of x_2 to the ALSEP package which is considered as rigid. These displacements multiplied by their respective spring rates indicate the forces developed in the structure.

Equations of Motion

The equations of motion describing the system were derived to be as follows:

$$m_1 \ddot{x}_1 + k_1 (x_1 - x_2) = F(t) \tag{1}$$

$$m_2 \ddot{x}_2 - k_1 (x_1 - x_2) + k_2 x_2 = 0 \tag{2}$$

Add and subtract the quantity $m_1 \ddot{x}_2$ to Equation (1) and define $x = x_1 - x_2$.

Then Eq. (1) becomes

$$\ddot{x} + \frac{k_1}{m_1} x + \ddot{x}_2 = \frac{F(t)}{m_1} \tag{3}$$

and Eq. (2) becomes

$$- \frac{k_1}{m_2} x + \ddot{x}_2 + \frac{k_2 x_2}{m_2} = 0 \tag{4}$$

The time solutions for x and x_2 in Equations (3) and (4) were determined in two different ways: (1) the Laplace transform method and, (2) direct integration by means of the IBM-360 Continuous Systems Modeling Program (CSMP). The two different methods gave identical results which served as a check on the calculations. Method (1), using Laplace transforms, was evaluated for only a portion of the solutions while Method (2) was used for the parametric variations.

The details of the Method (1) solution are included in this document for the sake of completeness and to offer a nearly closed form solution for Eqs. (3) and (4). These details are as follows:

Take Laplace transforms assuming zero initial conditions.*

$$(s^2 + \omega_1^2)\, x(s) + s^2\, x_2(s) = f(s)/m_1 \tag{5}$$

$$-\omega_3^2\, x(s) + (s^2 + \omega_2^2)\, x_2(s) = 0 \tag{6}$$

where
$$\omega_1^2 = k_1/m_1 \quad \omega_2^2 = k_2/m_2 \quad \omega_3^2 = k_1/m_2$$

and s = the Laplace transform variable

*For example see Churchill, Ruel V. Operational Mathematics, McGraw Hill Book Co., Inc. 1958.

These equations can now be solved for $x(s)$ and $x_2(s)$

$$x(s) = \frac{\begin{vmatrix} \frac{f(s)}{m_1} & s^2 \\ 0 & (s^2 + \omega_2^2) \end{vmatrix}}{\begin{vmatrix} (s + \omega_1^2) & s^2 \\ -\omega_3^2 & (s^2 + \omega_2^2) \end{vmatrix}} \qquad (7)$$

$$x(s) \quad \frac{f(s)\,(s^2 + \omega_2^2)}{m_1 \left[s^4 + (\omega_1^2 + \omega_2^2 + \omega_3^3) s^2 + \omega_1^2 \omega_2^2 \right]} \qquad (8)$$

The denominator can be expressed in the form using its roots

$$D = (s^2 + \beta^2)(s^2 + \lambda^2)$$

so that

$$x(s) = \frac{f(s)\,(s^2 + \omega_2^2)}{m_1 D}$$

where

$$\beta^2 = \frac{(\omega_1^2 + \omega_2^2 + \omega_3^2) - \left[(\omega_1^2 + \omega_2^2 + \omega_3^2)^2 - 4\,\omega_1^2 \omega_2^2 \right]^{1/2}}{2}$$

$$\lambda^2 = \frac{(\omega_1^2 + \omega_2^2 + \omega_3^2) + \left[(\omega_1^2 + \omega_2^2 + \omega_3^2)^2 - 4\,\omega_1^2 \omega_2^2 \right]^{1/2}}{2}$$

The inverse transform of Equation (8) will now give the desired expression for x(t). This can be accomplished by using the convolution integral for products of transforms.

$$x(t) = \frac{1}{m_1} \int_0^t \left[\frac{(\omega_2^2 - \beta^2)}{\beta\ (\lambda^2 - \beta^2)} \sin \beta\ (t - \tau) \right.$$

$$\left. + \frac{(\omega_2^2 - \lambda^2)}{\lambda\ (\beta^2 - \lambda^2)} \sin \lambda\ (t - \tau) \right] F(\tau)\, d\tau \qquad (9)$$

Equation (9) can be numerically integrated with $F(\tau)$ being an arbitrary function of time. A similar process yields for $x_2(t)$:

$$x_2(t) = \frac{\omega_3^2}{m_1} \int_0^t \left[\frac{\frac{1}{\beta} \sin \beta\ (t - \tau) - \frac{1}{\lambda} \sin \lambda\ (t - \tau)}{\lambda^2 - \beta^2} \right] F(\tau)\, d\tau \qquad (10)$$

The second method of solution to Equations (3) and (4) is a direct integration "analog" type of solution. Results of these calculations along with details of the method are given in section 3.0.

2.0 Structural Stiffness Calculations

If the #1 grenade rocket motor should be ignited while the grenade assembly is pinned to the launch tube assembly, the load path of the thrust force would be as follows:

K_1:

A. From the rocket motor thru the four welded motor tabs to the grenade housing. (K_a)

B. Thru the grenade housing to the safety pin (K_b)

C. Thru the safety pin to the launch tube (K_c) assembly.

K_2:

D. Thru the launch tube assembly to the mounting pins (K_d)

E. Thru the mounting pins to the ALSEP sunshield (K_e)

The elasticity of the path A, B and C provide the compliance which is modeled as the spring K_1 in section 1. That is:

$$\frac{1}{K_1} = \frac{1}{K_a} + \frac{1}{K_b} + \frac{1}{K_c} \qquad \text{(Eq 2-1)}$$

Similarly, the compliance modeled by spring K_2 in section 1 is given by:

$$\frac{1}{K_2} = \frac{1}{K_d} + \frac{1}{K_e} \qquad \text{(Eq 2-2)}$$

The numerical values for K_a thru K_e are calculated on the attached sheets.

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ENGINEERING REPORT

Bendix Aerospace Systems Division

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MODEL

Neglect deflection due to M_o.
Calculate deflection due to moment and shear of 1000 lb. load

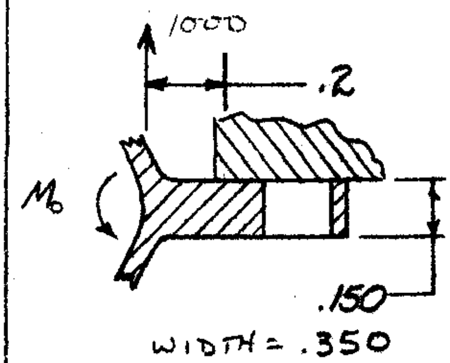
$$\Delta = \frac{1}{3}\frac{Pl^3}{EI} + {}^{*}F\int \frac{Vv}{AG}\,dx$$

$$= \frac{1}{3}\frac{1000(.2)^3(12)}{(29\times10^6)(.35)(.15)^3} + \frac{6}{5}\int_0^{.2}\frac{1000(1)\,dx}{.35(.15)(11\times10^6)}$$

$$\Delta\times10^6 = \frac{.092(12)}{.00118} + \frac{6000(.2)}{.35(.75)(11)}$$

$$= 935 + 416 = 1351$$

$$\therefore\ K_A = \frac{P}{\Delta} = \frac{\cancel{4000}}{1351\times10^{-6}} = 2.96\times10^6\ \text{lb/in.}$$



TWICE SCALE TYPICAL ROCKET MOTOR TAB

ROCKET MOTOR TAB STIFFNESS CALCULATION

$^{*}F = \frac{6}{5}$, a form factor for rectangular cross section Ref Roark p12

Calculate spring rate of grenade housing, K_B

Assume load is carried down one wall in compression:

$$L = 1 \qquad A = tw = (.050)(2.75) = .1375$$

$$E \approx 2 \times 10^6 \text{ psi}$$

$$K_B = \frac{AE}{L} = \frac{.1375(2 \times 10^6)}{1} = .275 \times 10^6$$

Calculate spring rate of short safety pin.

Consider pin acting as cantilever beam with load carried from inside grenade wall.

Dia = .3125 in.

L = .375 $\quad$ E = 29X10^6 psi

G = 11 X10^6 psi

$$\Delta = \frac{1}{3}\frac{Pl^3}{EI} + F\int \frac{Vv}{AG}dx$$

$$= \frac{1}{3}\frac{4000(.375)^3}{29\times10^6(.000468)} + \frac{10}{9}\int_0^{.375}\frac{4000(1)\,dx}{.0767(11\times10^6)}$$

$$= \frac{4000(.375)}{10^6}\left[\frac{\cancel{3}\times3}{8\times8(\cancel{3})(29)(.000468)} + \frac{10}{9}\,\frac{1}{.0767(11)}\right]$$

$$= \frac{1500}{10^6}\left[\;3.46 + 1.319\right] = .00716 \text{ in.}$$

$$K_c = \frac{P}{\Delta} = \frac{4000}{.00716} = .558 \times 10^6$$

USE K_A, K_B, K_c TO CALCULATE K_1:

$$\frac{1}{K_1} = \frac{1}{K_A} + \frac{1}{K_B} + \frac{1}{K_c} = \frac{1}{10^6}\left[\frac{1}{2.96} + \frac{1}{.275} + \frac{1}{.558}\right]$$

$$\frac{1}{K_1} = \frac{1}{10^6}\left[.338 + 3.64 + 1.791\right] = \frac{5.769}{10^6}$$

.338
3.640
1.791
5.769

$\therefore K_1 = .173 \times 10^6$ lb/in

SPRING D (SOS part 14-10298-676)

$$K = \frac{AE}{L} = \frac{.8(.075)\,16\times10^6}{1.77} = .541\times10^6$$

where, effective width = .8
" length = 1.77

SPRING E

Assume K_E acts as cantilever beam $\frac{1}{4}$ inch in diameter and of length, L = .88 Consider shear and bending. E = 16×10^6 psi. I = .00019175 A = .04908

$$\Delta = \frac{1}{3}\frac{PL^3}{EI} + \frac{10}{9}\int_0^L \frac{Vv}{AG}\,dx \qquad \text{Let } P = V = 1$$

$$\Delta = \frac{.88}{3\times10^3}\left[\frac{\overset{.7745}{.88^2}}{16(.19175)} + \frac{10}{3}\,\frac{1}{49.08(6.2\quad)}\right]$$

$$= \frac{.293}{10^3}\left[\frac{\overset{.246}{.7745}}{3.16} + .01092\right]$$

$$= \frac{.293(.257)}{10^3} = 75.4\times10^{-6}$$

$$K_E = \frac{P}{\Delta} = \frac{1}{75.4\times10^{-6}} = .01329\times10^6$$

USE K_D & K_E TO CALCULATE K_2:

$$\frac{1}{K_2} = \frac{1}{K_D} + \frac{1}{K_E} = \frac{1}{10^6}\left[\frac{1}{.541} + \frac{1}{.01329}\right] = \frac{1}{10^6}\left(1.85 + 75.3\right)$$

$$K_2 = 10^6\left(\frac{1}{77.15}\right) = .01295 \times 10^6 \ \frac{lb.}{in.}$$

$$\begin{array}{r} 1.85 \\ 75.3 \\ \hline 77.15 \end{array}$$

---

mass of #1 grenade = 1261 grams = m_1

(Ref 14-10298-600)

$$1261 \text{ gm} \times 2.205 \times 10^{-3} \ \frac{lb}{gm} = 2.78 \ lb.$$

weight of ASE = 22.54 (Ref ATM 268 dated 6/19/70) including thumper assy of 8 lb and grenade 2.78 lb

$$\begin{array}{r} 22.54 \\ -10.78 \\ \hline 11.86 \end{array}$$

Net weight of ASE = 11.86 lb.

In $\frac{lb\text{-}sec^2}{in.}$, we have:

$$m_1 = \frac{2.78}{386} = .0072$$

$$m_2 = \frac{11.86}{386} = .0307$$

3.0 Computed Loads

The CSMP program results for the peak forces F_1 and F_2 are parametrically presented in Figure 2. Results are included for zero damping and for 10% viscous damping. Each force is then the sum of the products of the appropriate spring stiffness times deflection and the viscous damping coefficient times velocity, i.e., $F = Kx + c\dot{x}$. It is believed that the assumption of 10% viscous damping is realistic for this problem. Figure 2 shows that this assumption has little effect on the calculated value of F_1, but decreases the calculated value of F_2 by approximately 10%. Because of the uncertainty of the load paths in the structure, the calculated spring rate K_2 is varied in the range from $K_2/2$ to $2K_2$ thus bracketing the calculated value to determine the effect of its change.

The graphs of Figure 2 show that the calculated forces are not particularly sensitive to the value K_2. If the actual value of K_2 is lower than that predicted, (for example due to yielding) then the calculated force value based on K_2 is conservative. Based on these considerations, a load value F_2 of 4950 lbs. is chosen based on $K_2 = .01295$ lb/in. and a viscous damping coefficient of 10%.

The computer program used in calculating these results is shown in Figure 3 with a typical set of input and output curves being shown in Figures 4 thru 8. The equations of motion here have been extended to include damping.

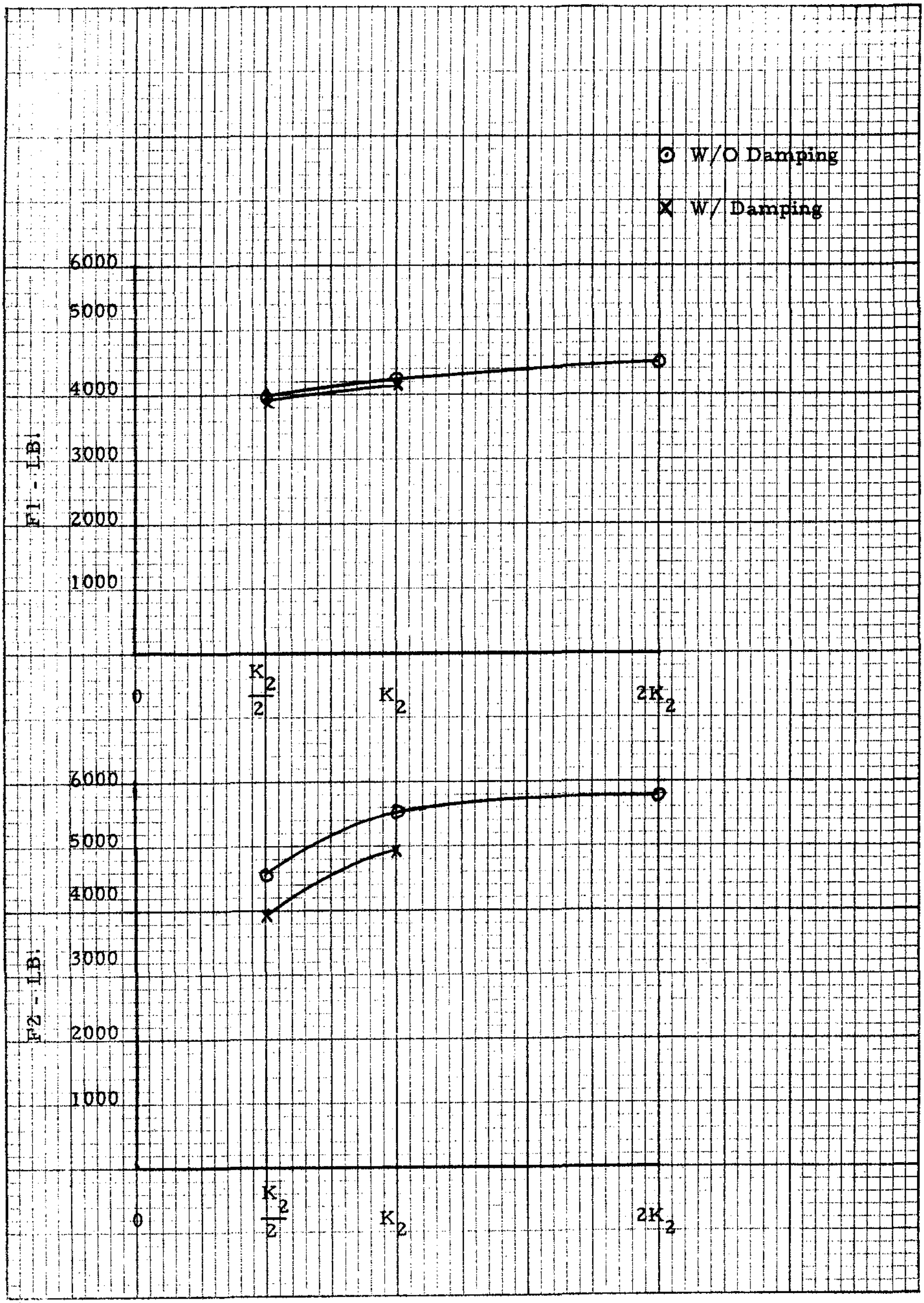


Figure 2 Peak Force Values

****CONTINUOUS SYSTEM MODELING PROGRAM****

PROBLEM INPUT STATEMENTS

```
TITLE ACTIVE SEISMIC STUDY
TITLE  JULY 1970
CONSTANT            K1=173000., K2=12950., M1=.0072  ,M2=.0307,...
     C1=7.85 , C2=3.59
INITIAL
      OM1SQ= K1/M1
      OM2SQ= K2/M2
      OM3SQ= K1/M2
        D1=C1/M1
        D2=C2/M2
        D3= C1/M2
FUNCTION FOFT= 0.0,0.0, .002,900., .005,4200., .007,0. , .02,0.
DYNAMIC
      XDOTD=-OM1SQ*X  -X2DOTD + FORCE/M1 -D1*XDOT
      X2DOTD=OM3SQ*X  -OM2SQ*X2  +D3*XDOT -D2*X2DOT
      XDOT =INTGRL(0.,XDOTD)
      X2DOT=INTGRL(0.,X2DOTD)
          X=INTGRL(0.,XDOT)
         X2=INTGRL(0.,X2DOT)
      FORCE=AFGEN(FOFT,TIME)
         F1=K1*X  +C1*XDOT
         F2=K2*X2 +C2*X2DOT
TIMER DELT=.00005  ,FINTIM=.02    ,PRDEL=.0005,OUTDEL=.0005
PRTPLT  X,X2,F1,F2,FORCE
PRINT OM1SQ, OM2SQ, OM3SQ, X2DOTD, X2DOT, XDOTD, XDOT
LABEL ACTIVE SEISMIC STUDY
METHOD RKSFX
END
STOP

OUTPUT VARIABLE SEQUENCE
OM1SQ  OM2SQ  OM3SQ  D1    D2    D3    FORCE  X2DOTD XDOTD  XDOT
X2DOT  X      X2     F1    F2

 OUTPUTS    INPUTS    PARAMS  INTEGS + MEM BLKS  FORTRAN  DATA CDS
 19(500)   65(1400)  11(400)   4+  0=  4(300)    15(500)     11

        ENDJOB
```

Figure 3

MINIMUM 0.0 FORCE VERSUS TIME MAXIMUM 4.2000E 03

TIME - SEC	FORCE
0.0	0.0
5.0000E-04	2.2500E 02
1.0000E-03	4.5000E 02
1.5000E-03	6.7500E 02
2.0000E-03	9.0000E 02
2.5000E-03	1.4500E 03
3.0000E-03	2.0000E 03
3.5000E-03	2.5500E 03
4.0000E-03	3.1000E 03
4.5000E-03	3.6500E 03
5.0000E-03	4.2000E 03
5.5000E-03	3.1500E 03
6.0000E-03	2.1000E 03
6.5000E-03	1.0500E 03
7.0000E-03	1.1719E-02
7.5000E-03	0.0
8.0000E-03	0.0
8.5000E-03	0.0
9.0000E-03	0.0
9.5000E-03	0.0
1.0000E-02	0.0
1.0500E-02	0.0
1.1000E-02	0.0
1.1500E-02	0.0
1.2000E-02	0.0
1.2500E-02	0.0
1.3000E-02	0.0
1.3500E-02	0.0
1.4000E-02	0.0
1.4500E-02	0.0
1.5000E-02	0.0
1.5500E-02	0.0
1.6000E-02	0.0
1.6500E-02	0.0
1.7000E-02	0.0
1.7500E-02	0.0
1.8000E-02	0.0
1.8500E-02	0.0
1.9000E-02	0.0
1.9500E-02	0.0
2.0000E-02	0.0

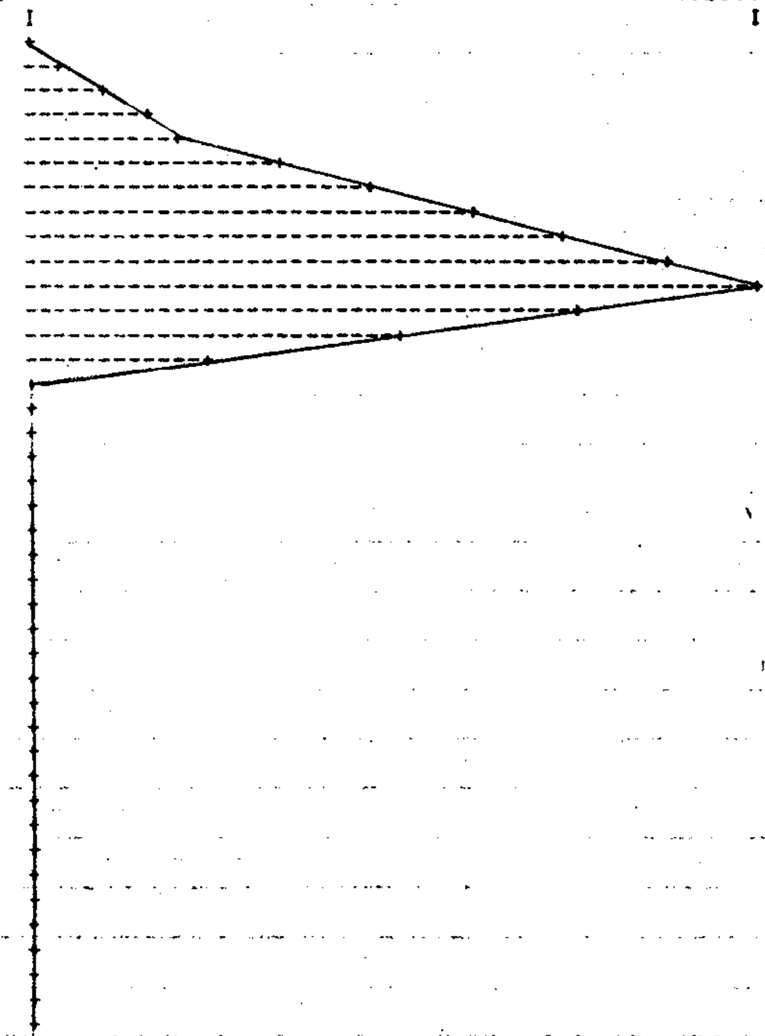
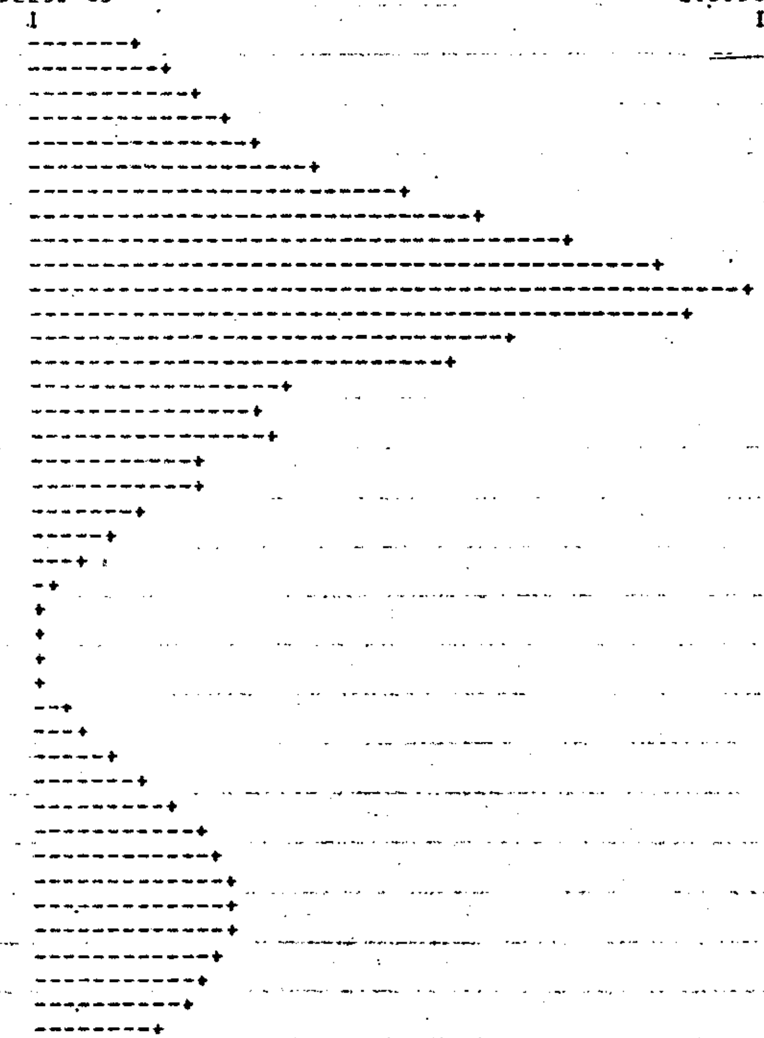


Figure 4

ACTIVE SEISMIC STUDY PAGE 1

MINIMUM X VERSUS TIME MAXIMUM

-4.3223E-03 2.3656E-02



TIME	X
0.0	0.0
5.0000E-04	7.8234E-04
1.0000E-03	2.2195E-03
1.5000E-03	3.0359E-03
2.0000E-03	4.4538E-03
2.5000E-03	6.7033E-03
3.0000E-03	1.0157E-02
3.5000E-03	1.2710E-02
4.0000E-03	1.6173E-02
4.5000E-03	1.9287E-02
5.0000E-03	2.2742E-02
5.5000E-03	2.0682E-02
6.0000E-03	1.3976E-02
6.5000E-03	1.1804E-02
7.0000E-03	5.2582E-03
7.5000E-03	4.5183E-03
8.0000E-03	4.8828E-03
8.5000E-03	2.3192E-03
9.0000E-03	2.1822E-03
9.5000E-03	-8.2422E-05
1.0000E-02	-9.8225E-04
1.0500E-02	-2.3860E-03
1.1000E-02	-3.3551E-03
1.1500E-02	-3.9108E-03
1.2000E-02	-4.3223E-03
1.2500E-02	-4.1394E-03
1.3000E-02	-3.8009E-03
1.3500E-02	-3.0451E-03
1.4000E-02	-2.1356E-03
1.4500E-02	-1.0701E-03
1.5000E-02	3.9055E-05
1.5500E-02	1.0776E-03
1.6000E-02	1.9992E-03
1.6500E-02	2.6952E-03
1.7000E-02	3.1486E-03
1.7500E-02	3.3147E-03
1.8000E-02	3.2017E-03
1.8500E-02	2.8293E-03
1.9000E-02	2.2391E-03
1.9500E-02	1.4927E-03
2.0000E-02	6.5579E-04

Figure 5

ACTIVE SEISMIC STUDY PAGE 1

MINIMUM -2.9353E-01 X2 VERSUS TIME MAXIMUM 3.7861E-01

TIME	X2
0.0	0.0
5.0000E-04	9.7614E-05
1.0000E-03	1.5094E-03
1.5000E-03	5.7279E-03
2.0000E-03	1.3490E-02
2.5000E-03	2.5735E-02
3.0000E-03	4.4351E-02
3.5000E-03	7.1405E-02
4.0000E-03	1.0745E-01
4.5000E-03	1.5284E-01
5.0000E-03	2.0676E-01
5.5000E-03	2.6724E-01
6.0000E-03	3.2375E-01
6.5000E-03	3.6340E-01
7.0000E-03	3.7861E-01
7.5000E-03	3.6179E-01
8.0000E-03	3.1558E-01
8.5000E-03	2.4590E-01
9.0000E-03	1.5863E-01
9.5000E-03	6.2644E-02
1.0000E-02	-3.4341E-02
1.0500E-02	-1.2390E-01
1.1000E-02	-1.9913E-01
1.1500E-02	-2.5447E-01
1.2000E-02	-2.8619E-01
1.2500E-02	-2.9284E-01
1.3000E-02	-2.7496E-01
1.3500E-02	-2.3521E-01
1.4000E-02	-1.7783E-01
1.4500E-02	-1.0841E-01
1.5000E-02	-3.3230E-02
1.5500E-02	4.1240E-02
1.6000E-02	1.0887E-01
1.6500E-02	1.6440E-01
1.7000E-02	2.0378E-01
1.7500E-02	2.2451E-01
1.8000E-02	2.2574E-01
1.8500E-02	2.0826E-01
1.9000E-02	1.7437E-01
1.9500E-02	1.2764E-01
2.0000E-02	7.2513E-02

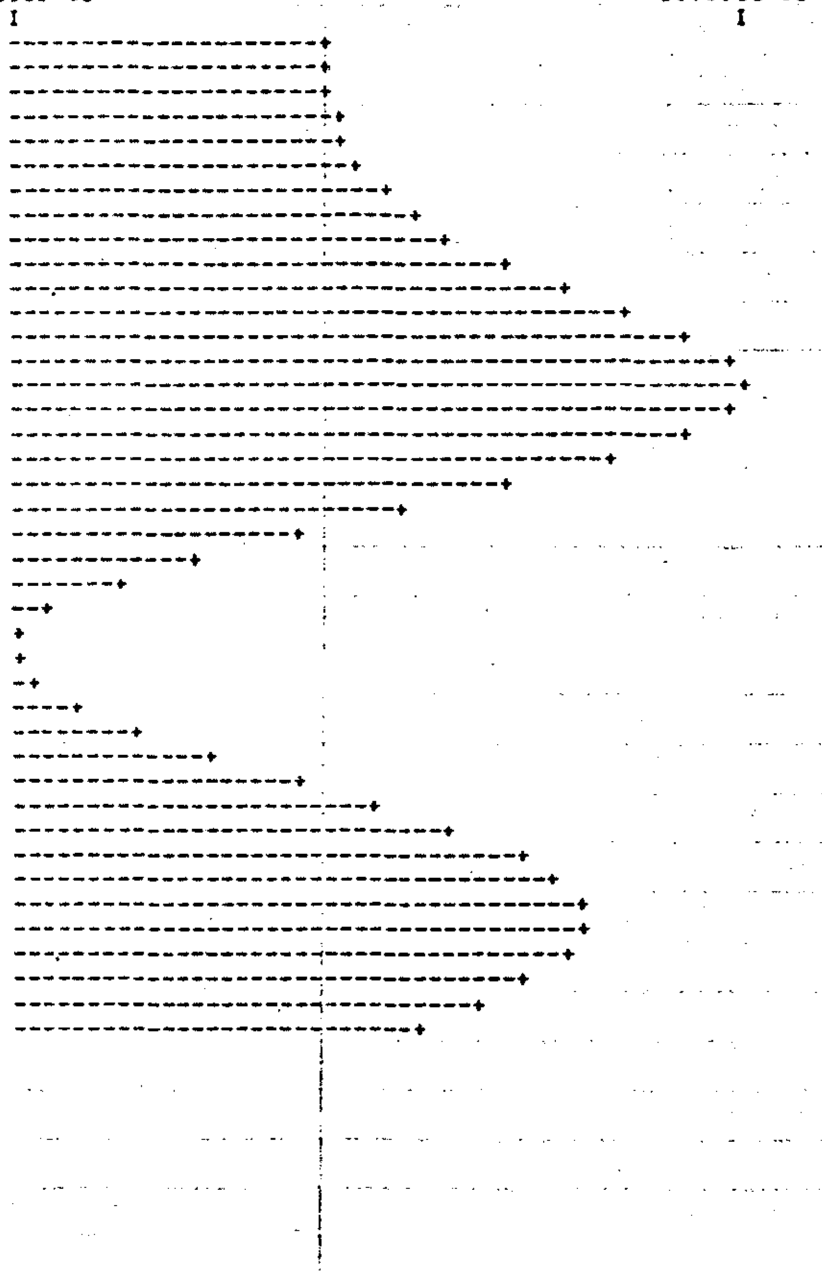


Figure 6

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ACTIVE SEISMIC STUDY                                                 PAGE   1

                                MINIMUM              F1      VERSUS TIME            MAXIMUM
                              -7.4831E 02                                           4.1031E 03
 TIME              F1              I                                                  I
0.0               0.0            --------+
5.0000E-04        1.6204E 02     ----------+
1.0000E-03        3.9684E 02     ------------+
1.5000E-03        5.4419E 02     --------------+
2.0000E-03        7.9095E 02     ----------------+
2.5000E-03        1.2164E 03     ---------------------+
3.0000E-03        1.7990E 03     ---------------------------+
3.5000E-03        2.2468E 03     -------------------------------+
4.0000E-03        2.8507E 03     --------------------------------------+
4.5000E-03        3.3857E 03     -------------------------------------------+
5.0000E-03        3.9915E 03     -------------------------------------------------+
5.5000E-03        3.4415E 03     --------------------------------------------+
6.0000E-03        2.3837E 03     ---------------------------------+
6.5000E-03        1.9630E 03     ----------------------------+
7.0000E-03        8.2033E 02     -----------------+
7.5000E-03        8.3226E 02     -----------------+
8.0000E-03        7.9353E 02     ----------------+
8.5000E-03        3.9598E 02     ------------+
9.0000E-03        3.5441E 02     ------------+
9.5000E-03       -4.2540E 01     --------+
1.0000E-02       -1.8228E 02     -----+
1.0500E-02       -4.3813E 02     ---+
1.1000E-02       -5.8762E 02     -+
1.1500E-02       -6.8741E 02     +
1.2000E-02       -7.4768E 02     +
1.2500E-02       -7.1246E 02     +
1.3000E-02       -6.4897E 02     -+
1.3500E-02       -5.1303E 02     --+
1.4000E-02       -3.5424E 02     ----+
1.4500E-02       -1.6736E 02     -----+
1.5000E-02        2.3555E 01     --------+
1.5500E-02        2.0218E 02     ----------+
1.6000E-02        3.5848E 02     ------------+
1.6500E-02        4.7539E 02     -------------+
1.7000E-02        5.4964E 02     --------------+
1.7500E-02        5.7378E 02     --------------+
1.8000E-02        5.5003E 02     --------------+
1.8500E-02        4.8176E 02     -------------+
1.9000E-02        3.7672E 02     ------------+
1.9500E-02        2.4560E 02     -----------+
2.0000E-02        1.0001E 02     ---------+
```

Figure 7

ACTIVE SEISMIC STUDY PAGE 1

MINIMUM -3.8517E 03 | F2 VERSUS TIME | MAXIMUM 4.9638E 03

TIME	F2
0.0	0.0
5.0000E-04	4.2285E 00
1.0000E-03	3.8842E 01
1.5000E-03	1.1609E 02
2.0000E-03	2.4545E 02
2.5000E-03	4.4056E 02
3.0000E-03	7.3724E 02
3.5000E-03	1.1505E 03
4.0000E-03	1.6840E 03
4.5000E-03	2.3372E 03
5.0000E-03	3.0925E 03
5.5000E-03	3.9009E 03
6.0000E-03	4.5470E 03
6.5000E-03	4.9138E 03
7.0000E-03	4.9023E 03
7.5000E-03	4.4492E 03
8.0000E-03	3.6664E 03
8.5000E-03	2.6104E 03
9.0000E-03	1.3368E 03
9.5000E-03	1.0876E 02
1.0000E-02	-1.1241E 03
1.0500E-02	-2.2032E 03
1.1000E-02	-3.0535E 03
1.1500E-02	-3.6107E 03
1.2000E-02	-3.8446E 03
1.2500E-02	-3.7500E 03
1.3000E-02	-3.3496E 03
1.3500E-02	-2.6913E 03
1.4000E-02	-1.8405E 03
1.4500E-02	-5.7708E 02
1.5000E-02	1.1462E 02
1.5500E-02	1.0511E 03
1.6000E-02	1.8577E 03
1.6500E-02	2.4736E 03
1.7000E-02	2.8568E 03
1.7500E-02	2.9863E 03
1.8000E-02	2.8631E 03
1.8500E-02	2.5090E 03
1.9000E-02	1.9636E 03
1.9500E-02	1.2815E 03
2.0000E-02	5.2477E 02

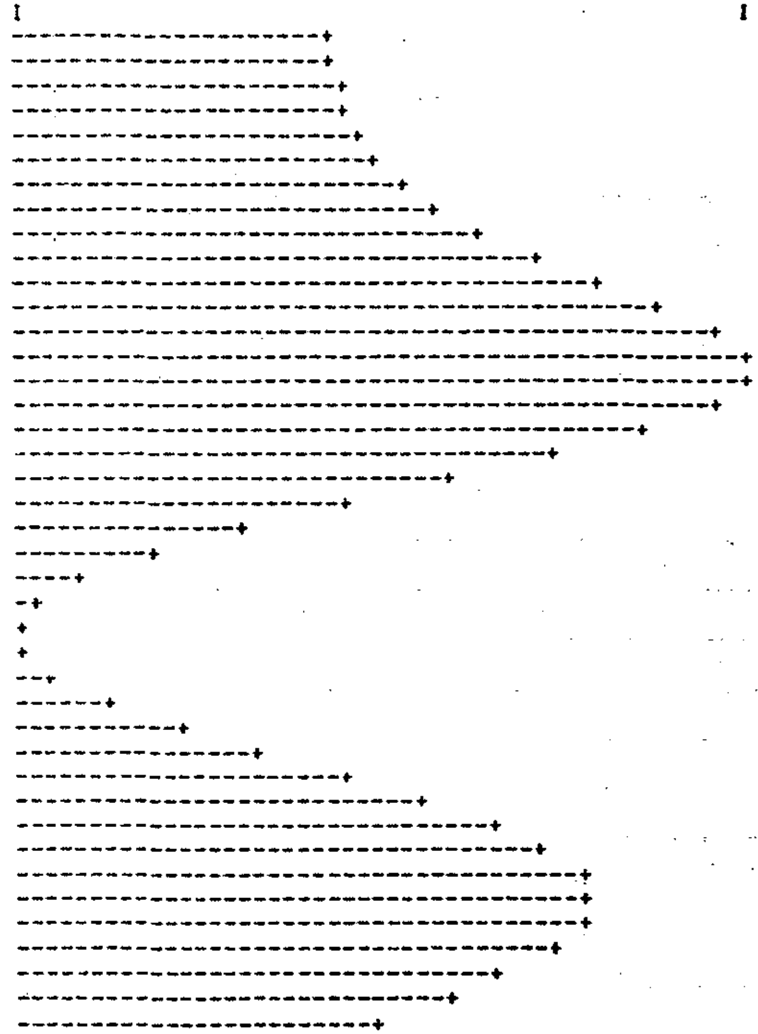


Figure 8

4.0 Stress Analysis

This section consists of two separate studies: (a) Evaluation of static and firing tests conducted on the grenade launch assembly (Ref 1); and (b) Detail study and analysis of existing grenade launch assembly attachment structure to ALSEP.

(a) Evaluation of tests conducted on GLA

A study of Ref (1) shows that firing tests were conducted on the launch assembly with restraining pins through the tubes. These pins were installed specifically to restrain the grenades and prevent them from leaving the launch tubes, in the case of inadvertent firing. They are removed when the experiment is deployed. For the large grenades (1) and (2) a 3/16 inch diameter and a 5/16 inch diameter pin pass through the tubes (Ref Dwg 14>10298-14). For the small grenades (3) and (4) one 3/16 pin is used. Test reports show that these pins prevent the grenades from exiting from the tubes although some tube deformation is possible.

However in these tests the tubes were resting vertically on a concrete slab which resisted thrust forces and no effort was made to simulate the attachments to ALSEP.

It is concluded from these tests that the grenades will remain contained inside the tubes unless pins are removed prior to firing. However, since the tests did not simulate the attachment to ALSEP there are no assurances that the ALSEP mounting pins will not fail under grenade launch motor thrust forces.

(b) Analysis of GLA attachment to ALSEP:

The attachment of the grenade launch assembly is shown on Bendix Dwg 2334845, sheet 4.

The launch tube assembly has four pin sockets on the lower side which mate with pins on the ALSEP sunshield (see page 22 - for Pin-Socket Interface Detail).

Immediately above these pins on the upper side are four preloaded pressure pads which resist upward movement of the package (See page 20). Although these pads can resist vertical load, their resistance to horizontal load is entirely due to friction and is neglected.

Pages 21 - 32 show an analytical investigation of the lower pins.

Usually a stress analysis is conducted to ensure that a structure will not fail under specified loading conditions.

This analysis is unique in the sense that a stress analysis is desired for a circumstance which was not originally considered a design requirement. As a result, well defined load paths have not necessarily been designed into the structure. This causes some uncertainty in the results of the analysis.

Pins at A, C, and D would be free to move if it were not for the friction forces due to pre-load on screws through mounting plate end retainer (see pages 22, 28 and 29). In standard analysis, it would be assumed that all pins except B were free to move. This would neglect uncertain frictional forces, a generally accepted, i. e., conservative stress analysis approach. Since frictional forces, to some extent exist, they have been considered.

It is probable that fracture will occur under condition 1 at points B and C (Page 15). This fracture will be in shear and bending at sect. C-C (Page 22). After this complete separation, some small resistance to movement will occur due to friction effects. The entire box will tend to rotate about point A. Fracture at A and D is improbable but if this should occur, the entire package will become lodged against the posts shown on Page 15 and Dwg 2334845 sheet 4. Damage to surrounding structure from release of mechanical energy should be small but this does not preclude damage from thermal effects.

To positively evaluate the effect of inadvertent firing a test should be conducted on a simulated pallet with mounting pins and other GLA interfaces similar to flight hardware.

Loads Investigation

Discussion

On the following pages, the motor package stress analysis loading diagrams are shown.

For load condition 1, all loads are assumed reacted at C and B due to their stiff load paths. Since subsequent analyses show that under this load pattern failure will take place, this diagram does not show the true condition. After failure of B and C the package will deform considerably with reactions at A and D.

For condition 2, considerable plastic deformation and slippage will take place but complete failure is unlikely.

The ALSEP structural interface should withstand the loads of conditions 3 and 4.

MORTAR PACKAGE INVESTIGATION ~ ASE

EFFECT OF ACCIDENTAL MORTAR LAUNCH IN LM

PEAK THRUSTS

REF. SOS DDT TEST REPORT 6542

T_1 = 3960 LBS FOR 6.0 MS

T_2 = 2340 LBS FOR 6.4 MS

T_3 = 990 LBS FOR 10.4 MS

T_4 = 870 LBS FOR 7.3 MS

WITH DYNAMIC AMPLIFICATION FACTOR

T_1 = 4950 LBS. (REF. PAGES 3-22)

T_2 = 2925 LBS.

T_3 = 1238 LBS.

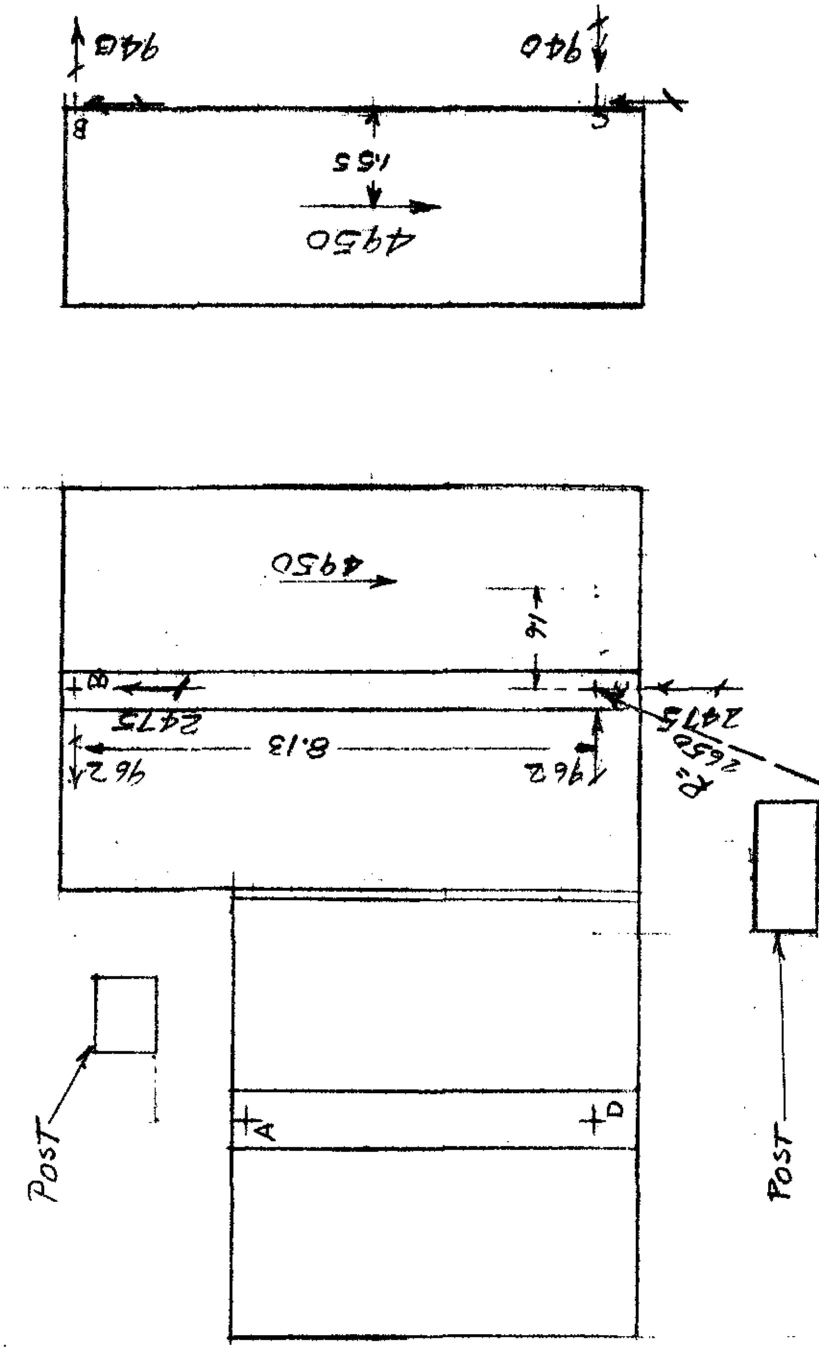
T_4 = 1088 LBS.

LOADS WITH DYNAMIC AMPLIFICATION FACTORS ARE USED FOR INVESTIGATION OF ALSEP STRUCTURE LOADS.

MORTAR PACKAGE INVESTIGATION ~ ASE

EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

LOADS INVESTIGATION ~ COND. 1

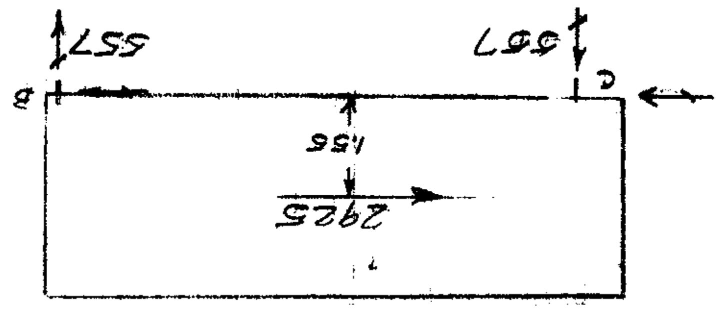


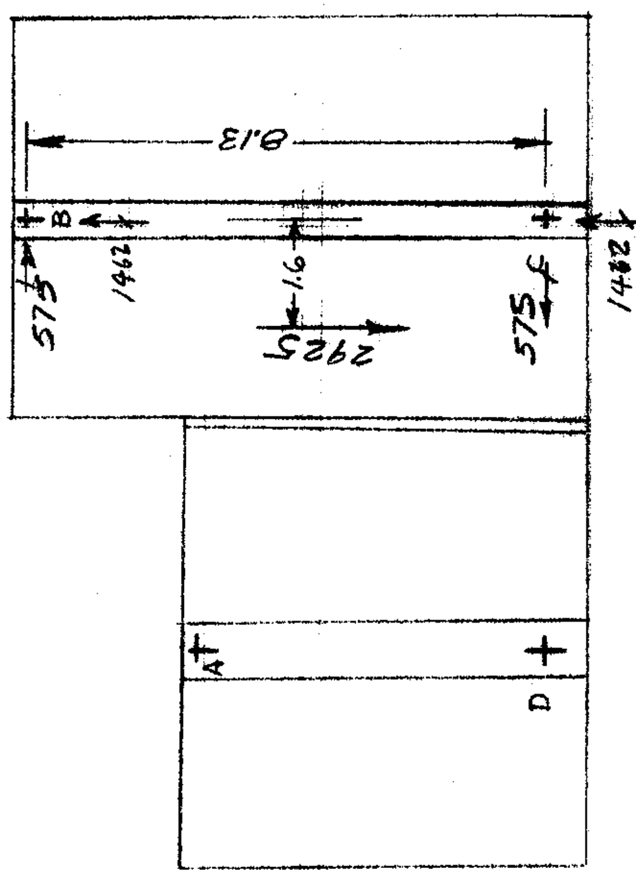
NOTE:- AT FAILURE OF B & C PACKAGE MIGHT TEND TO ROTATE ABOUT A AND IMPACT AGAINST POSTS.

MORTAR PACKAGE INVESTIGATION ~ ASE

EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

LOADS INVESTIGATION ~ COND. 2



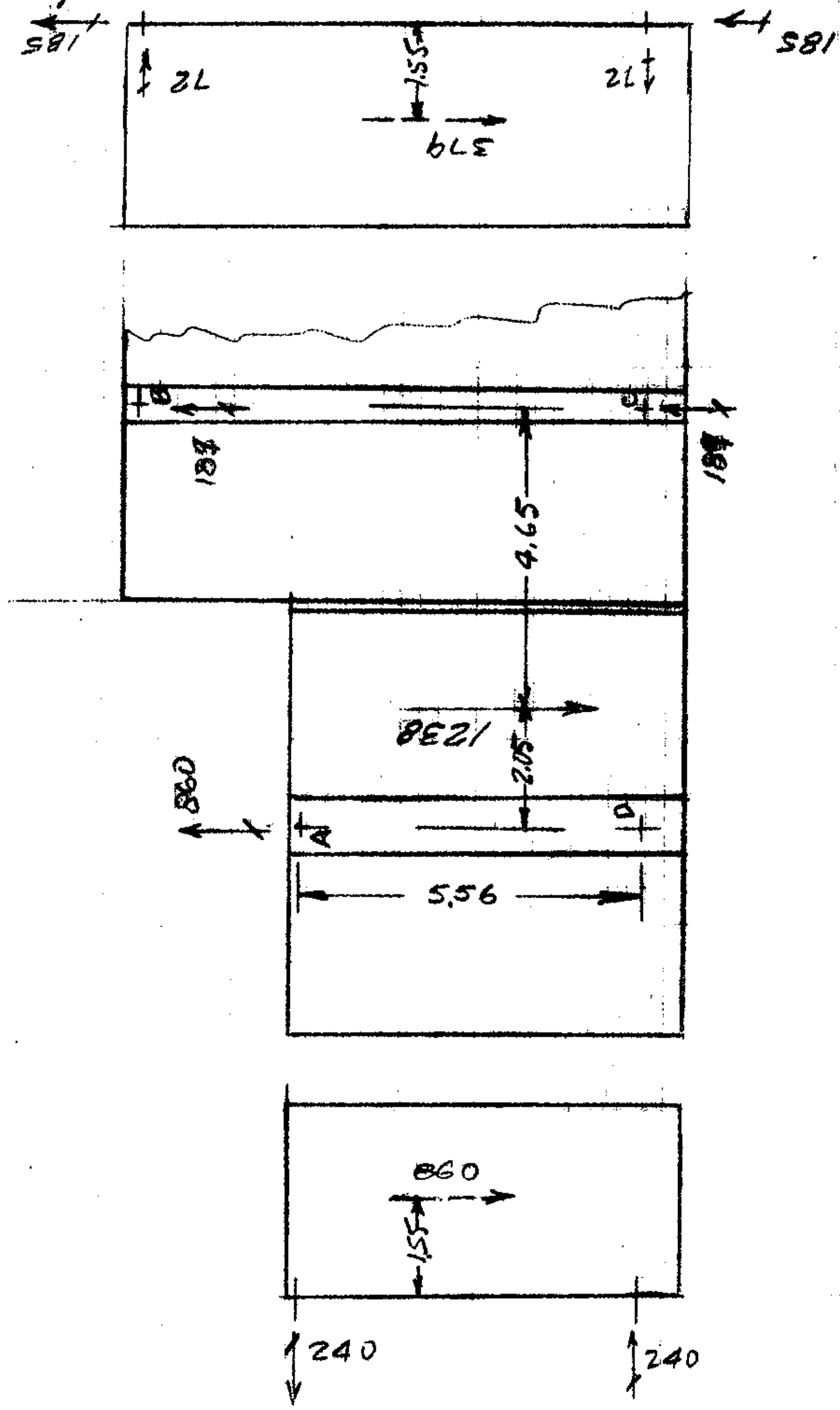


$R = \sqrt{1462^2 + 575^2} = 1570^{\#}$

MORTAR PACKAGE INVESTIGATION ~ ASE

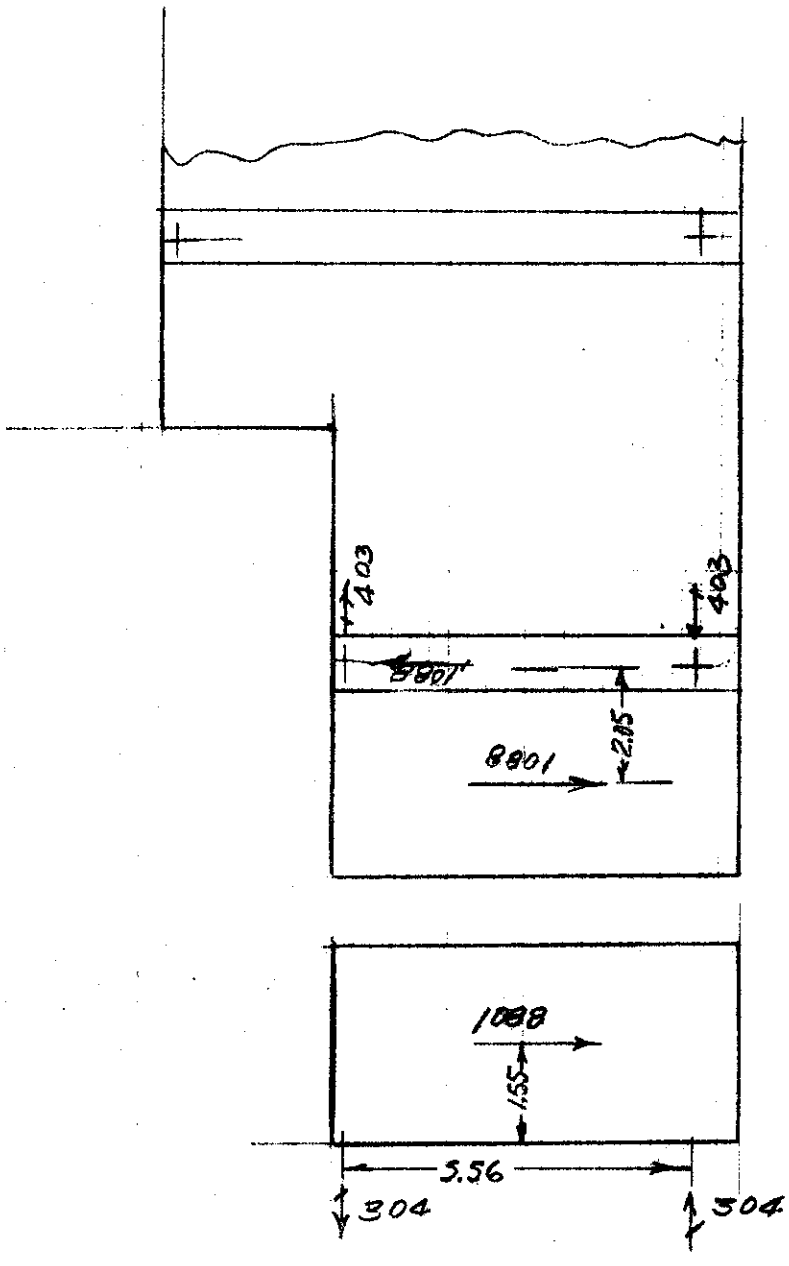
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

LOADS INVESTIGATION ~ COND. 3



MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

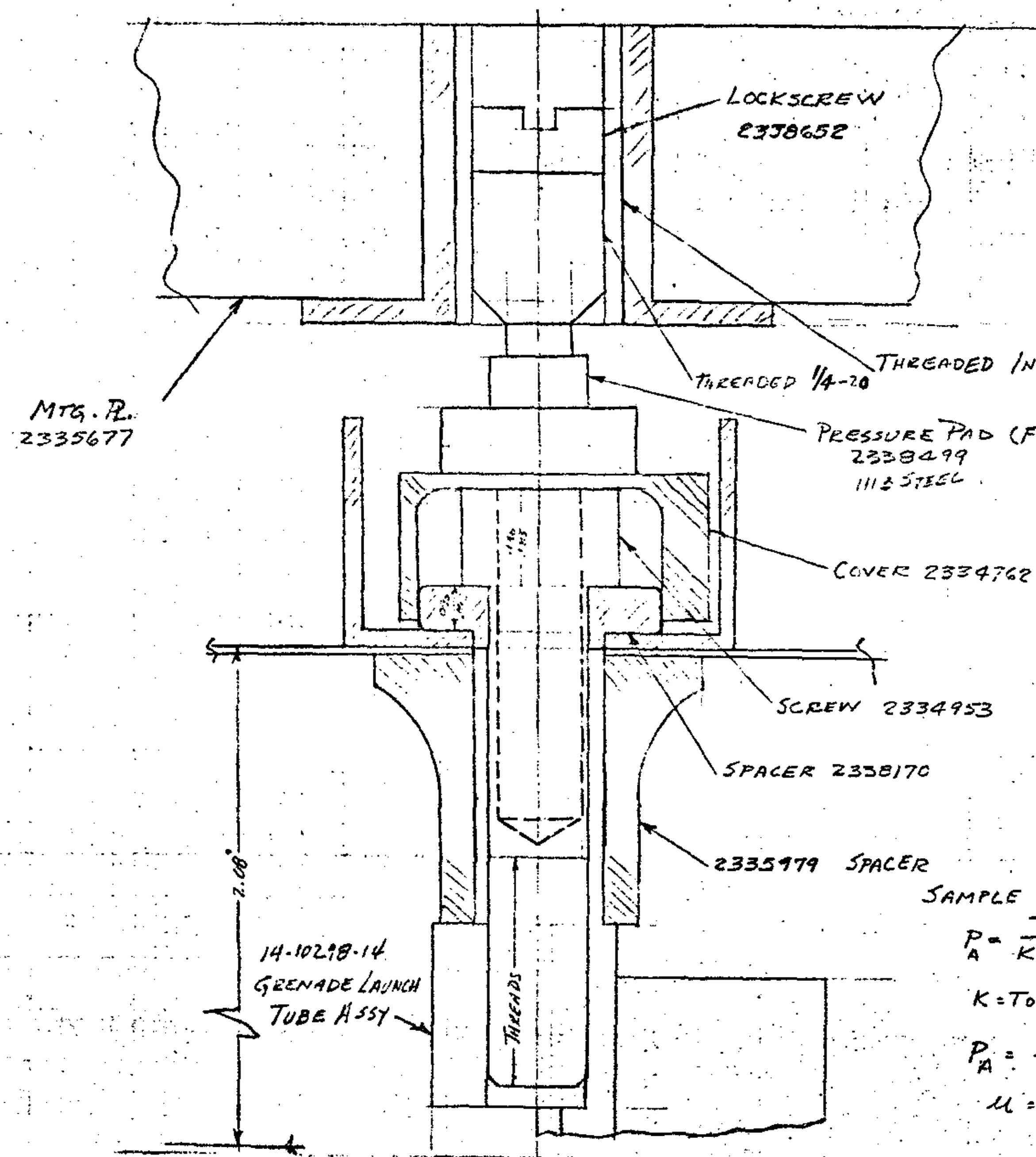
LOADS INVESTIGATION ~ COND. 4



ASE - Upper Support

Pressure Pad Detail

The sketch on the following page shows the upper mounting pad details. Using the torques specified on the assembly drawing 2334845, sheet #4, preloads in fittings have been calculated. Preloads are small and the upper attachments are incapable of resisting high loads. Friction forces to resist horizontal loads are so small as to be negligible.



ASE ~ UPPER SUPPORT
PRESSURE PAD DETAIL
SCALE 5:1

PRESSURE PAD TORQUES & PRELOADS

PAD	TORQUE*	APP. PRELOAD	FRICT. FORCE
A	5.9 ± 0.2	118 - 122	34.2 - 122
B	2.4 ± 0.2	44 - 52	13 - 52
C	1.5 ± 0.2	26 - 34	7.8 - 34
D	3.2 ± 0.2	60 - 68	18 - 68

* REF. DWG. 2334845 SH'T. #4

SAMPLE CALCULATIONS

$P_A = \frac{T}{KD} = \frac{6.1}{.2 \times .25} = 122$ PRELOAD

K = TORQUE COEFF. USUALLY ASSUMED .2

$P_A = \mu P_A = (.3 \text{ TO } 1) P_A$

μ = FRICTION COEFF. VARYING BETWEEN .3 & 1

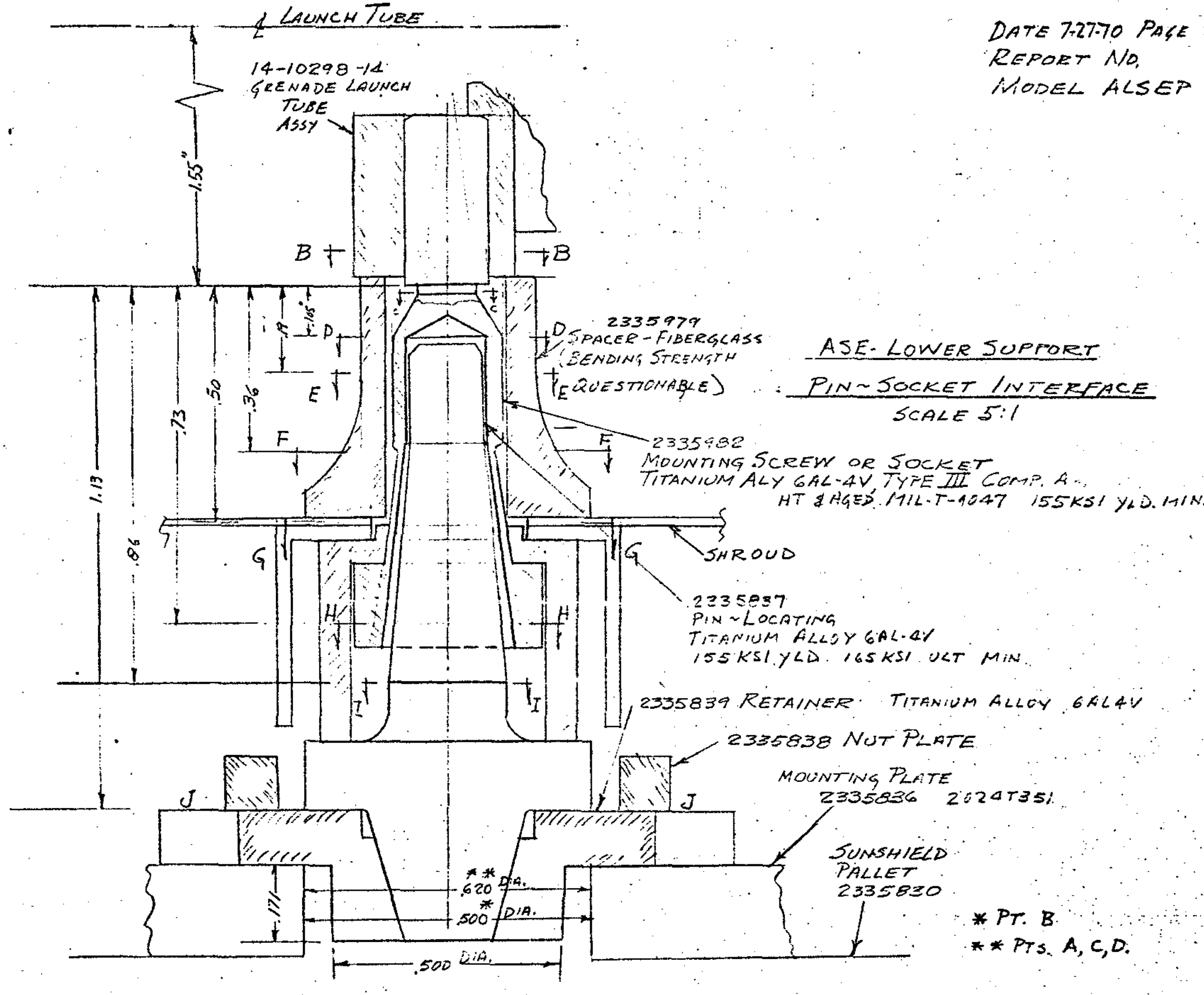
ASE - Lower Support

Pin-Socket Interface

The following pages show the analysis of the ALSEP to ASE interface. As previously discussed, the attachments will not resist a load due to an inadvertent launch, although complete separation is unlikely. Allowable bending moments on the pins have been determined and compared with actual moments. Actual point of failure on pin B will probably be a C-C, it requiring the least energy to fail at this point, although imminent failure will exist through the entire pin.

The accompanying sketches give sufficient data so that analyses can be followed. Referenced Dwgs give complete information.

ASE- LOWER SUPPORT
PIN ~ SOCKET INTERFACE
SCALE 5:1

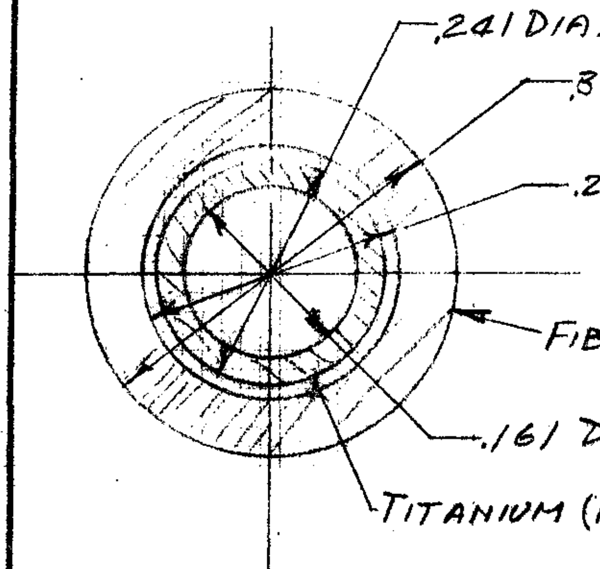


MORTAR PACKAGE INVESTIGATION ~ ASE

EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

PIN ~ SOCKET INTERFACE ~ SECTION PROPERTIES

SECT. D-D*



(1)

$$I = \frac{\pi(\overline{.241}^4 - \overline{.161}^4)}{64} =$$

$$= \frac{\pi}{64}(.00337 - .000672) = .000133$$

$$(2)\ \frac{\pi}{64}(\overline{.38}^4 - \overline{.25}^4)$$

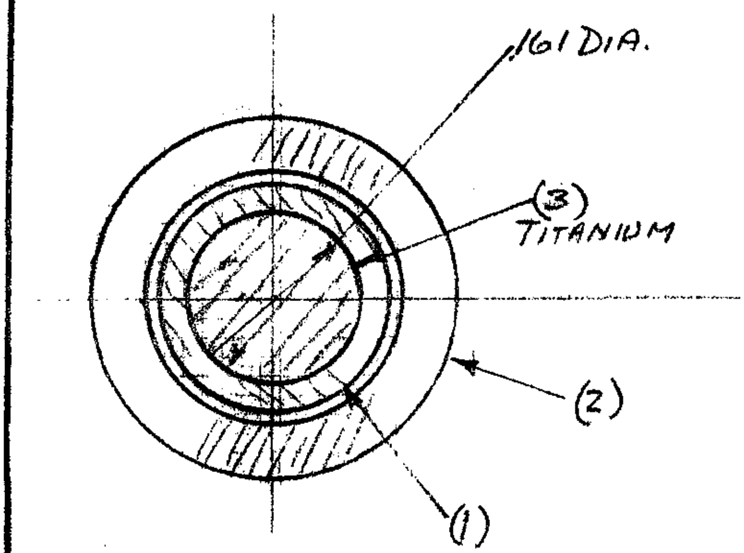
$$= (.020 - .0039)\ .0491$$

$$= .00788 \times 10^{-1} = .000788$$

$$EI_{(1)} = .000133 \times 16 \times 10^6 = 2125$$

$$EI_{(2)} = .000788 \times 3.4 \times 10^6 = 2680$$

SECT. E-E



(1) & (2) SAME AS D-D

$$(3)\ I = .0491(\overline{.161}^4) = .329 \times 10^{-4}$$

$$EI_3 = .329 \times 10^{-4} \times 16 \times 10^6$$

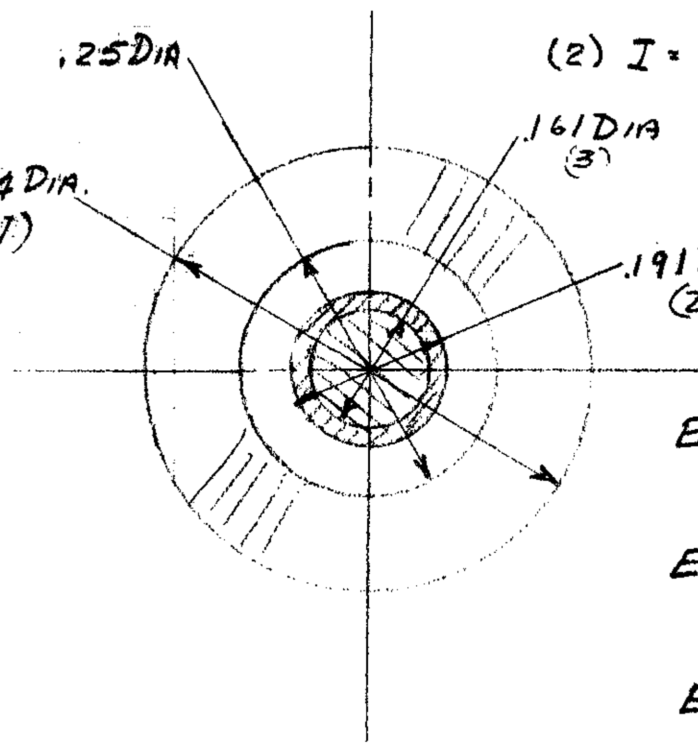
$$= 5.27 \times 10^2$$

* ALL SECTIONS REFER TO SKETCH ON PG. 35

MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

PIN ~ SOCKET INTERFACE ~ SECTION PROPERTIES

SECT. F-F*



(1) $I = .0491(\overline{.44}^4 - \overline{.25}^4)$
$= .0491(.0375 - .0039) = .00165$

(2) $I = .0491(\overline{.191}^4 - \overline{.161}^4)$
$= .0491(13.3 - 6.72)10^{-4}$
$= .322 \times 10^{-4}$

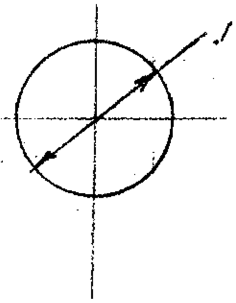
(3) $I = .0491(.161)^4$
$= .329 \times 10^{-4}$

$EI_{(1)} = 3.4 \times 10^6 \times .00165$
$= .00562 \times 10^6$

$EI_{(2)} = .322 \times 10^{-4} \times 16 \times 10^6$
$= 5.15 \times 10^2$

$EI_{(3)} = .339 \times 10^{-4} \times 16 \times 10^6$
$= 5.42 \times 10^2$

SECT. C-C*



$AREA = \frac{\pi D^2}{4} = .0211$

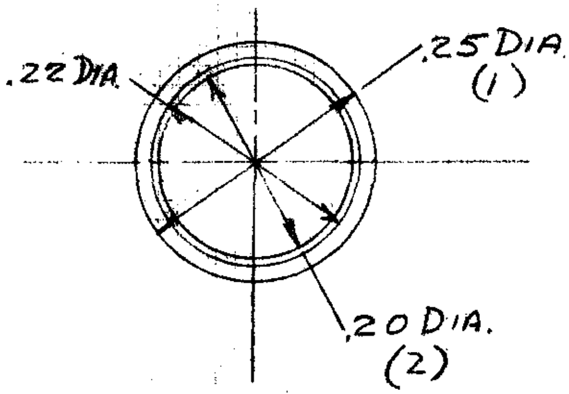
$P_{ALLOW} = .0211 \times 98000 = 2080^{\#}$

* ALL SECTIONS REFER TO SKETCH ON PG. 35

MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH VIA LM

PIN ~ SOCKET INTERFACE ~ SECTION PROPERTIES

SECT. G-G *



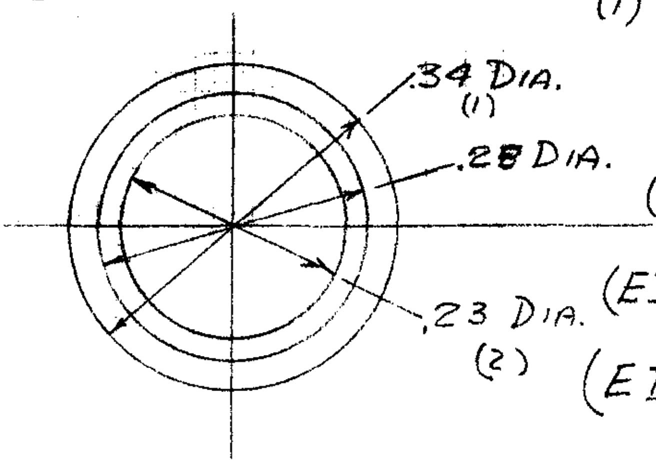
(1) $I = .0491(\overline{.25}^4 - \overline{.22}^4)$
$= .0491(.0039 - .00224) = .0815 \times 10^{-3}$

(2) $I = .0491(\overline{.20}^4) = .785 \times 10^{-4}$

$(EI)_1 = .0815 \times 10^{-3} \times 16 \times 10^6 = 1.305 \times 10^3$

$(EI)_2 = .0785 \times 10^{-3} \times 16 \times 10^6 = 1.255 \times 10^3$

SECT. H-H *



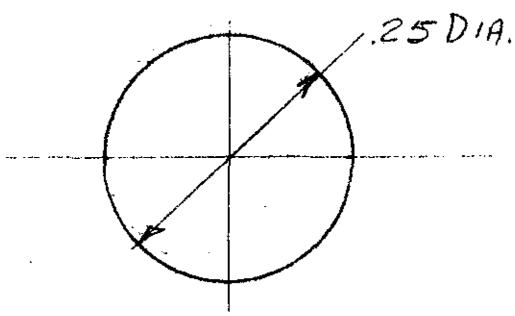
(1) $I = .0491(\overline{.34}^4 - \overline{.28}^4)$
$= .0491(.0134 - .0061)$
$= .354 \times 10^{-3}$

(2) $I = .0491(.23)^4 = .1375 \times 10^{-3}$

$(EI)_1 = .354 \times 10^{-3} \times 16 \times 10^6 = 5.65 \times 10^3$

$(EI)_2 = .1375 \times 10^{-3} \times 16 \times 10^6 = 2.20 \times 10^3$

SECT. I-I *



$I = .0491 \times \overline{.25}^4 = .000192$

$EI = .000192 \times 16 \times 10^6 = .00308 \times 10^6$

* ALL SECTIONS REFER TO SKETCH ON PG. 35

MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

ALLOWABLE MOMENTS

SECT. F-F *

$$B.M. = \frac{1.7 \times 165000 \times .651 \times 10^{-4}}{.0905} = 202''\# \quad \text{(FAILURE PT)}.$$

ASSUME FIBERGLASS ACTING ALONE

$$B.M. = \frac{85000 \times .00165}{.22} = 640''\#$$

$$2080 \times .35 = 727''\# \quad \text{STILL FAILS}$$

SECT. G-G *

$$B.M. = \frac{1.7 \times 165000 \times (.815 + .785)10^{-4}}{.125} = 360.0''\# \quad \text{FAILS}$$

SECT. H-H *

$$B.M. = \frac{1.54 \times 165000 \times (.354 + .138)10^{-3}}{.17} = 640''\#$$

SECT. I-I *

$$B.M. = \frac{1.7 \times 165000 \times .000192}{.125} = 430''\#$$

* ALL SECTIONS REFER TO SKETCH ON PG. 35

MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

ALLOWABLE MOMENTS

SECT. D-D* ~ NEGLECT FIBERGLASS

USE FORM FACTOR = 1.55 REF. MIL HDBK5A FIG. 5.6.1.1.1

$F_{tu} = 165000$

$$B.M. = \frac{1.55 \times 165000 \times .000133}{.12} = 283''^{\#}$$

NOTE: - EVEN IF FIBERGLASS IS INCLUDED (SOMEWHAT UNREALISTIC) BENDING STRENGTH OF THIS SECTION IS VERY SMALL. HOWEVER IF WE ASSUME PT C-C FAILS AT 2080# IN SHEAR

$$B.M. \text{ AT } DD = 2080 \times .1 = 208''^{\#}$$

SECT. E-E* ~ NEGLECT FIBERGLASS

NOTE: - FIBERGLASS WILL NOT PICK UP LOAD UNLESS THERE IS SERIOUS DEFORMATION. IF THERE IS THIS MUCH DEFORMATION TITANIUM WILL FAIL OR WILL BE APPROACHING FAILURE.

ASSUME (1) & (3) ACTING TOGETHER

$$I = (.329 + 1.33)10^{-4} = 1.66 \times 10^{-4}$$

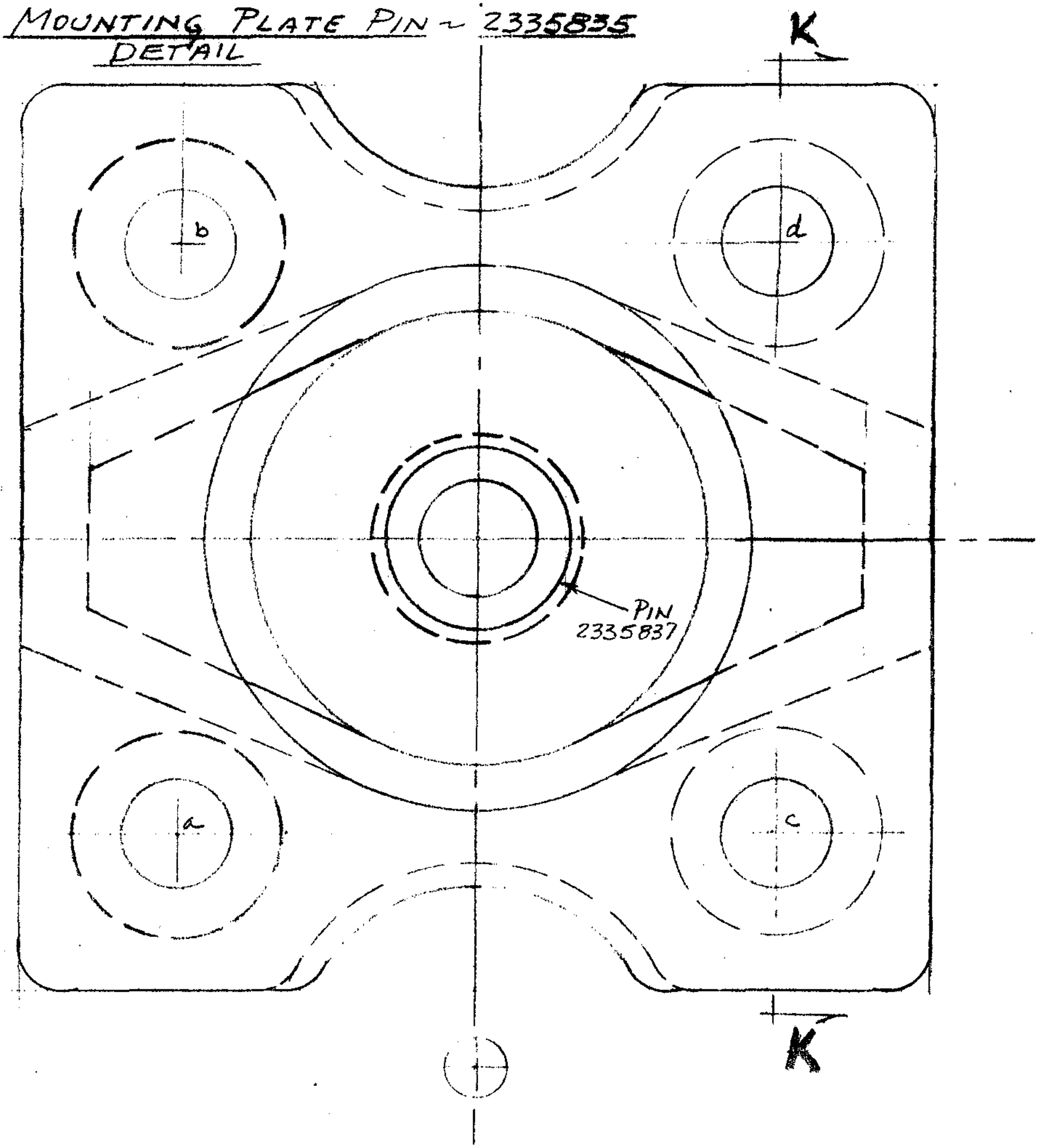
$$B.M. = \frac{1.7 \times 165000 \times 1.66 \times 10^{-4}}{.12} = 390''^{\#}$$

* ALL SECTIONS REFER TO SKETCH ON PG 35

MORTAR PACKAGE INVESTIGATION ~ ASE

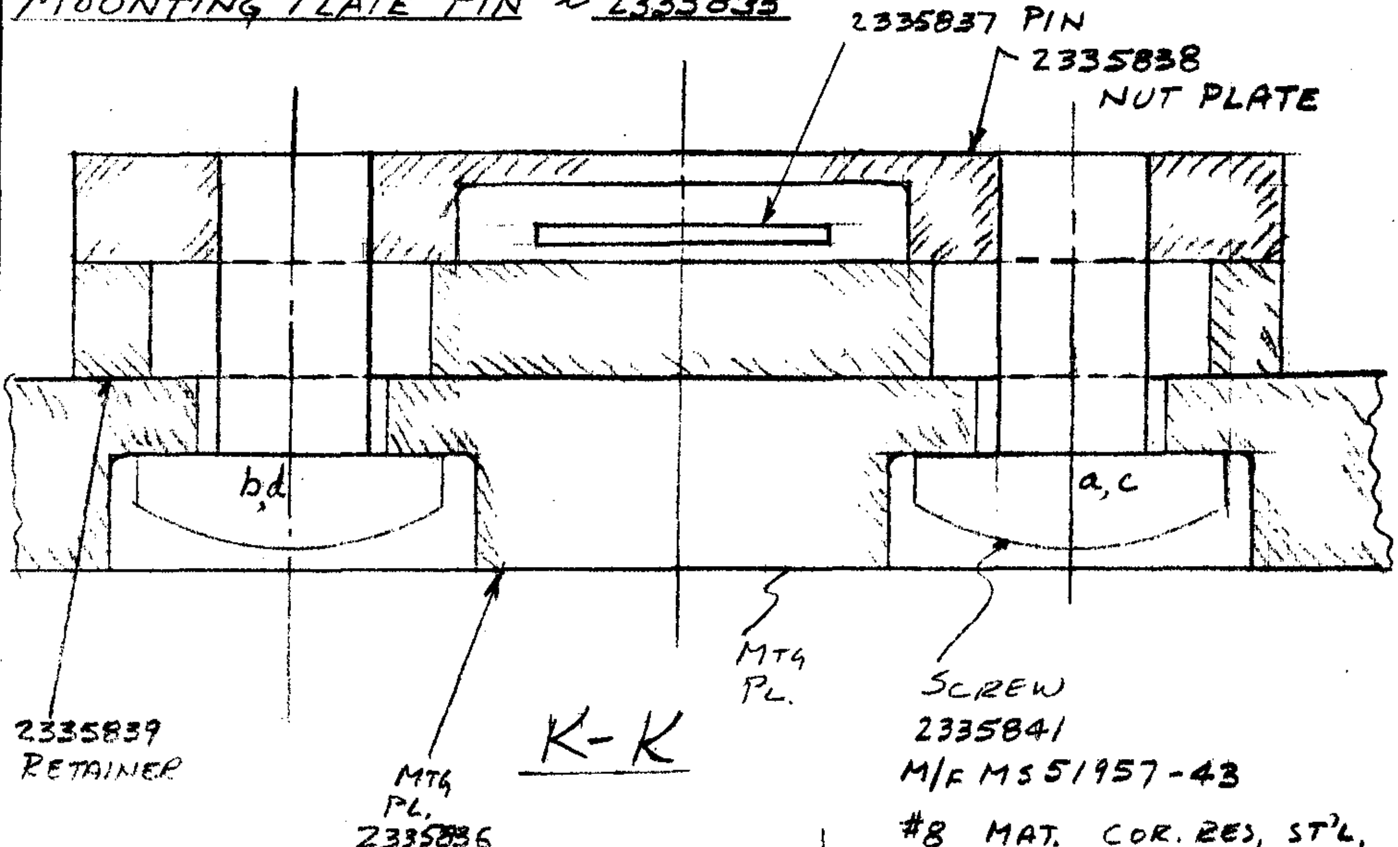
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

MOUNTING PLATE PIN ~ 2335835
DETAIL



MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

MOUNTING PLATE PIN ~ 2335835



K-K

#8 MAT. COR. RES. ST'L.
UTS = 80000 PSI
$P_{ULT} = 1120^{\#}$

TORQUE = 18 ± 2 IN LBS

$$P = \frac{T}{KD} = \frac{20}{.2 \times .139} = 720^{\#} \text{ MAX}$$

$$P = \frac{16}{.2 \times .164} = 487^{\#} \text{ MIN.}$$

TORQUE TO BE APPLIED

ASSUMING $K = .20$

ASSUME PRELOAD WILL CAUSE EVEN PRESSURE ON SURFACES

$$\omega = \frac{720 \times 4}{1.25} = 2300^{\#}/\text{IN MAX.}$$

$$\omega = \frac{487 \times 4}{1.25} = 1560^{\#}/\text{IN MIN.}$$

MOMENT AT PLATE SEPARATION

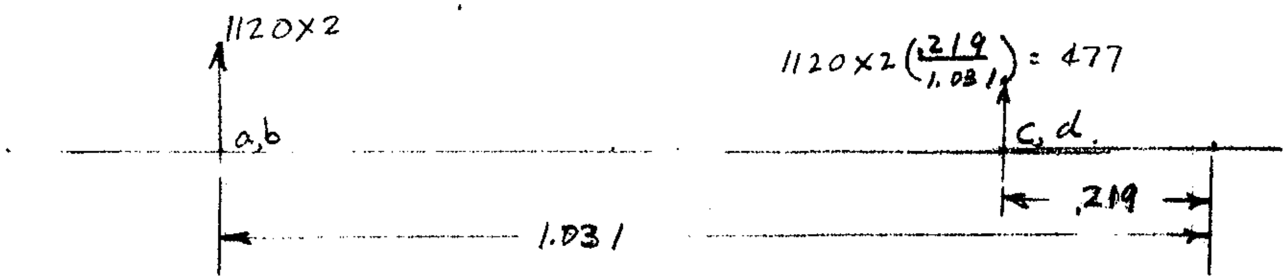
$$M_{MAX} = \frac{2300 \times 1.25}{4} \times 2/3 \times 1.25 = 600^{\#"}$$

$$M_{MIN} = \frac{1560 \times 1.25}{4} \times 2/3 \times 1.25 = 405^{\#"}$$

PLATE WILL SEPARATE

MORTAR PACKAGE INVESTIGATION ~ ASE
EFFECT ON STRUCTURE OF INADVERTENT MORTAR LAUNCH IN LM

MAX. PLATE MOMENT ~ ASSUMING SCREWS CRITICAL



$$M_{MAX} = 2240 \times 1.031 + 477 \times .219$$
$$= 2310 + 105 = 2415 \text{ ''\#}$$

MAX. MOMENT AT B ~ RETAINER TO MTG. PLATE

REF. REPUBLIC AVIATION CORP. FIG. 1.6400-2

TREAT AS BEAM IN A SOCKET

$L = .171 \quad P_{ALL.} = 118000 \times .5 = 59000 \text{ \#/IN}$

$F_{bru} = 118$ KSI

REF MIL HDBK5A $\quad K = 6.0$

$P = KM/L^2 \qquad M = \frac{59000 \times .171^2}{6} = 2880 \text{ ''\#}$

SECT J-J PAGE 35

MORTAR PACKAGE INVESTIGATION ~ ASE

EFFECT OF INADVERTENT MORTAR LAUNCH IN LM

ALLOWABLE VS ACTUAL BENDING MOMENTS ~ POINT C

P_{ACT} = 2650 LBS P_{ALLOW} = 2080#

SECT. PG.	ARM "a" PG —	P_{ACT} (a)	ALLOW. M. * PGS —	M.S.
C-C	0	0	—	-.178
D-D	.105	278	208	-.250
E-E	.190	503	390	-.225
F-F	.360	955	640	-.330
G-G	.500	1325	360	-.728
H-H	.730	1940	640	-.670
I-I	.860	2280	430	-.812
J-J	1.130	3000	2250	-.250

* P_{ALLOW} (a) OR CAL. ALLOW AT SECT.
WHICHEVER IS LESS

5.0 References

(1) Space Ordnance Systems letter and informal report from William Gordon to Jack McDowell July 20, 1970

(2) Space Ordnance Systems

DDT Test Report 6542

(3) MIL-HDBK-5A

Metallic Materials and Elements for Aerospace Vehicle Structures

Drawings

(1) Space Ordnance Systems Inc.

14-10298-14-ALSEP Grenade and Launch System and Details

(2) Bendix Corporation - Aerospace Systems Division

2334845 Final Assembly, Subpackage 1, ALSEP and Details