STRUCTURAL ANALYSIS REPORT

LUNAR EJECTA AND METEORITE EXPERIMENT

Prepared by:

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INTRODUCTION

This report consists of the stress analysis performed to substantiate the structural integrity of the Lunar Ejecta and Meteorite Experiment. (LEAM).

The analysis is based on a breakdown of weights of the experiment components based on a total weight of 14.0 pounds from references (1) and (2). Final experiment weight deviated slightly from that assumed but not enough to significantly affect the analysis or structural performance.

Analysis loads are from references (1) and (3). Outer structure, UHT socket and attachment fittings are based on loads from reference (3). A factor of safety of 1.5 has been used to obtain ultimate loads.

In most cases, the margins of safety are high. Low margins of safety are based on conservative assumptions and a more vigorous analysis would show a higher margin. Items not shown in this report have been investigated and can be shown to have high margins of safety using defined load factors.

The LEAM structure consists of an outer box, an inner box, and an interface bracket, or flange.

The internal box or inner structure supports the sensors, electronics and radiator plate. It is directly attached to the interface flange which is mounted by astronaut removable Boyd bolts to the ALSEP structure. (Loads and analysis are shown on pages 4-10). The inner structure has ample strength throughout.

The outer structure is a fiberglass cover which houses the insulation, and is back-up structure for lunar mounting legs and deployment fittings. It is thermally isolated from the inner structure by special fiberglass clevis fittings and with titanium pins. The outer structure is critical for deployment loads and special reinforcing is added to the cover for deployment conditions. (Loads and analysis are shown on pages 11-27).

A discussion of the testing and development of mounting methods to protect the thin parylene films is given in dynamics documents.

At the back of the report is an appendix including supplementary investigations conducted as part of the structural analysis task, although not directly related to structural integrity.

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REFERENCES

(1) AL900130 Performance and Design Requirements for Lunar Ejecta and Meteorite Experiment.

(2) IC 314130 Interface Control Specification for Lunar Ejecta and Meteorite Experiment.

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

(4) Roark, R.J., "Formulas for Stress and Strain", McGraw Hill Book Company, Inc. 1943.

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

(6) MIL-HDBK-17 and 17A, "Plastic for Aerospace Vehicles", Part 1. Reinforced Plastics, Department of Defense, Washington, D.C.

(7) Lockheed Stress Memo No. 88 "Tension Type Fittings "Lockheed Aircraft Corporation

CRITERIA SUMMARY

Analysis Conditions

1. 20 g limit load factor along each major axis acting independently
2. 30 lbs. handling load on end of UHT (Universal Handling Tool - Drawing 2338102 per Reference (3).

Factor of Safety

Ult Load/Limit Load = 1.5

Design Weight Summary

Inner Structure and Interface Flange

Up Sensor	2.02 lbs.
East Sensor	2.03 lbs.
West Sensor	.89 lbs.
Central Electronics	2.88 lbs.
Thermal Radiator & Masks	.36 lbs.
Interface Flange	.28 lbs.
Paint	.10 lbs.
Internal Structure Assy.	1.77 lbs.
Thermal Bay Assy.	.65 lbs.
	10.98 lbs.

Outer Structure

Outer Housing Assembly	1.50 lbs.
UHT Pivot and Socket Assy	.16 lbs.
Leg & Release Hardware	.49 lbs.

Outer Structure (continued)

Dust Covers & Release Hardware	.18 lbs.
Gnomon and Bubble	.16 lbs.
Paint	.30 lbs.
Cable	.23 lbs.
	3.02 lbs.
Total Weight	14.00 lbs.

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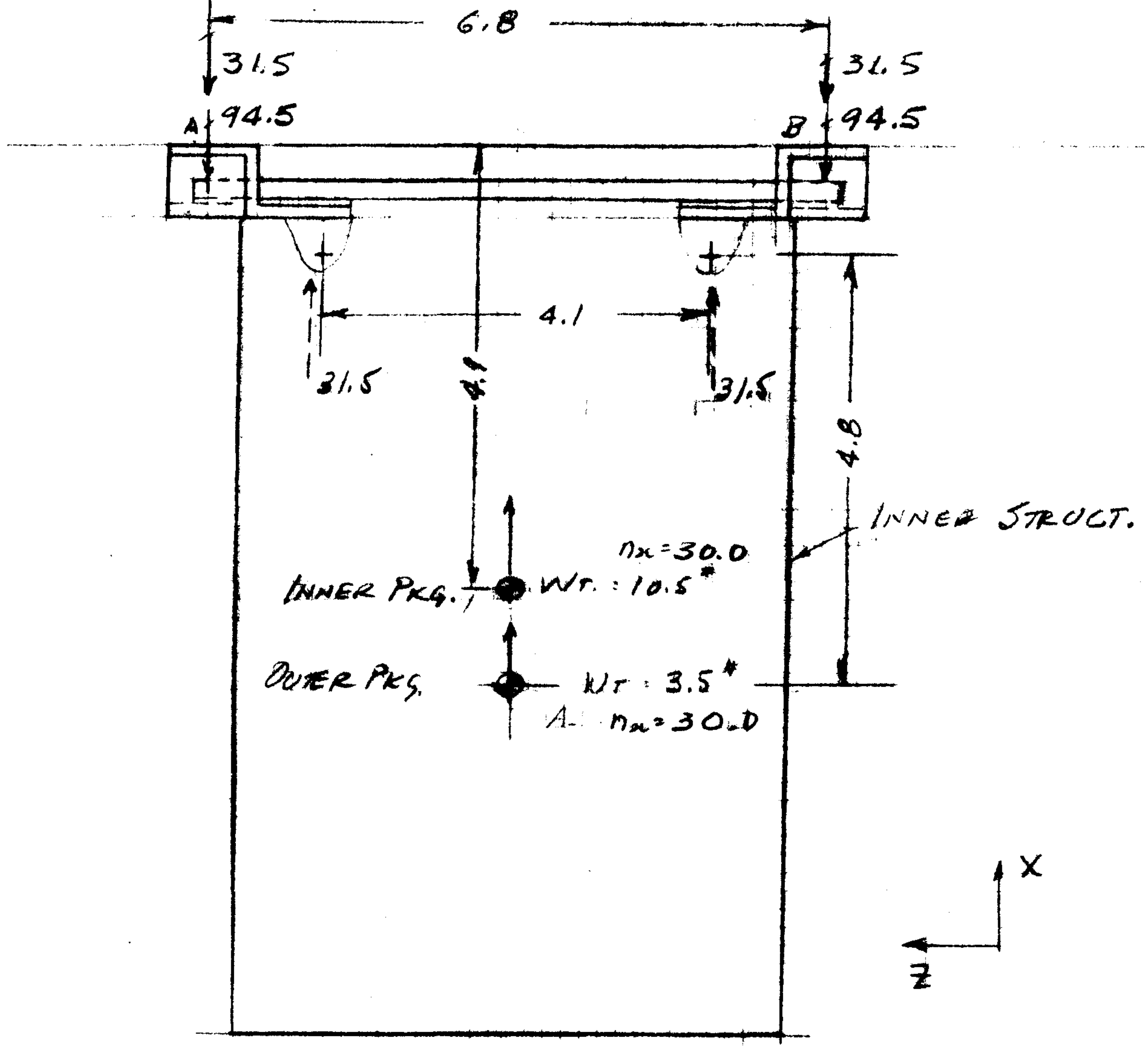
LUNAR EJECTA AND METEORITE EXPERIMENT

BRACKET ATTACHMENT TO ALSEP ~ MOUNTING LOADS



CONSERVATIVELY ASSUME 60% OF LOAD REACTED AT A & B.

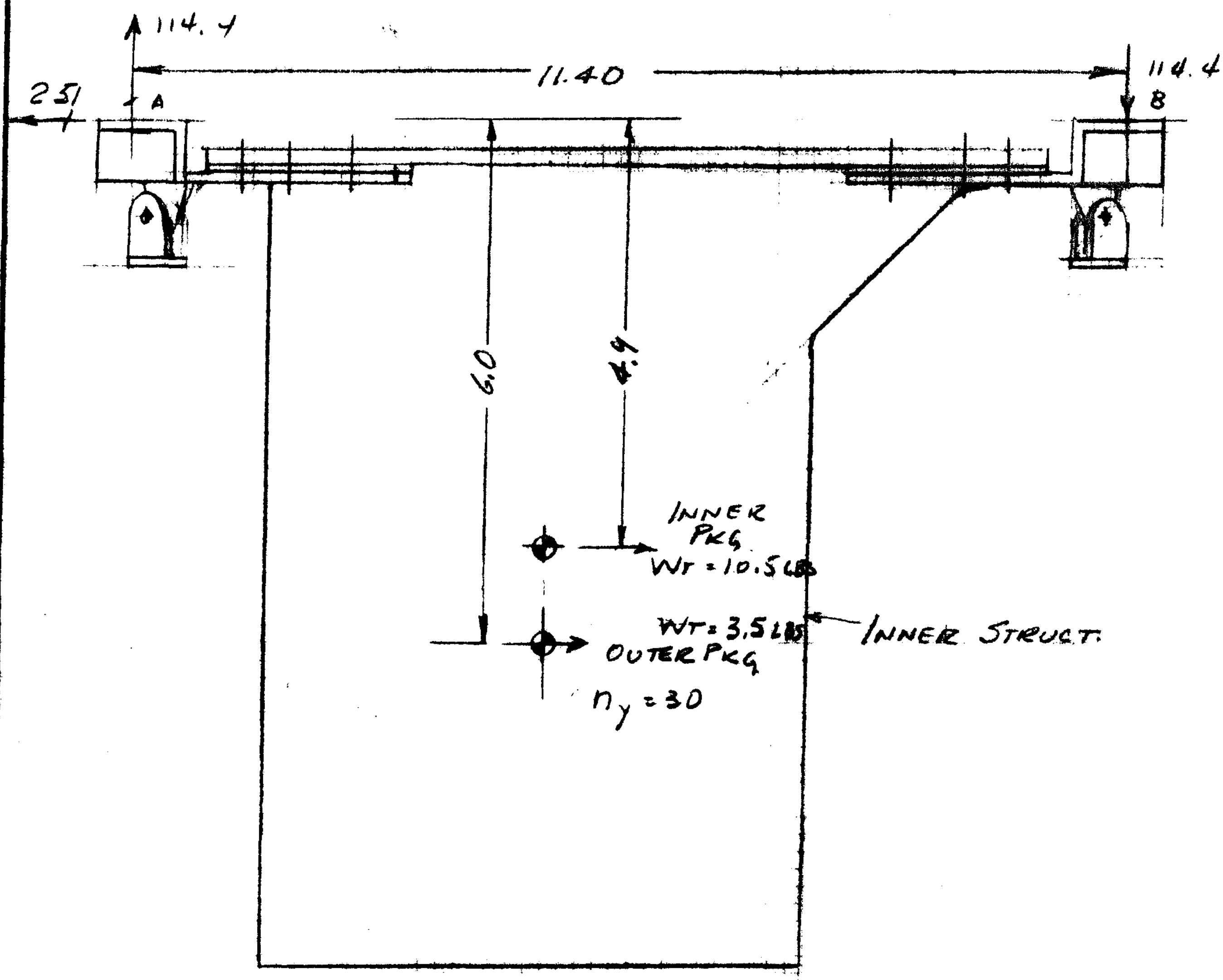
FLIGHT ACCELERATION $n_x = 20$

ULT. $n_x = 20 \times 1.5 = 30$

BxA 542

LUNAR EJECTA AND METEORITE EXPERIMENT

BRACKET ATTACHMENT TO ALSEP ~ MOUNTING LOADS

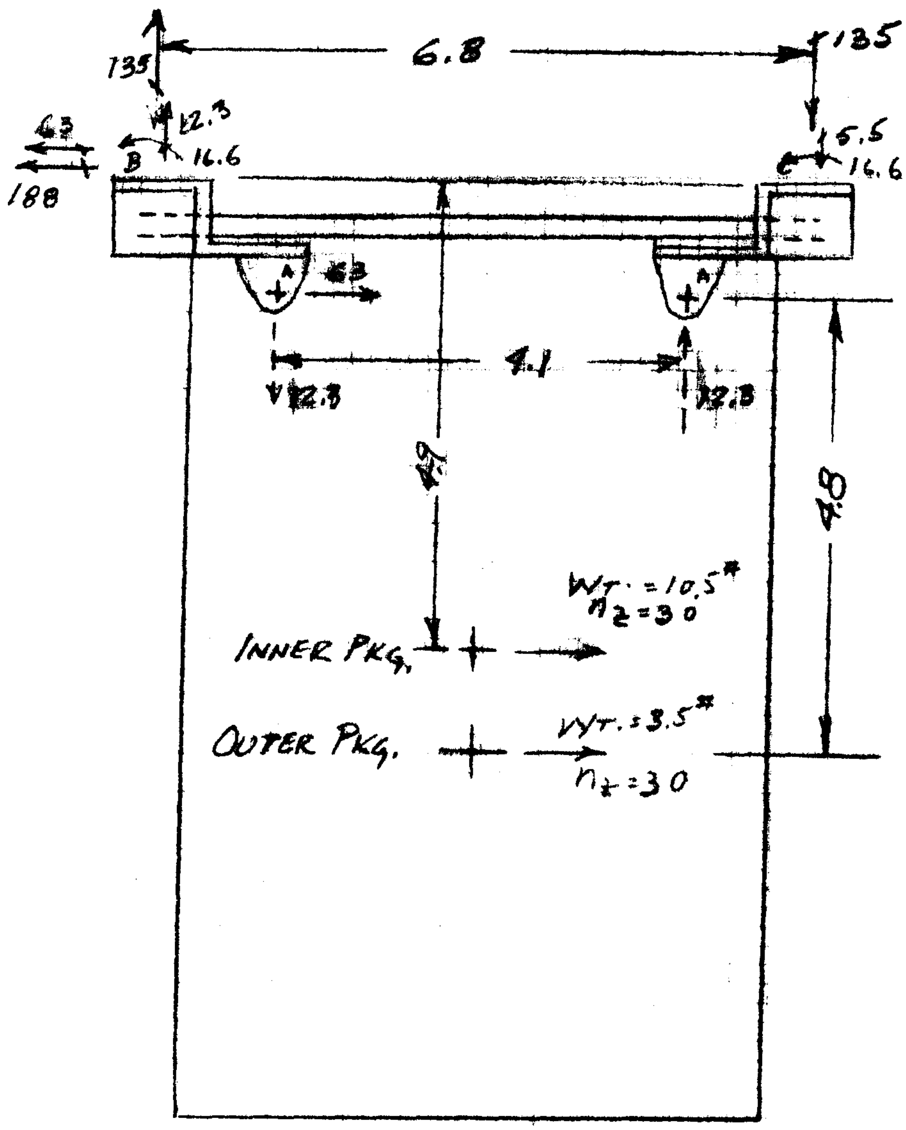


ASSUME 60% OF LOAD REACTED AT A & B

FLIGHT ACCELERATION $n_y = 30.0$

LUNAR EJECTA AND METEORITE EXPERIMENT

BRACKET ATTACHMENT TO ALSEP ~ MOUNTING LOADS



ASSUME 60% OF LOAD REACTED AT B & C

FLIGHT ACCELERATION n_z = 20 ULT. n_z = 30

INTERNAL STRUCTURE - THREE VIEW

REF. DWG. NO. 341928 1/2 SCALE

MATERIAL ~ 2024T351

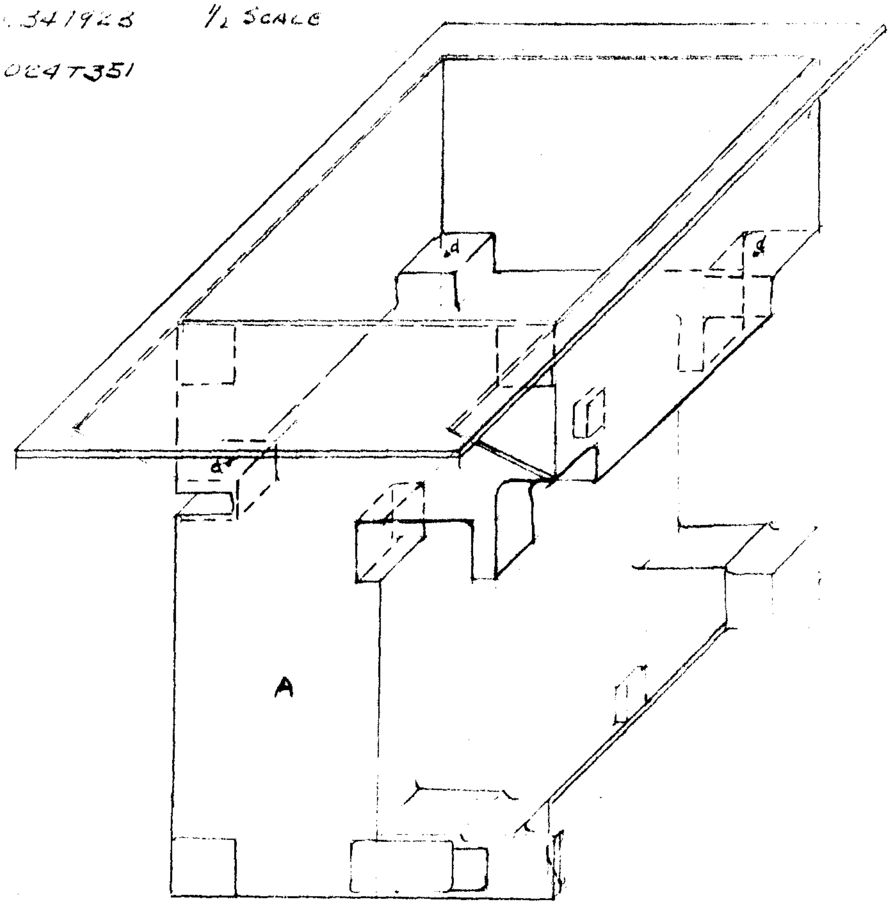


FIG. 1

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DATE: 12-1-70 PG 5
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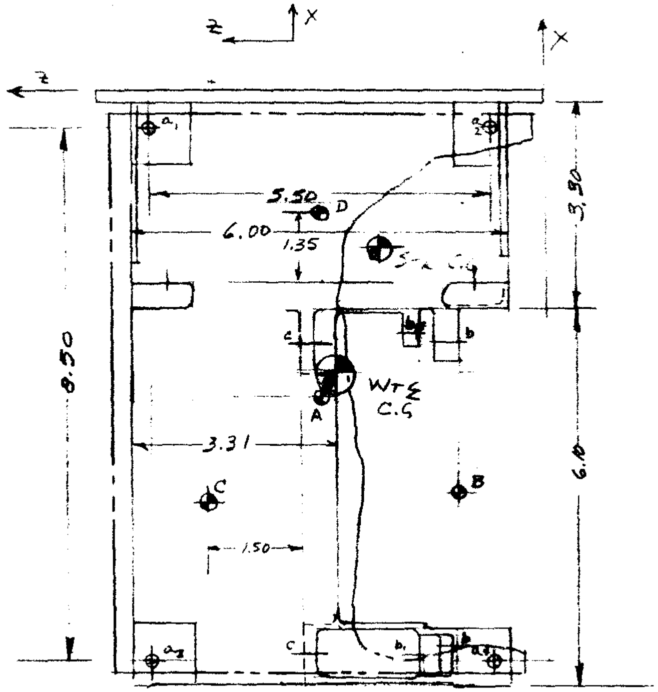
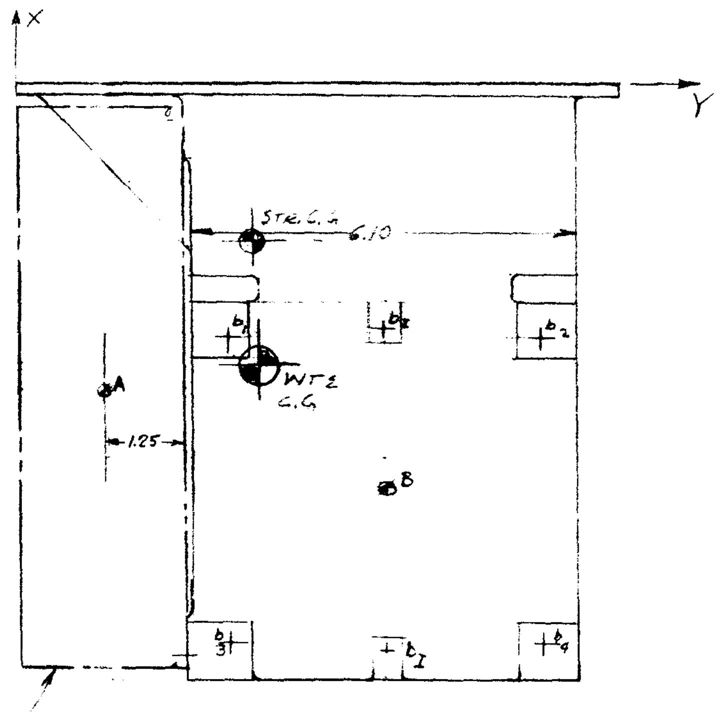
MODEL LEAM

INTERNAL STRUCTURE - MOUNTING FACES



MOUNTING FACE A

FIG. 2



ELECTRONICS PACKAGE
WT. 12.88 LBS

MOUNTING FACE B
(EAST SENSOR - DUAL)
FIG. 3 WT. 2.03 LBS

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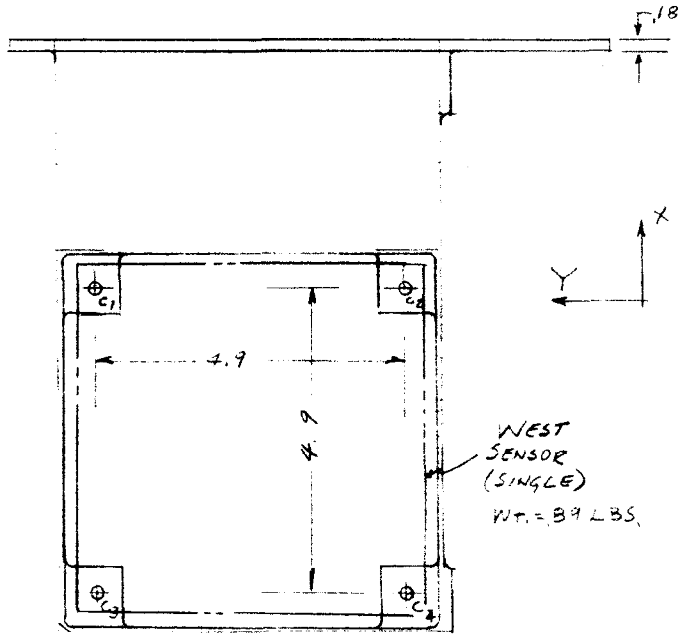
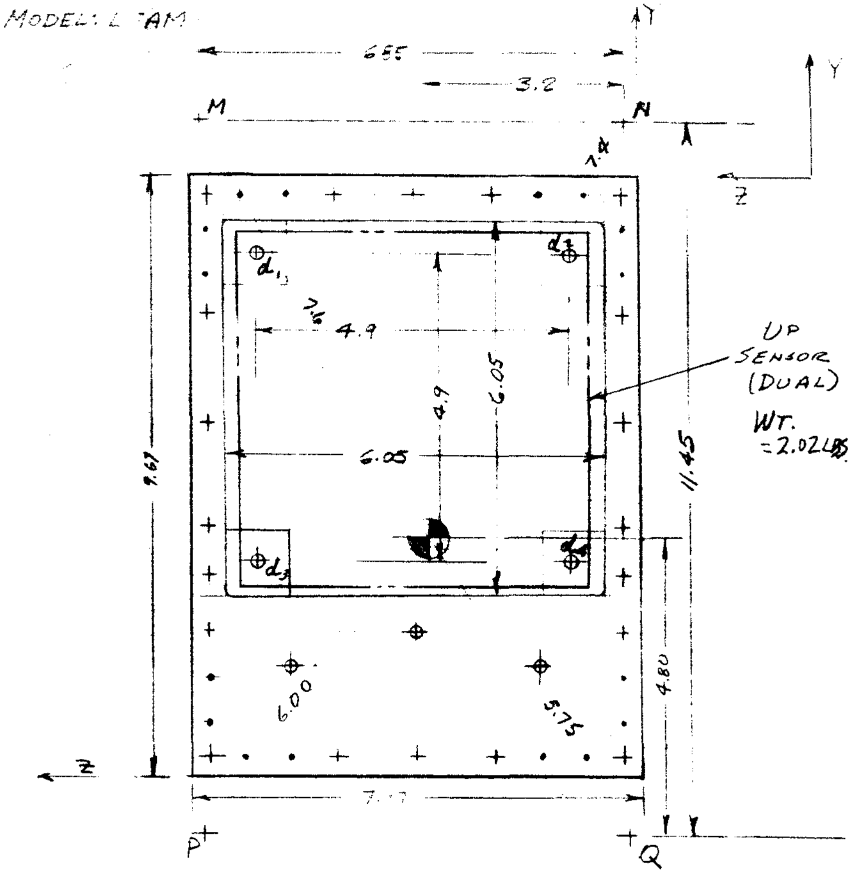
MODEL: L TAM

INTERNAL STRUCTURE – MOUNTING FACES



MOUNTING FACE C

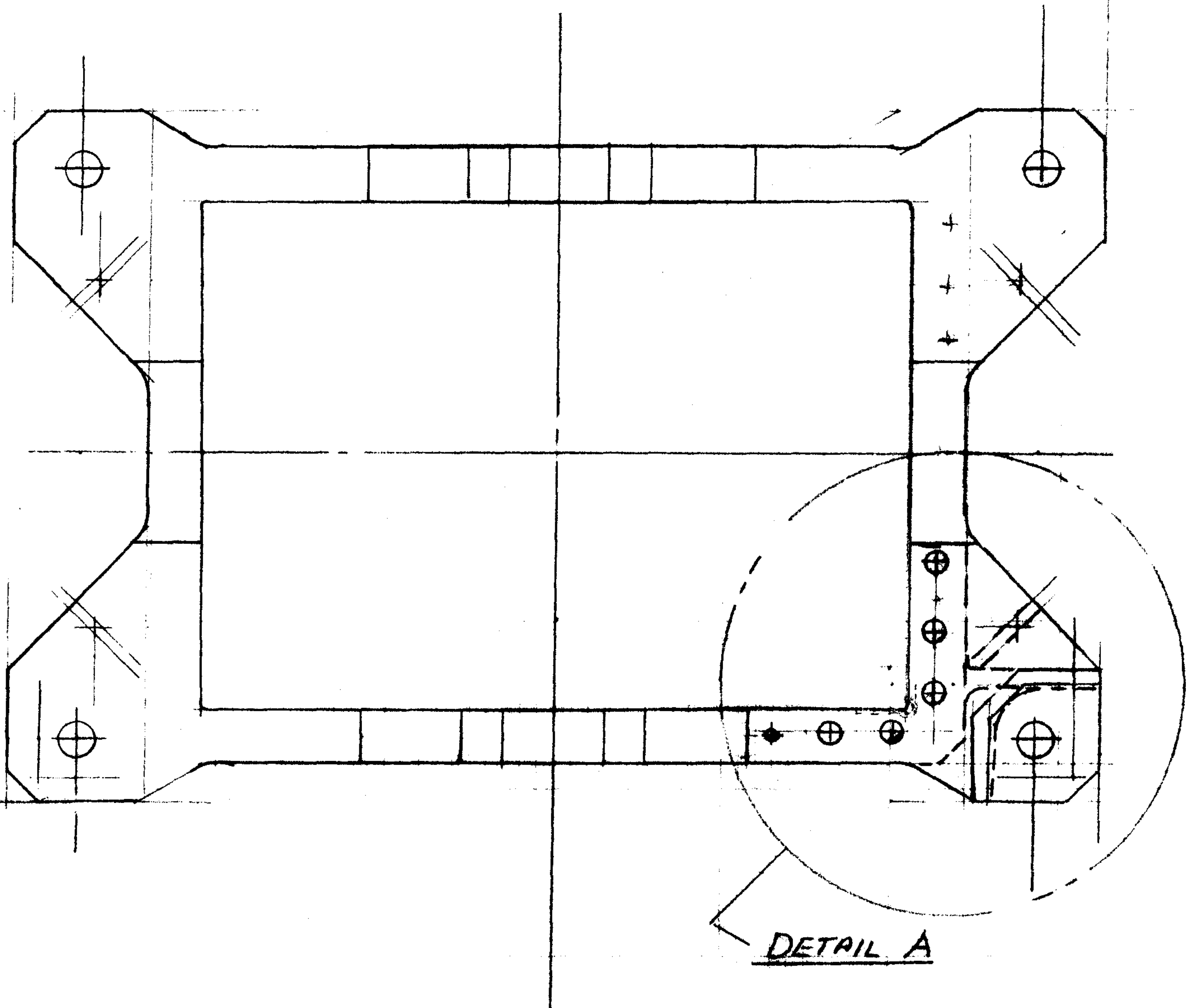
FIG. 4



MOUNTING FACE D
FIG. 5

LUNAR EJECTA AND METEORITE EXPERIMENT

FLANGE ~ INTERFACE BRACKET ~ DWG 2347721



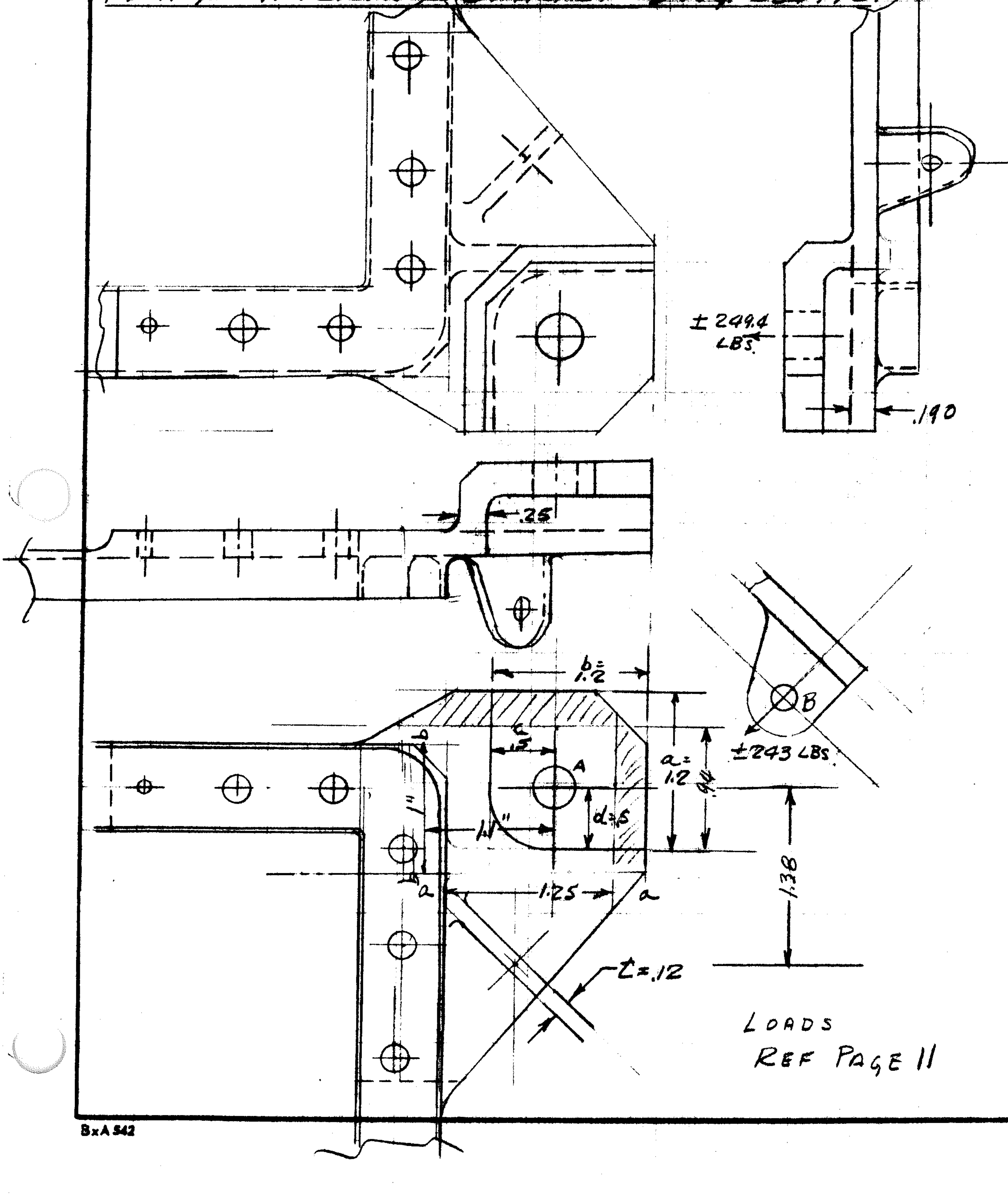
MATERIAL

FIBERGLASS LAMINATE PER SPEC. MIL-P-25421B TYPE 2 CLASS I GLASS FIBER BASE; TYPE III, CLASS 2 CLOTH BASE; NO. 120

MIN. NO. OF PLIES ~ 4

LUNAR EJECTA AND METEORITE EXPERIMENT

FLANGE ~ INTERFACE BRACKET ~ DWG. 2347721



LOADS
REF PAGE 11

LUNAR EJECTA AND METEORITE EXPERIMENT

FLANGE~INTERFACE BRACKET~DWG. 2347721

PT A

ANALYZE AS AN ANGLE FITTING

REF. LOCKHEED STRESS MEMO NO. 88

P=249.4 LBS. (REF. PG. 11) HANDLING LOADS

$$M_x = \frac{P}{(a+b)} ac = \frac{249.4}{2.4} \times .60 = 62.5 \text{ IN LBS} = M_y$$

SEE PG. 8 FOR DIAGRAM

$$\sigma_b = \frac{6M}{bd^2} = \frac{6 \times 62.5}{1.2 \times .25^2} = 5000 \text{ PSI}$$ M.S. AMPLE

WITH HATCHED AREA REMOVED

$$M = \frac{249.4}{1.88} \times .47 = 62.5 \text{ IN LBS}$$ $\sigma_b = 5000$ PSI

P=147 LBS (REF. PG 11)

$M_x = M_y = 36.80$ IN. LBS.

$$\sigma_b = \frac{6M}{bd^2} = \frac{6 \times 36.8}{1.2 \times .25^2} = 2940 \text{ PSI}$$ M.S. AMPLE

NOTE: EDGE DISTANCES DO NOT CONFORM TO THOSE RECOMMENDED IN MIL HDBK 17 (REF. 6) OTHER SOURCES. HOWEVER AT THE LOW LOADS IT SEEMS THAT THESE REQUIREMENTS ARE INAPPLICABLE.

LUNAR EJECTA AND METEORITE EXPERIMENT

FLANGE ~ INTERFACE BRACKET ~ DWG. 2347221

PT. B

$$\sigma_{BR} = \frac{243}{.188 \times .12} = 10800 \text{ PSI} \quad \text{M.S. AMPLE}$$

BENDING OF WEB a-a (HANDLING LOAD)

$$M = \frac{243 \times 1.38}{2} = 167.5$$

$$\sigma_b = \frac{6 \times 167.5}{1.25 \times .19^2} = 22200 \text{ PSI}$$

$$\sigma_{b\,ALLOW} = 28000 \quad \text{M.S.} = \frac{28000}{22200} - 1 = .26$$

BENDING OF WEB b-b (LAUNCH LOAD)

$$M = 147 \times 1.1 = 162$$

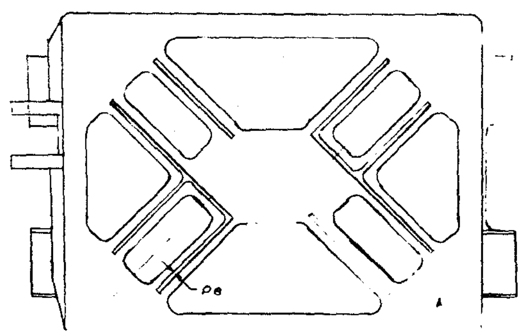
$$\sigma_b = \frac{6 \times 162}{1.1 \times .19^2} = 22300 \text{ PSI} \quad \text{M.S.} = \frac{28000}{22300} - 1 = .26$$

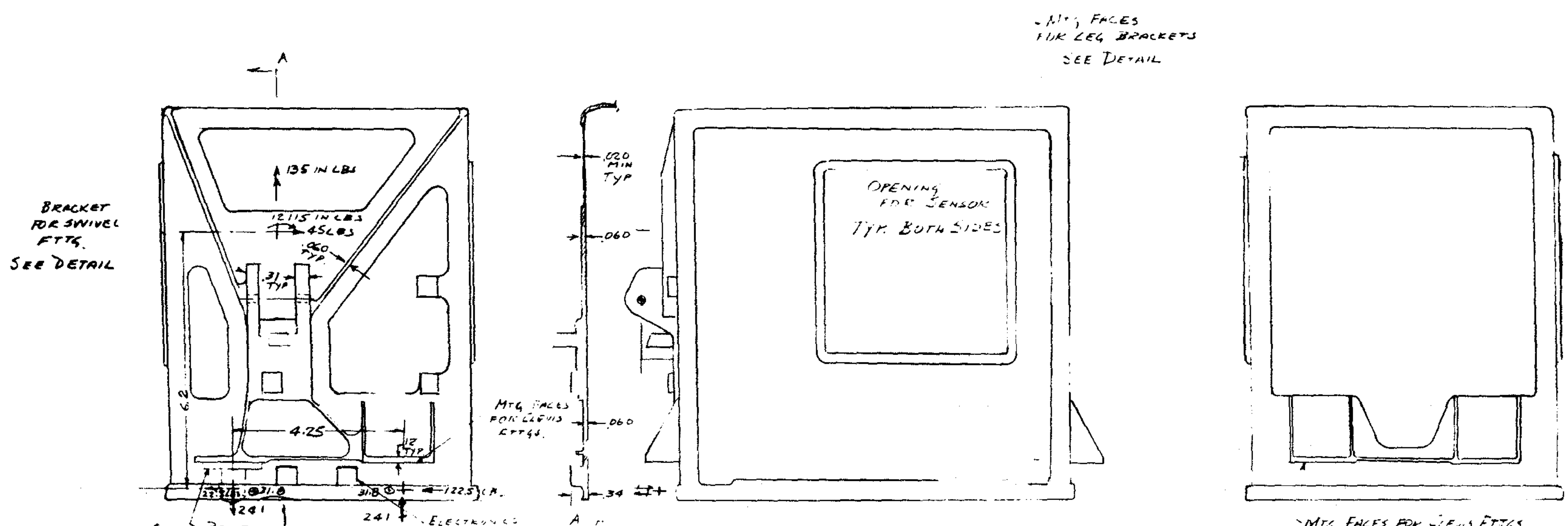
$F_b = 28000$ ~ CONSERVATIVE

MATERIAL: FIBERGLASS LAMINATE PER MIL-P-25421 TYPE II CLASS 1
GLASS FIBERBASE - TYPE 1 CLASS 2 CLOTH BASE NO. 1 2
MIN. NO. OF PLIES ~ 4

NOTES: - CRITICAL CONDITION FOR FIBERGLASS OUTER STRUCTURE IS DEPLOYMENT LOAD APPLIED TO SWIVEL FITTING BRACKET.
(REF 3)

DATE 10-18-7[illegible] PG. 11
K[illegible] NO. ATM 1065
[illegible] LEAM





OUTER FIBERGLASS STRUCTURE DWG. 241734 1/2 SCALE

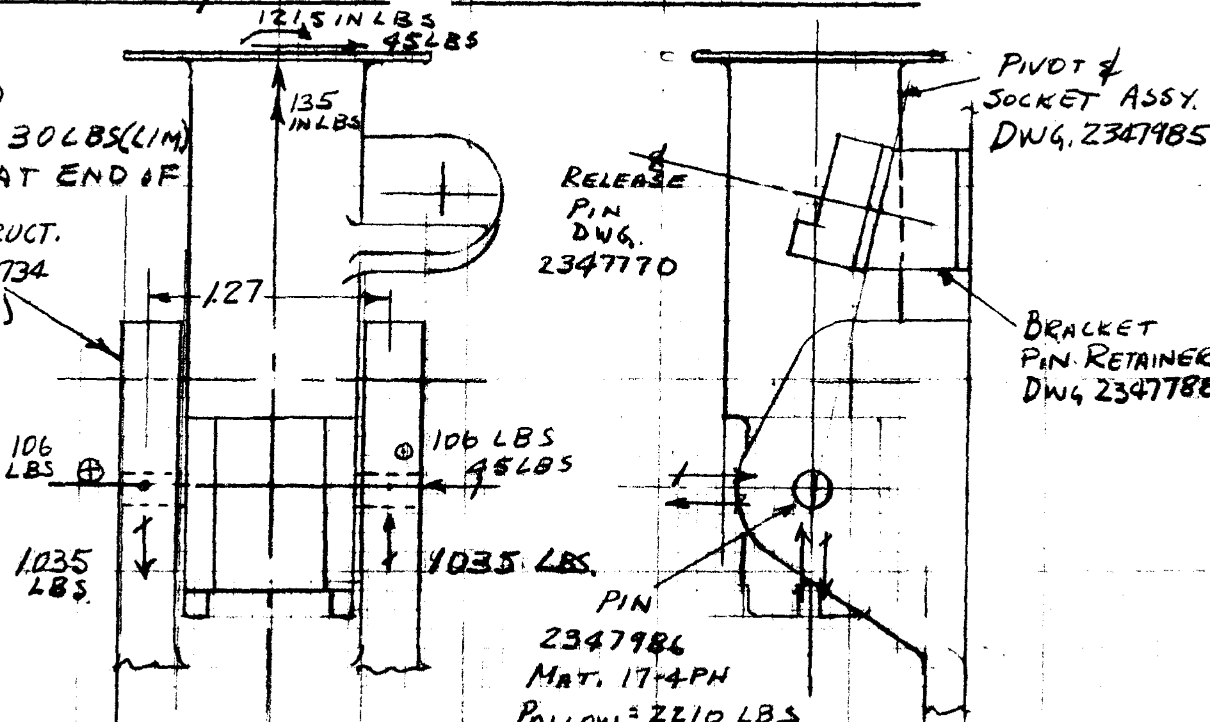
LUNAR EJECTA AND METEORITE EXPERIMENT

SWIVEL FITTING DETAIL ~ OUTER STRUCTURE

LOADS

REF. (3)
ASSUME 30 LBS (LIM) APPLIED AT END OF UHT

OUTER STRUCT. DWG. 2347734 (FIBERGLASS)



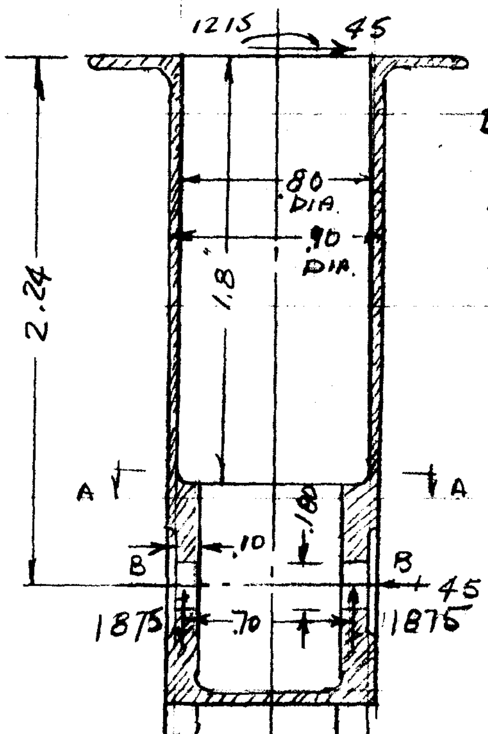
PIN BRG ON FIBERGLAS

$\sigma_{BE} = \frac{1035}{.31 \times .187} = 17800$ PSI M.S. AMPLE

$P_{ALLOW} = 2210$ LBS

$M.S. = \frac{2210}{1035} - 1 = 1.14$

SOCKET ANALYSIS ~ DWG. 2347931 ~ NEXT ASSEM. - 2347985



MATERIAL 7075T6

SECT. A - A

$B.M. = 1215 + 45 \times 1.8 = 1296$

$I = \frac{.90^4 - .80^4}{64}\pi = .0121$ $\qquad$ $R/t = \frac{.90}{.05} = 18$

$\sigma_b = \frac{1296 \times .45}{.0121} = 48000$ PSI

REF MIL-HDBK 5A

$F_b = 1.1 \times 72000 = 79000$

$M.S. = \frac{79000}{48000} - 1 = \underline{.64}$

BEARING AT B-B

$\sigma_{br} = \frac{1875}{.18 \times .10} = 104000$

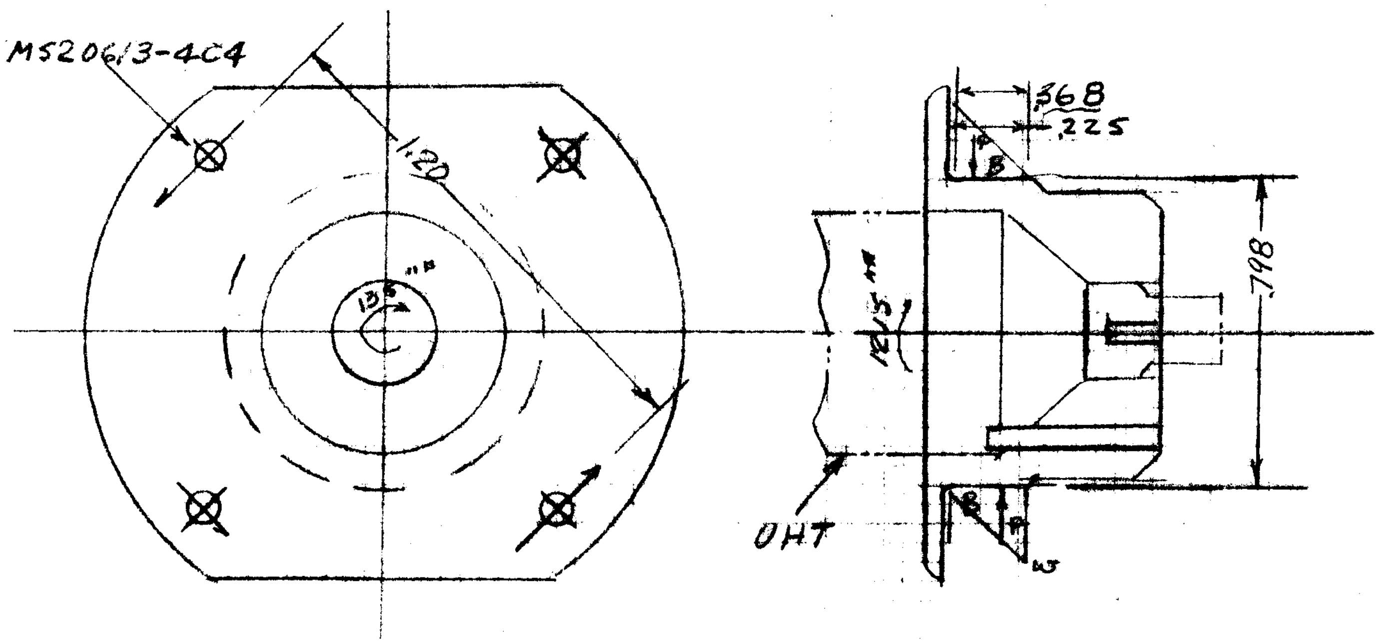
$F_{br} = 148000$ $\qquad$ $M.S = \frac{148000}{104000} - 1 = .42$

LUNAR EJECTA AND METEORITE EXPERIMENT

UHT SOCKET INSERT (REF. PAGE 12)

DWG. 2347984
NEXT ASSEM. 2347985
LOADS REF. (3)

MATERIAL 17-4PH H900



FOR ANALYSIS OF UHT SOCKET INTERFACE SEE ATM 871 PAGES 1-40 TO 1-45 INCL.

BEARING ON FACES B-B

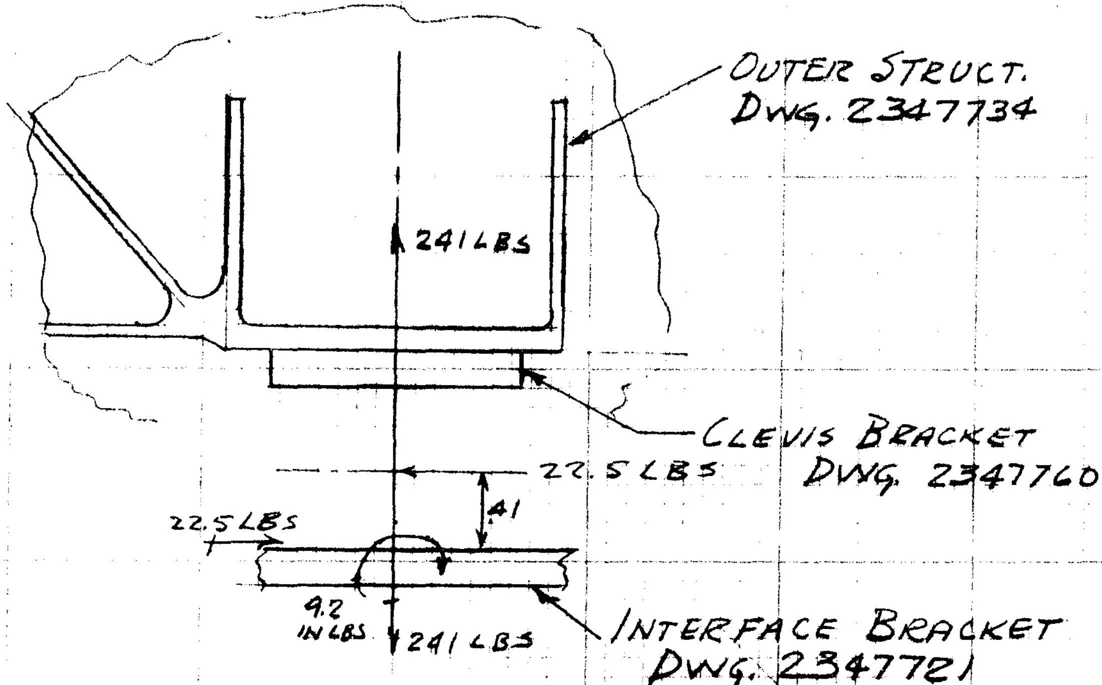
$P = \frac{1215}{.313/3} = 11620 \text{ LBS}$ $\quad w \times .313/2 = 11620$ $\quad w = 74300 \text{ LBS/IN}$

$\sigma_{br} = \frac{74300}{.798} = 93200$ $\quad M.S. = \frac{120000}{93200} - 1 = .29$

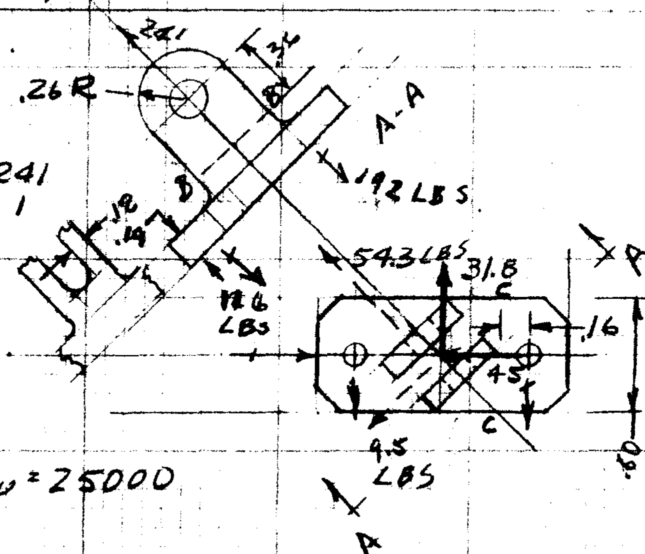
RIVETS 20613-C4 MATERIAL CRES $F_{SU} = 65000 \text{ PSI}$

$P = \frac{135}{1.2 \times 2} = 56.2 \text{ LBS}$ M.S. AMPLE

LUNAR EJECTA AND METEORITE EXPERIMENT
OUTER FIBERGLASS STRUCTURE ~ CLEVIS BRACKET DETAIL TO INTERFACE BRACKET (REF. PAGE 11)



CLVIS BRACKET ANALYSIS
DWG. 2347760



MATERIAL:-
FIBERGLASS LAMINATE PER-MIL-P-25241
TYPE II CLASS I
GLASS FIBER BASE -TYPE I CLASS 2
CLOTH BASE NO. 112

SECT. B-B

B.M. = .36 × 54.3 = 19.6 IN. LBS.

$\sigma_b = \frac{6 \times 19.6}{.52 \times .12^2} = 15700$ PSI ASSUME $F_{bu} = 25000$

$M.S. = \frac{25000}{15700} - 1 = .60$

SECT. C-C

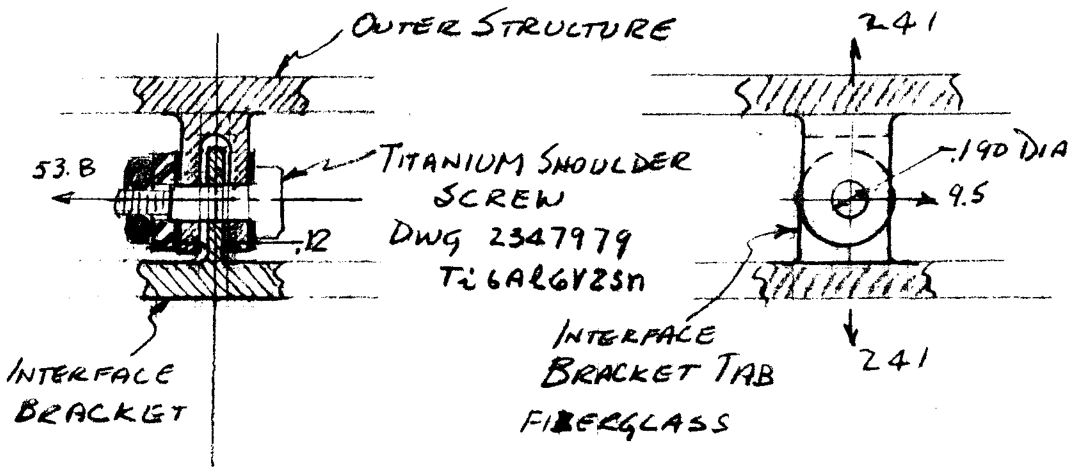
B.M. = 192 × 16 = 30.6 IN LBS $\sigma_b = \frac{30.6 \times 6}{.6 \times .19^2} = 8470$ PSI M.S AMPLE

OTHER AREAS OBVIOUSLY SATISFACTORY.

LUNAR EJECTA AND METEORITE EXPERIMENT

OUTER FIBERGLASS STRUCTURE ~ HINGE PIN DETAIL

DWG 2347725 (REF. PAGE 11)



BEARING ON INTERFACE BRACKET TAB

$$\sigma_{br} = \frac{241}{.12 \times .190} = 9250 \text{ PSI} \quad \text{M.S. AMPLE}$$

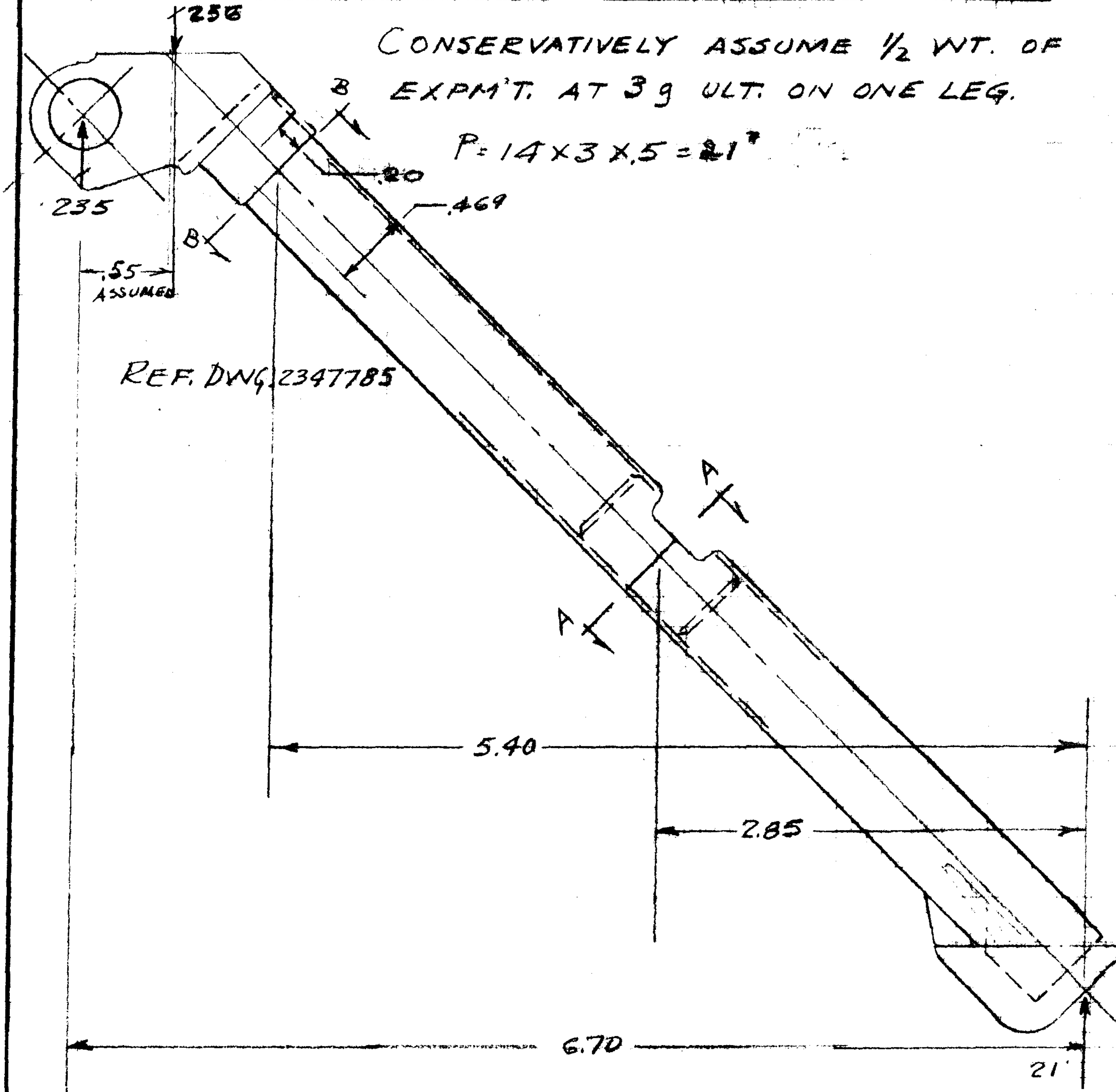
NOTE: ALL M.S.'S OBVIOUSLY HIGH

LUNAR EJECTA AND METEORITE EXPERIMENT

OUTER STRUCTURE ASSY ~ LEG & BRACKET ~ UPPER

CONSERVATIVELY ASSUME 1/2 WT. OF EXPM'T. AT 3 g ULT. ON ONE LEG.

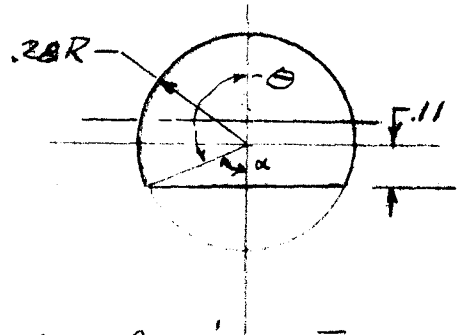
$P = 14 \times 3 \times .5 = 21^{\#}$



LUNAR EJECTA & METEORITE EXPERIMENT

OUTER STRUCTURE ASSY ~ LEG & BRACKET ~ UPPER

SECT. A-A



$B.M. = 21 \times 2.85 = 59.7''^{\#}$

MATERIAL ~ FIBERGLASS
PER MIL-P-18177 TYPE GEB

$F_b = 35000$ PSI

$\alpha = 66°50'$

$\theta = 113°10'$

$\bar{a} = K_2 R = .224 \times .28 = .063$

$I_8 = K_4 R^4 = .135 \times .28^4$

$= .000832$

REF SAWE WT. HDBK PG 1.76

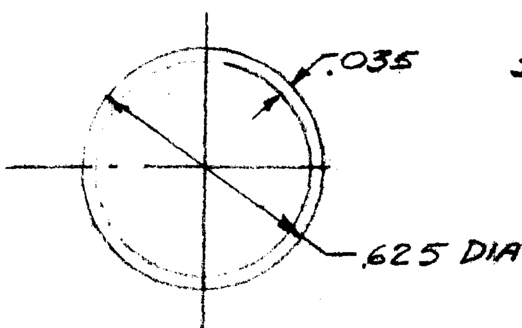
$\sigma_b = \dfrac{59.7 \times .217}{.000832} = 15600\ \#/\square''$

$M.S. = \dfrac{35000}{15600} - 1 = 1.24$

SECT B-B

MATERIAL ~ FIBERGLASS PER MIL-P-18177 TYPE GEB

$F_b = 35000$ PSI



$S = .0091$

$B.M. = 21 \times 5.40 = 113.5''^{\#}$

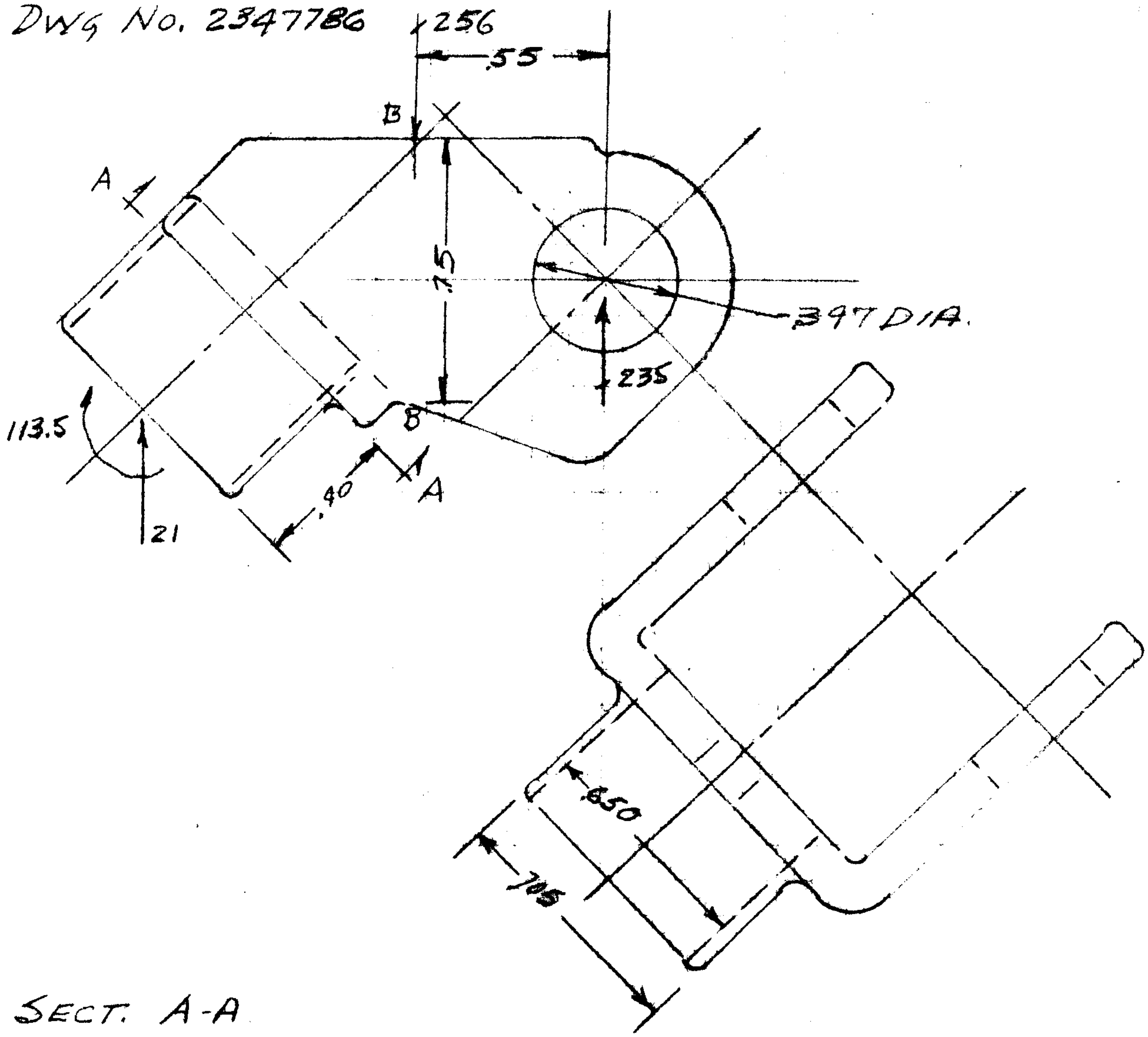
$\sigma_b = \dfrac{113.5}{.0091} = 12450\ \#/\square''$

$M.S. = \dfrac{35000}{12450} - 1 = 1.81$

LUNAR EJECTA & METEORITE EXPERIMENT

OUTER STRUCTURE ASSY. ~ CLEVIS FITTING - UPPER

DWG NO. 2347786



SECT. A-A

$A = .0597 \quad I = .00334$

$B.M. = 113.5 + 21 \times .40 \times .707 = 113.5 + 5.9 \cong 119.4$

$\sigma_b = \frac{119.4 \times .353}{.00334} = 12620\ \#/\square''$ $\qquad F_b = 1.2 \times 42000 = 50300$

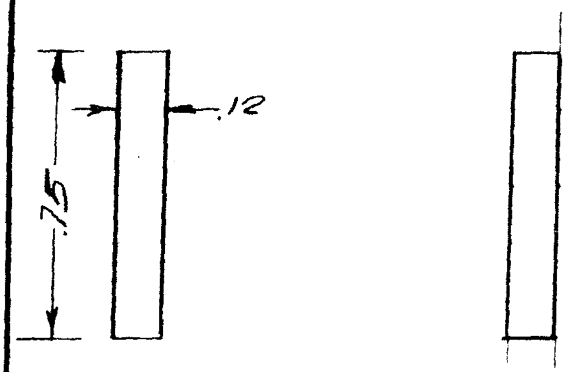
REF. MIL-HDBK 5A

$M.S. = \frac{50300}{12620} - 1 = 2.99$

LUNAR EJECTA & METEORITE EXPERIMENT

OUTER STRUCTURE ASSY. ~ CLEVIS FITTG - UPPER

SECT. B-B



$$B.M. = 235 \times .55 = 129.5$$

$$\sigma_b = \frac{6 \times 129.5}{.12 \times 2 \times .75^2} = 5750\ \#/\square''$$

M.S. = AMPLE

PIN BEARING

$$\sigma_{br} = \frac{235}{.12 \times 2 \times .397} = 2460\ \#/\square''$$ M.S. AMPLE

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LUNAR EJECTA AND METEORITE EXPERIMENT

OUTER STRUCTURE ASSY. ~ LEG & BRACKET ~ LOWER

DWGS. 2347799
2347797

CONSERVATIVELY ASSUME 1/2 WT. OF EXP'M'T. AT 3g ULT. ON ONE LEG

$P = 15 \times 3 \times .5 = 22.5^{\#}$

TUBE ANALYSIS - SECT A-A

$B.M. = 22.5 \times 5.25 = 118.5$ IN.LBS.

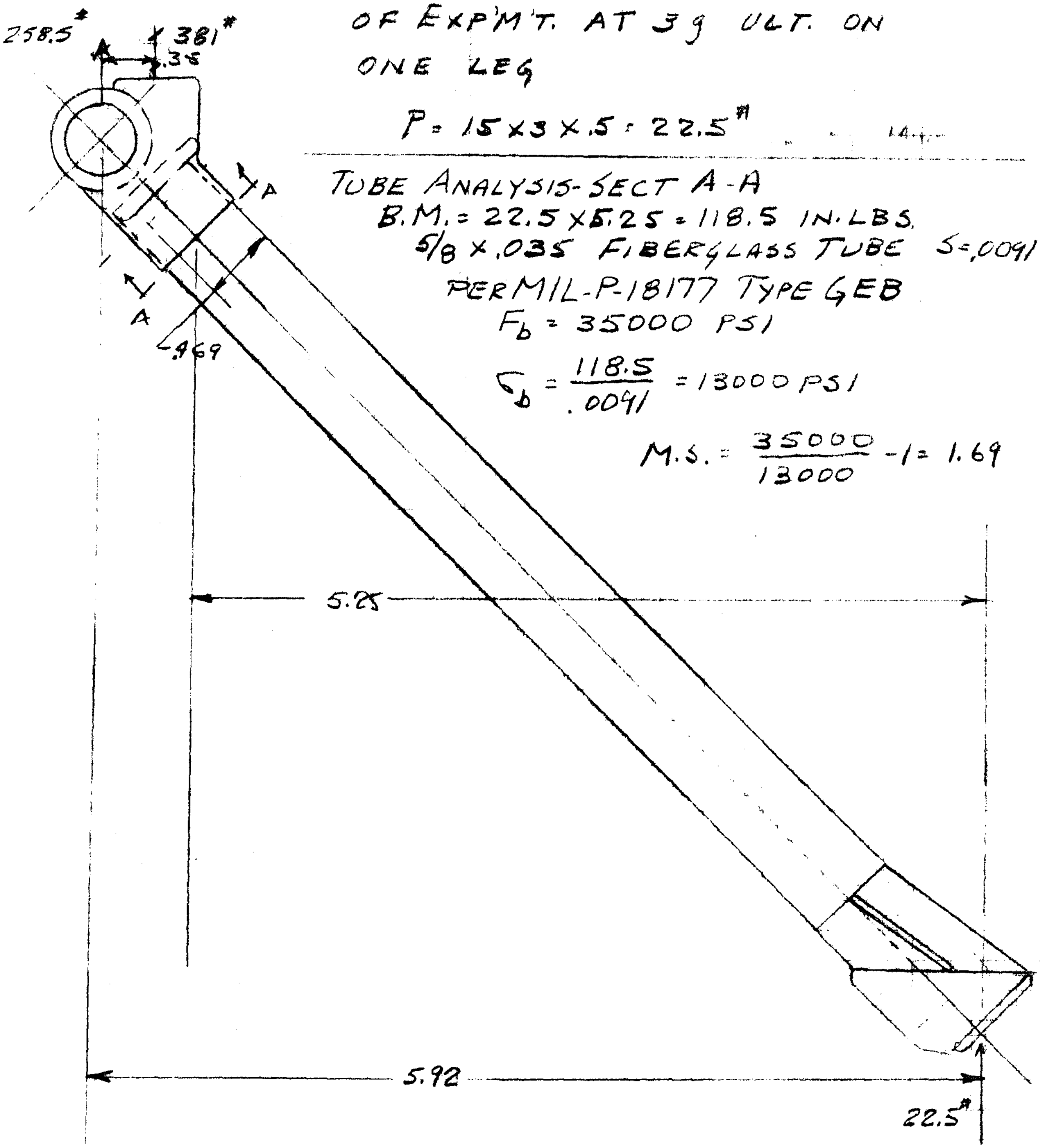
5/8 × .035 FIBERGLASS TUBE $S = .0091$

PER MIL-P-18177 TYPE GEB

$F_b = 35000$ PSI

$$\sigma_b = \frac{118.5}{.0091} = 13000 \text{ PSI}$$

$$M.S. = \frac{35000}{13000} - 1 = 1.69$$



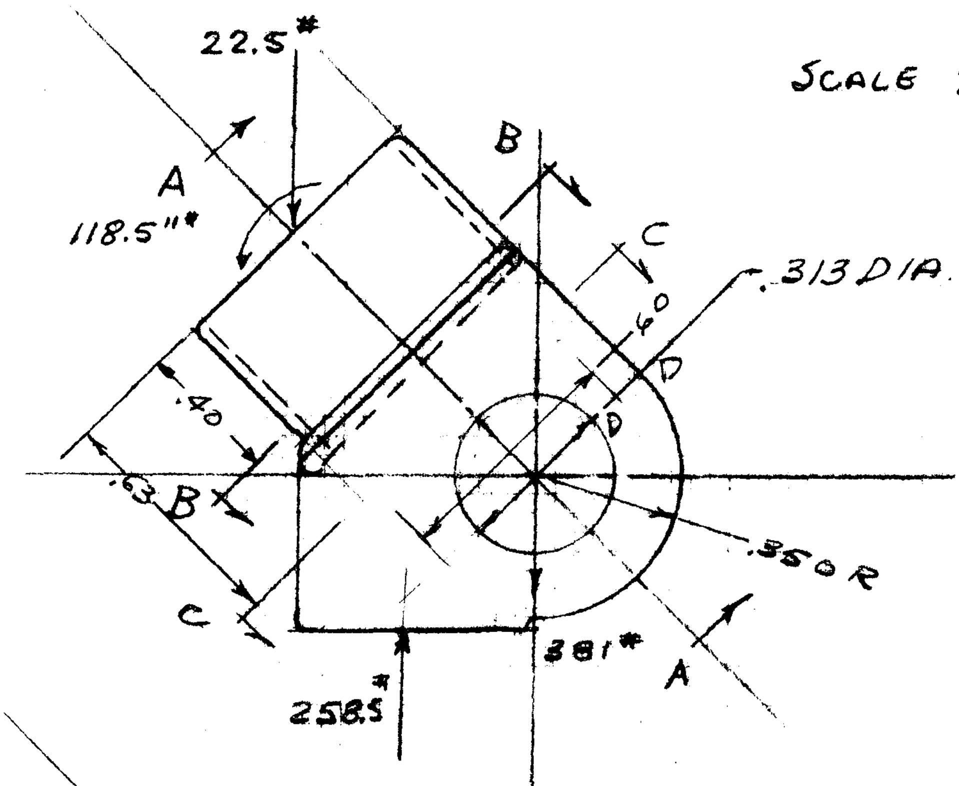
BxA 542

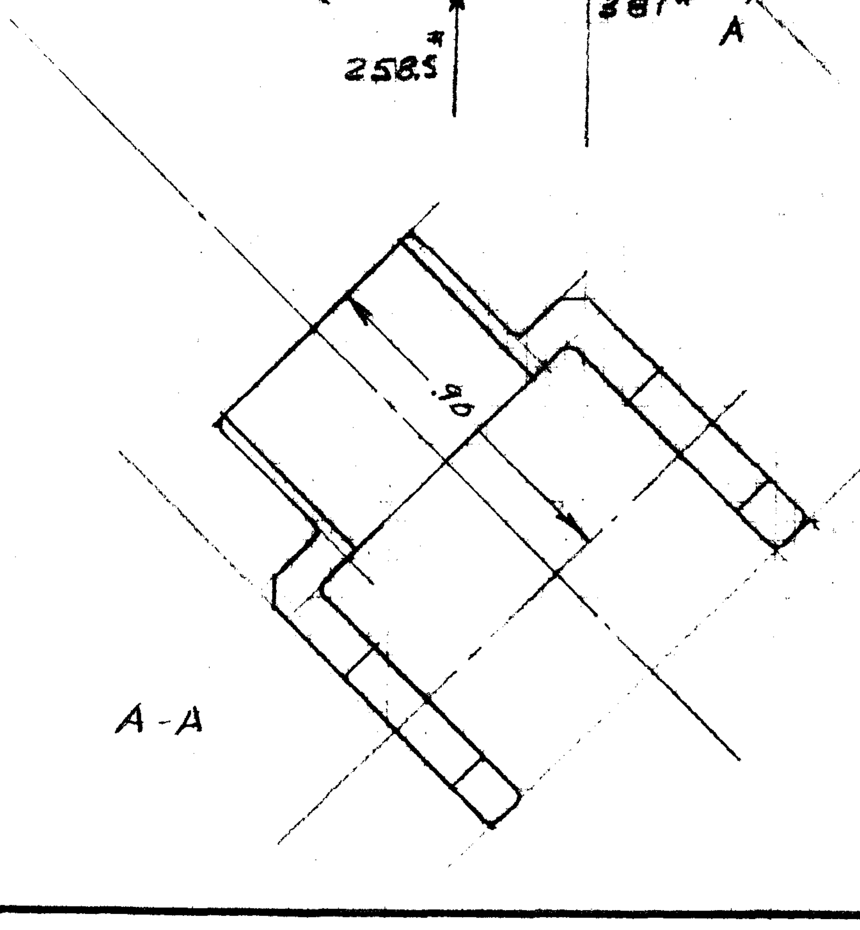
LUNAR EJECTA & METEORITE EXPERIMENT

OUTER STRUCTURE ASSY. ~ CLEVIS FITTING - LOWER

DWG. 2347797

SCALE 2:1



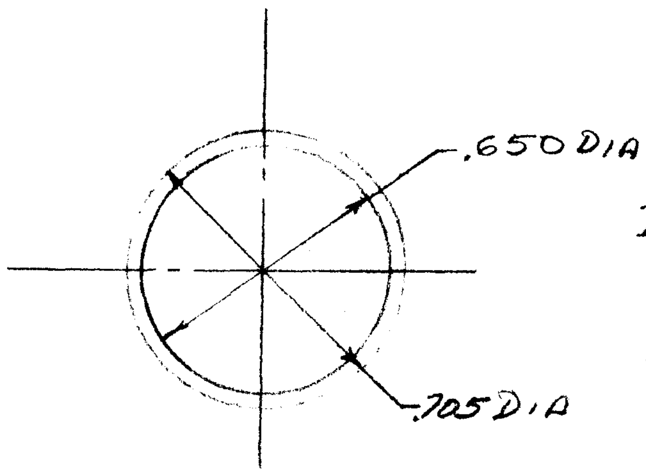


A-A

LUNAR EJECTA & METEORITE EXPERIMENT

OUTER STRUCTURE ASSY ~ CLEVIS FITTING - LOWER

SECT. B-B



$$A = \left[\left(\frac{.705}{2}\right)^2 - \left(\frac{.650}{2}\right)^2\right]\pi$$

$$= (.1245 - .1055)\pi = .0597$$

$$I = \left[.705^4 - .650^4\right]\frac{1}{64}\pi$$

$$= \left[.247 - .179\right]\frac{\pi}{64} = .00334$$

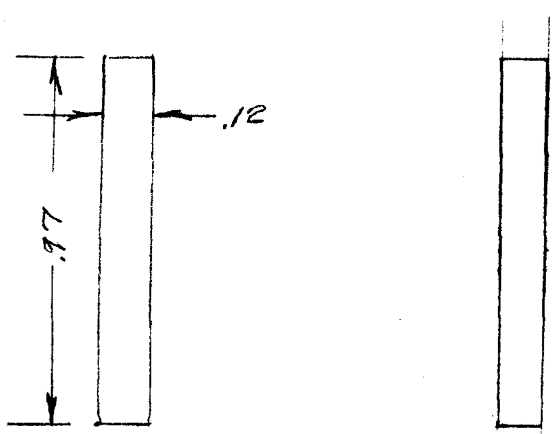
$$D/t = .705/.0275 = 25.6$$

$$B.M. = 118.5 + 22.5 \times .707 \times .40 = 118.5 + 6.4 = 124.9$$

$$\sigma_b = \frac{124.9 \times .353}{.00334} = 13100 \text{ \#/}\square'' \qquad F_b = 1.2 \times 42000 = 50300$$

$$M.S. = \frac{50300}{13100} - 1 = 2.75$$

SECT. C-C



$$B.M. = 118.5 + 22.5 \times .707 \times .63$$

$$= 118.5 + 10 = 128.5$$

$$\sigma_b = \frac{6 \times 128.5}{.12 \times 2 \times .97^2} = 3420 \text{ \#/}\square''$$

M.S. = AMPLE

LUNAR EJECTA AND METEORITE EXPERIMENT

OUTER STRUCTURE ASSY. ~ CLEVIS FITTING - LOWER

PIN BEARING

$$\sigma_{br} = 381/.12 \times 2 \times .313 = 5100\ \#/\square'' \qquad M.S. = AMPLE$$

TENSION AT D-D

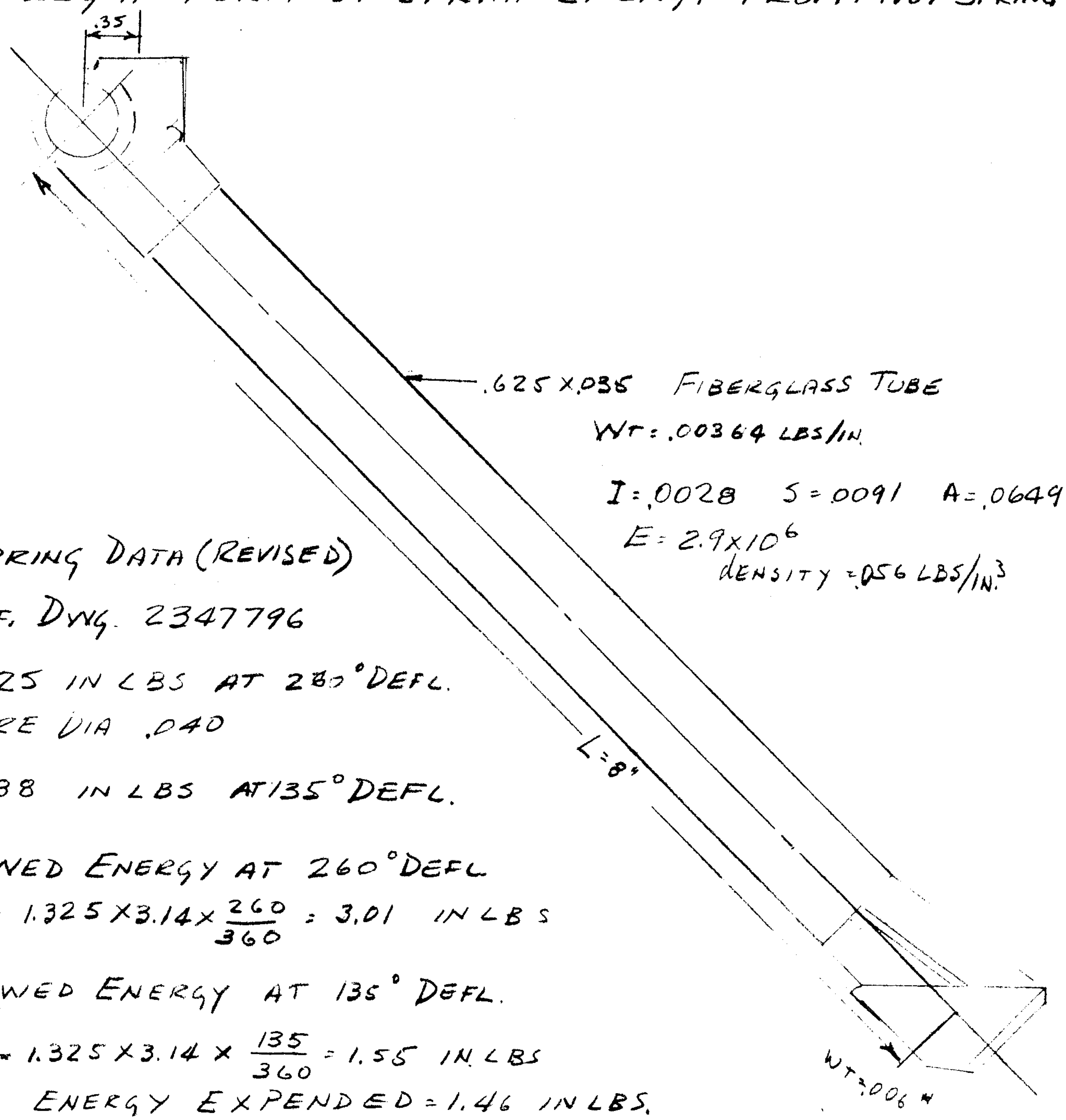
$$M = 118.5 + 22.5 \times .707 \times .9 = 118.5 + 14.3 = 132.8''\#$$

$$\sigma_t = \frac{132.8}{.6 \times .12 \times 2 \times .201} = 4580\ \#/\square'' \qquad M.S. = AMPLE$$

LUNAR EJECTA & METEORITE EXPERIMENT
LEG, PIVOT BRACKET, & BACK-UP STRUCTURE

INVESTIGATION OF DEPLOYMENT WITH 1.375 IN LBS STORED ENERGY.

CONSERVATIVELY ASSUME ALL ENERGY TRANSFERRED TO LEG IN FORM OF STRAIN ENERGY FROM PIVOT SPRING



SPRING DATA (REVISED)

REF. DWG. 2347796

1.325 IN LBS AT 280° DEFL.

WIRE DIA .040

.688 IN LBS AT 135° DEFL.

STOWED ENERGY AT 260° DEFL

$$1.325 \times 3.14 \times \frac{260}{360} = 3.01 \text{ IN LBS}$$

STOWED ENERGY AT 135° DEFL.

$$= 1.325 \times 3.14 \times \frac{135}{360} = 1.55 \text{ IN LBS}$$

ENERGY EXPENDED = 1.46 IN LBS.

LUNAR EJECTA & METEORITE EXPERIMENT
LEG, PIVOT BRACKET, ETC (CONT'D)

STRAIN ENERGY OF A BEAM IN BENDING

$$U = \frac{1}{2}\int_0^l EI[w''(x)]^2 dx$$

WHERE $W(x)$ = DEFLECTION
U = STRAIN ENERGY

ASSUME $W(x) = \frac{w_o x^2}{24EI}(x^2+6L^2-4Lx)$
(UNIFORMLY LOAD BEAM)

$$\therefore \quad W''(x) = \frac{w_o}{2EI}(x-l)^2$$

SO, $U = \frac{w_o^2}{8EI}\int_0^l (x-l)^4 dx = \frac{w_o^2 l^5}{40EI}$

THEN: $w_o = \sqrt{\frac{40UEI}{l^5}}$

FIND MAX STRESS DUE TO BENDING :

$$\sigma = \frac{Mc}{I}$$

$$\text{MAX } M = \frac{w_o l^2}{2} \quad \text{(AT BASE)}$$

$$\sigma_{max} = \frac{y}{2}\sqrt{\frac{40UE}{Il}}$$

$U = 1.375$ IN lb
$I = 2.8 \times 10^{-3}$ IN^4
$y = .3125$ IN
$l = 8$ IN
$E = 2.9 \times 10^6$ psi

LUNAR EJECTA & METEORITE EXPERIMENT
LEG, PIVOT BRACKET, ETC (CONT'D)

$$\sigma_{max} = \frac{.3125}{2}\sqrt{\frac{40(1.375)(2.9)\times10^{6}}{2.8\times10^{-3}(8)}}$$

$$f_b = \sigma_{max} = 13{,}200 \text{ psi}$$

$$F_b \cong 22{,}000 \text{ psi} \qquad S.F. = \frac{F_b}{f_b} = 1.67$$

FOR CHANGE OF U TO 1.46 IN-LB/SPRING (2 SPRINGS)

$$f_b = 13200\sqrt{\frac{1.46(2)}{1.375}} = 19{,}100 \text{ psi}$$

FOR CHANGE TO 2024 ALUM ALLOY TUBING:

$$\frac{D}{t} = \frac{.625}{.035} = 17.8 \qquad \frac{F_b}{F_{tu}} = 1.1 \text{ (REF MIL HDBK 5A SECT 3.4.1.1)}$$

$$F_b = 64{,}000 \times 1.1 = 70{,}500 \text{ psi}$$

ΔE's:

$$F_b = 70{,}500 \times \frac{3.2\times10^{6}}{10.7\times10^{6}} = 21{,}000 \text{ psi}$$

$$\therefore \quad M.S. = \frac{21000}{19{,}100} - 1 = 0.10$$

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

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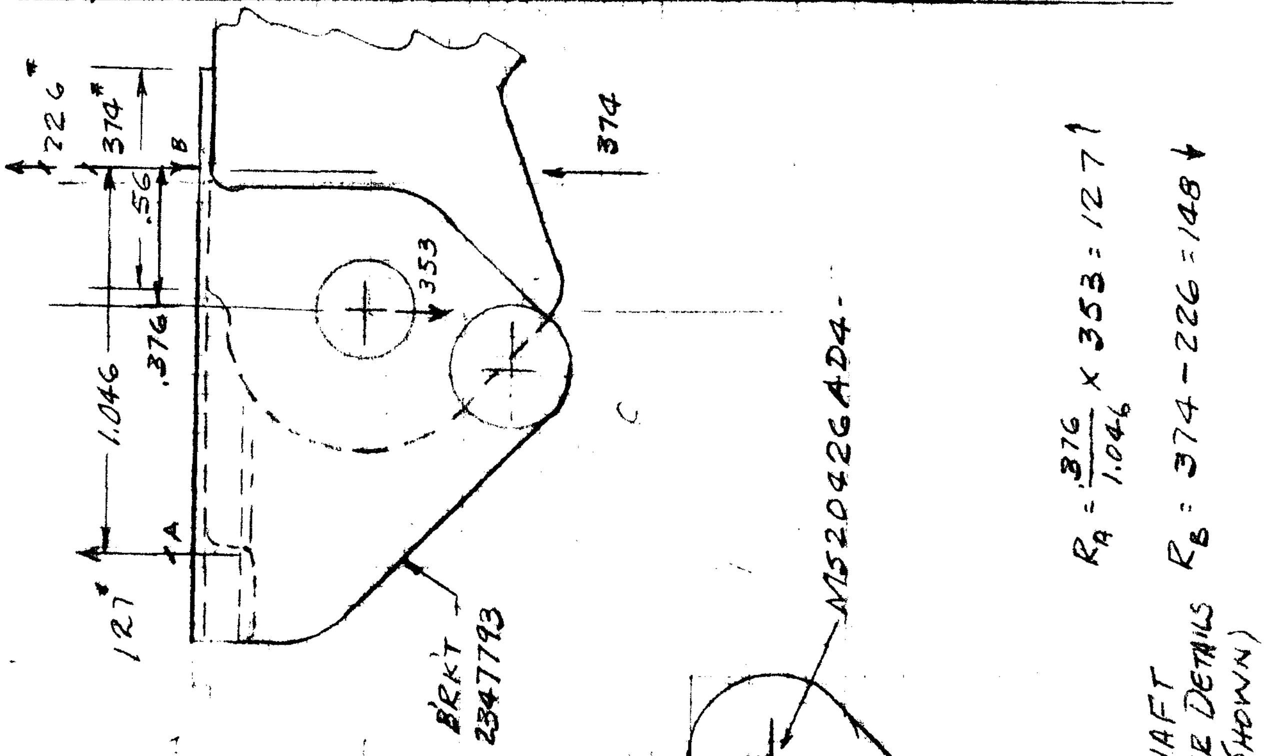
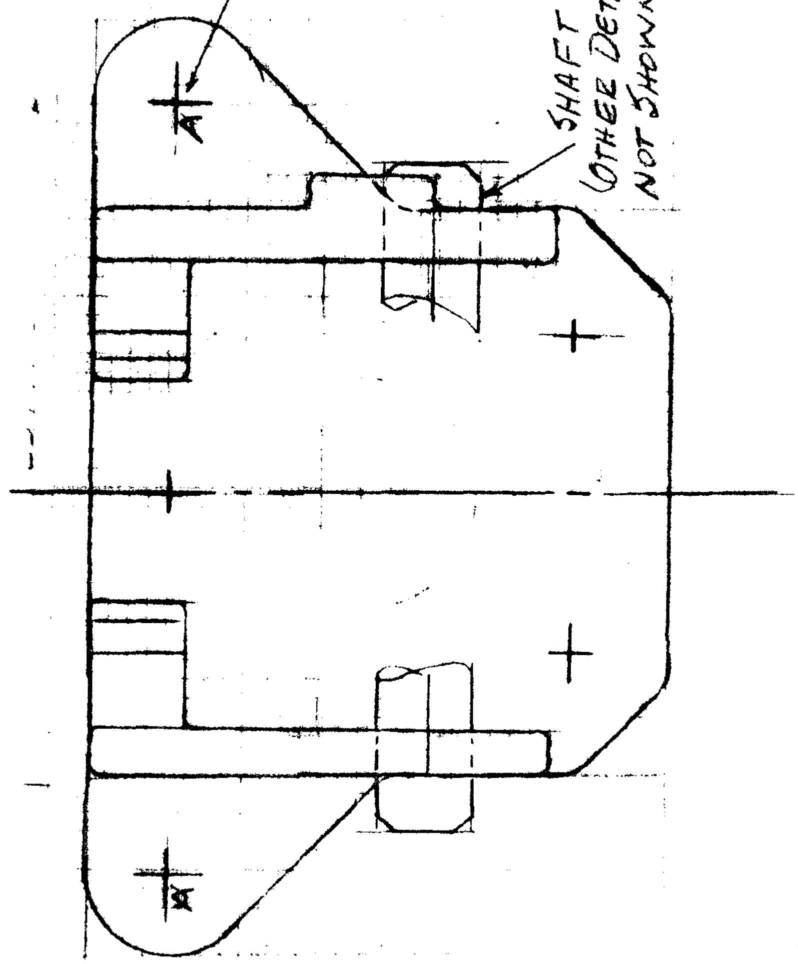
LUNAR EJECTA & METEORITE EXPERIMENT

LEG ATTACHMENT TO PIVOT BRACKET DETAIL





NOTE:-

ALL MARGINS OF SAFETY ARE HIGH ON THIS FITTING AND NO ANALYSIS IS SHOWN

MATERIAL:

2024T4 AL. ALLOY

BxA 542

APPENDIX

This appendix includes items not directly connected with structural integrity of the LEAM experiment, but reports of work conducted by the Engineering Mechanics Group to assure satisfactory transportation, deployment, and operation of the LEAM experiment.

The studies consist of the following:

(1) An investigation of socket design and deployment loads together with a recommended method of release to ensure quick and efficient deployment of the experiment.

(2) An investigation of the quartz impact plates as to possible causes of cracks, and recommendations as to what could be done to alleviate the situation.

22 June 1971 Reference: 71-210-402

To: P. Pilon

From: J. H. Owens, Jr.

Subject: LEAM UHT Socket Design Loads

References:

(1) ALSEP Array E CDR 15 - 18 June 1971 Chit No. LEAM-CDR-1 LEAM UHT Socket

(2) "Force Emission Capability of the Suited Astronaut", Letter No. 9783-951-009, A. J. Micocci to J. Owens 4/14/71

(3) "Mechanical Engineers Handbbok", 4th Edition, Lionel S. Marks, Editor; McGraw-Hill

(4) California Testing Laboratories, Inc., Los Angeles, California Tension Tests of Ball-Lok Quick Release Pins.

This memorandum is in answer to the second part of reference (1) which states that "BxA shall provide MSC with UHT Socket Design Loads". In defining "design loads", it should be emphasized that there are three separate sets of loads with which we should concern ourselves.

(a) Operational loads: These are the loads which the astronaut must use to deploy the experiment. These are based on the normal operating forces. Every effort is made to keep the applied loads which the astronaut must exert well within his capabilities. (Pages A4-A6)

(b) Limit and Ultimate Design Handling Loads: These are the maximum loads the astronaut can apply on the handle of the UHT tool (Ref. 2). Limit loads are the loads from Ref. 2. Ultimate loads are for failure analysis and include an additional 1.5 factor of safety.

(c) Flight loads: These are the loads experienced during launch, boost and lunar descent, and are small for the socket.

In the existing design, release pin deployment loads have been drastically reduced from the DVT by changing the position of the quick release pin so that when the ball locks are released the unbalanced moment of the experiment weight causes the experiment to rotate while the astronaut supports the experiment with the UHT. This is shown in Figure 1. Further details of this release system are shown in detail A and section A-A on pages following Figure 1.

The following additional features of the design are emphasized:

(1) The moment arm between separation point C and pivot point B has been approximately doubled thus reducing separation force.

(2) The pin axis is normal to the radius BC so that separation faces release freely.

(3) The pin has been mounted on the inner side of the socket in approximate alignment with the lateral C.G. This should eliminate any possible lateral moment on the pin.

(4) A pin retainer mounted on the experiment housing has the pin hole countersunk to give a better bearing face for the pin balls. This results in a force component tending to push the balls toward the center of the pin, making separation more positive at release. This was done after consultation with the pin manufacturer.

(5) The pin hole has been elongated in the vertical direction to eliminate some sliding friction on the retainer. With this it was necessary to insure that balls were horizontal by providing a non-rotating feature on the pin handle.

With this design, upon applying force to the pull pin ring, the experiment should rotate freely. The manufacturer states the necessary spring force on the ring for release to be 3 to 5 pounds. This will increase slightly to overcome ball bearing forces as shown by the friction calculations included on the page with Section A-A. In flight the only force on this pin is the very slight unbalanced force of the socket. The writer has test data showing this pin having a tension strength of 500 pounds. (Ref. 4).

Figure 2 are diagrams showing the ultimate loads used for stress analysis of the socket. Detail analysis of these parts will be included in the final stress analysis.

J. H. Owens Jr.

J. H. Owens, Jr.

LUNAR EJECTA AND METEORITE EXPERIMENT

EXPERIMENT DEPLOYMENT LOADS

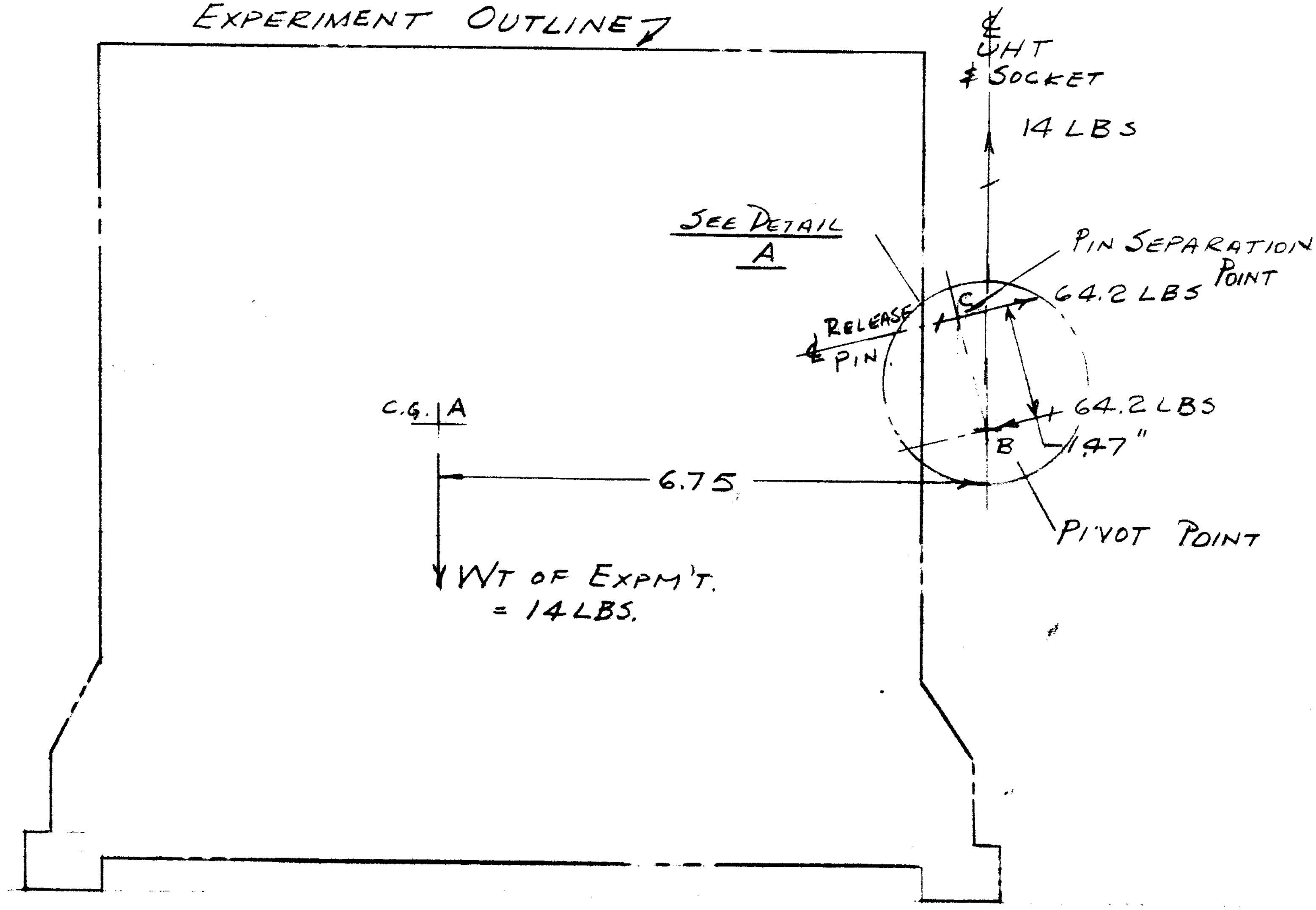
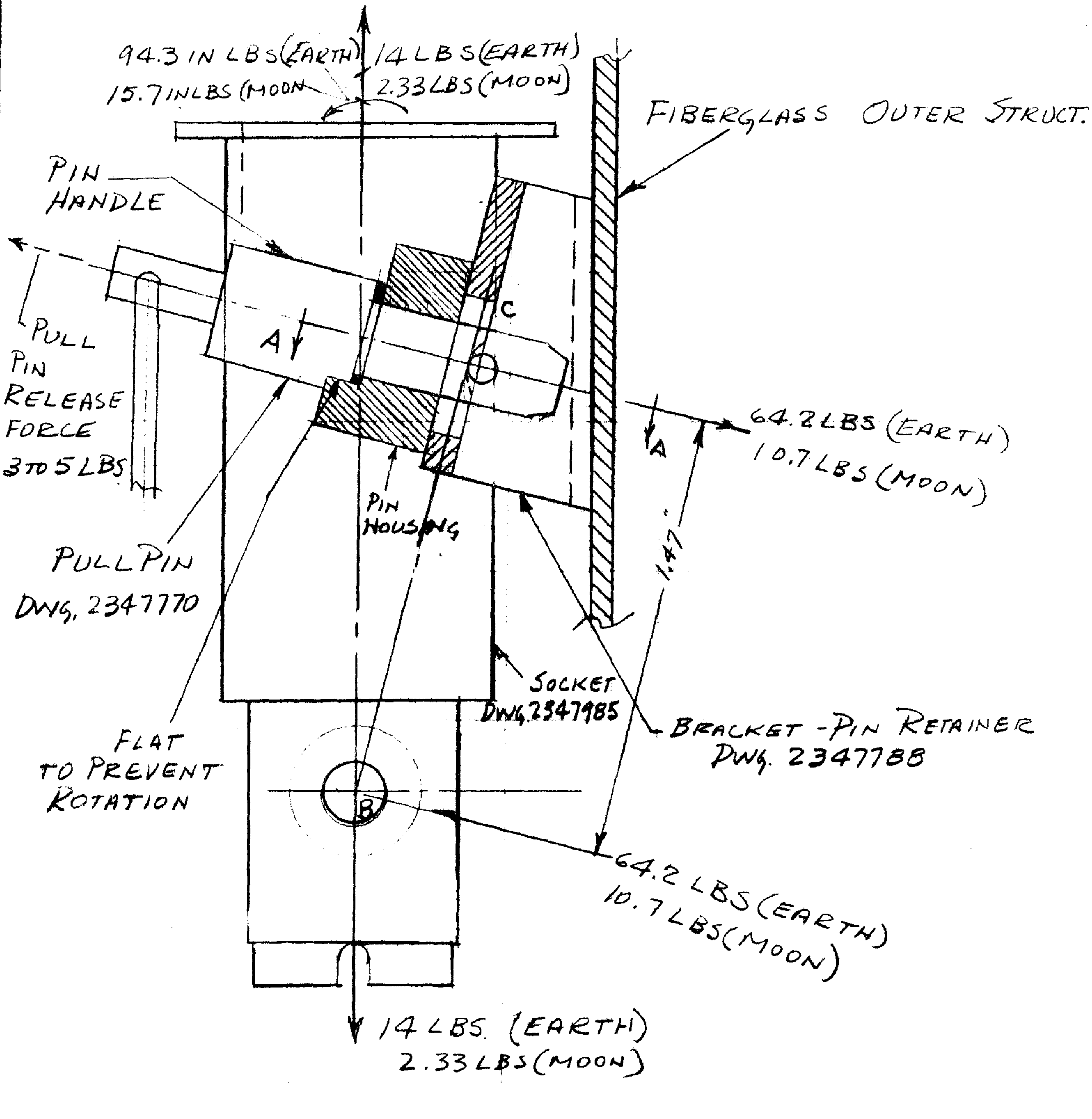


FIG. 1

LUNAR EJECTA AND METEORITE EXPERIMENT

EXPERIMENT DEPLOYMENT LOADS ON SOCKET



DETAIL A - SCALE 2/1

VIEW LOOKING OUTBOARD

ENGINEERING REPORT

Bendix Aerospace Systems Division

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

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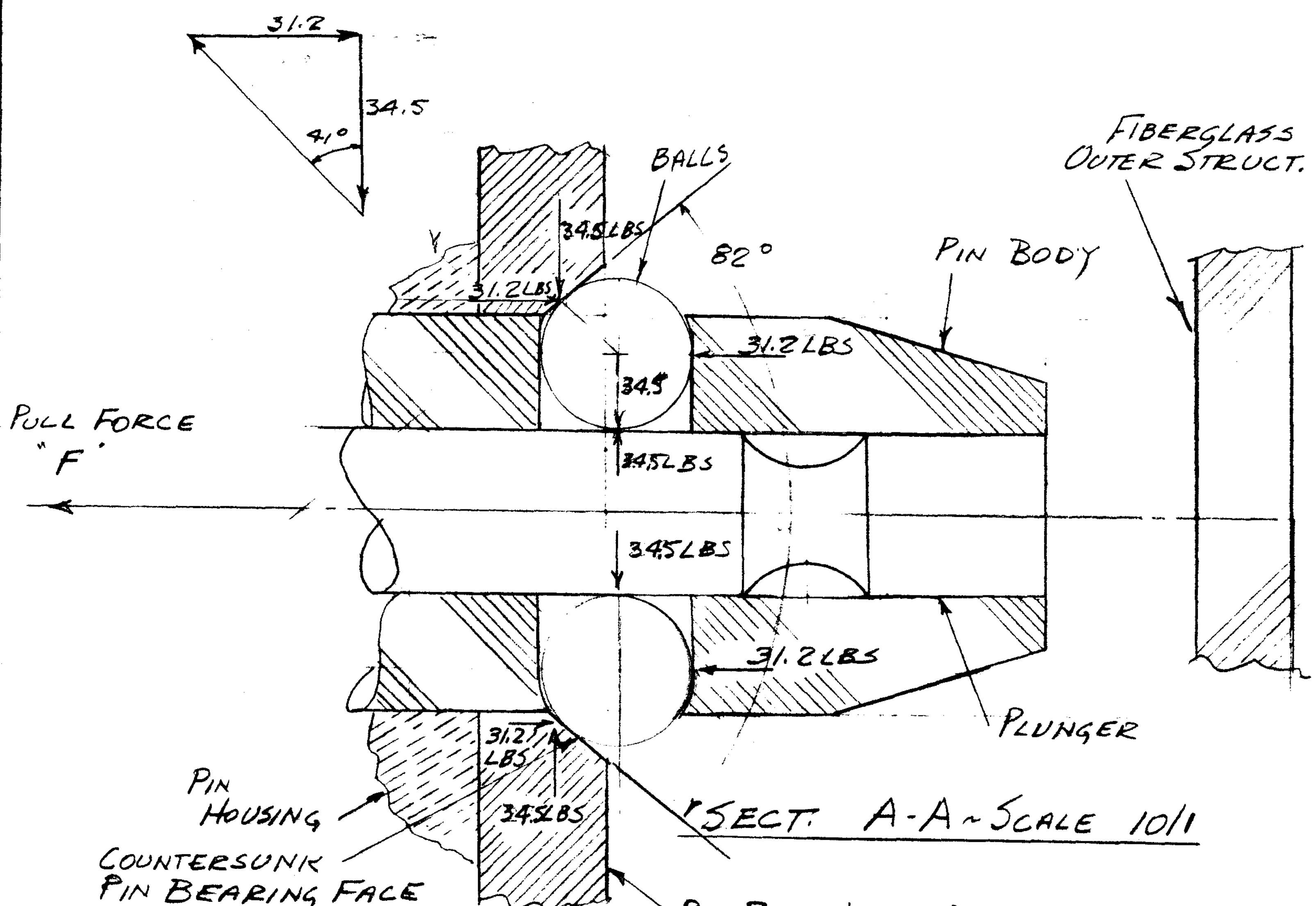
LUNAR EJECTA AND METEORITE EXPERIMENT
EXPERIMENT DEPLOYMENT LOADS ON SOCKET



$F_{MAX} = 5 \text{ LBS} + \nu \times 34.5 \times 4 = 5 + .42 = 5.42 \text{ LBS.}$

ν: COEFF. OF ROLLING FRICTION = .003 (VERY CONSERVATIVE)
REF MARKS' HANDBOOK (REF. 3)

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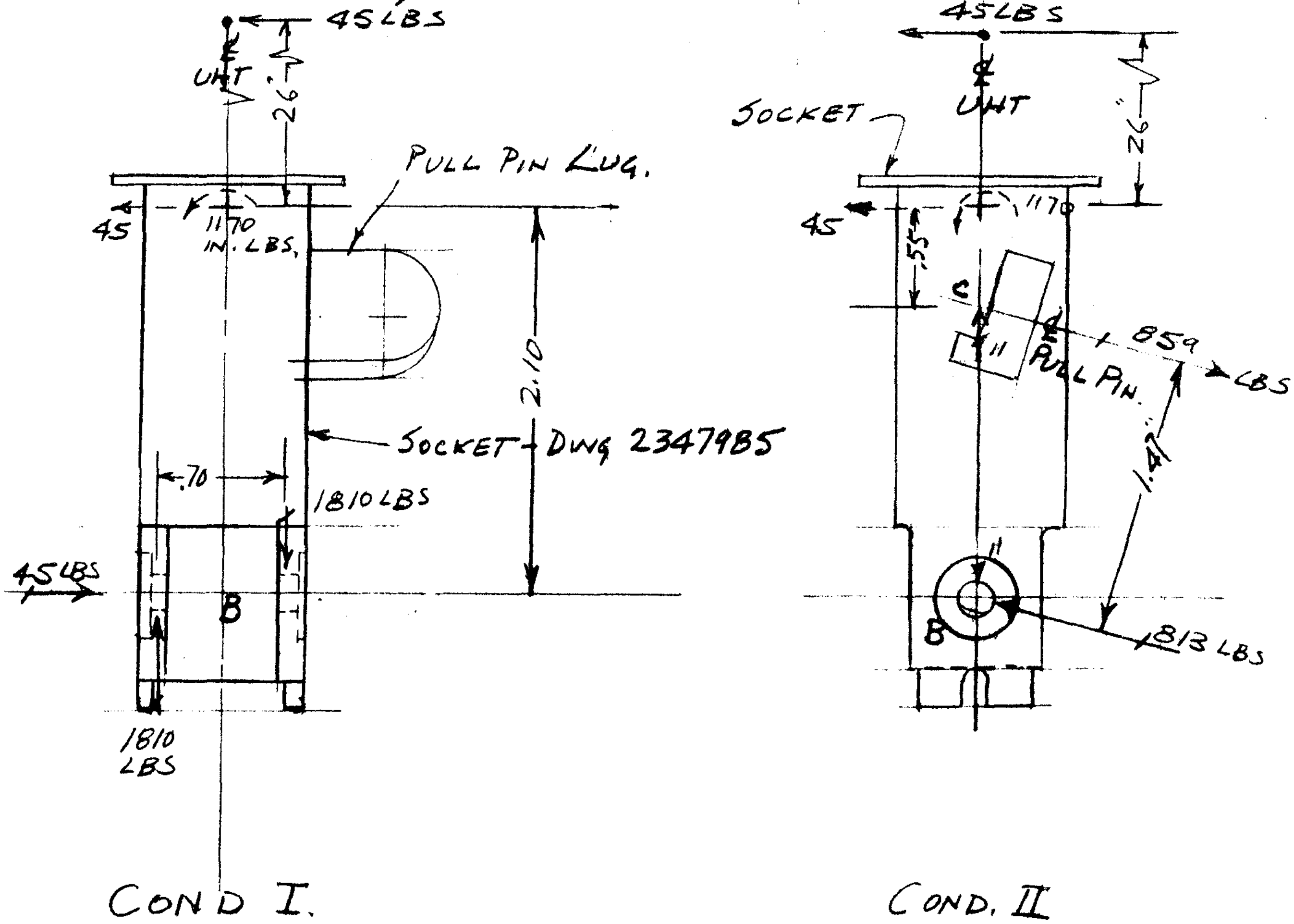
REVISED BY		MODEL LEAM

LUNAR EJECTA AND METEORITE EXPERIMENT

ULTIMATE DESIGN AND ANALYSIS LOADS ON SOCKET



LOADS SHOWN ARE BASED ON REF. (3)

FIG. 2

To: Paul Pilon, L. Galan Informal Memorandum

From: J. H. Owens, Jr.

Subject: Results of Investigation of Cracks and Fracture of LEAM Quartz Impact Plates

References:

(1) Roark, R. J. "Formulas for Stress and Strain", McGraw Hill

(2) MIL-HDBK-17A "Plastics for Aerospace Vehicles", Dept. of Defense.

(3) Oklahoma State University ERB No. 118 "Analysis of Flat Plates by the Algebra Carry Over Method"

(4) Corning Glass Works, Inc. "Engineering with Glass".

(5) MIL-HDBK-722 (MR) "Military Standardization Handbook - Glass"

(6) Machine Design July 22, 1971, "What is Fracture Mechanics".

The writer has been investigating the problem of cracks on the LEAM quartz impact plates. From ref (4) he has found that the glass used, (7940 fused silica) is a glass with a very low coefficient of thermal expansion and is used particularly for applications where a wide temperature range is anticipated. The cracks should not be due to anything inherent in the glass due to temperature variations.

However it does appear possible that stresses of a small magnitude could be built up in the glass under the epoxy bond due to differences in thermal expansion of the glass and the bond. An investigation of bonding materials might show a more desirable bonding agent.

Handling appears more likely to have caused the cracks. A small load at the top of the crystal (.6" off the plate) could induce stresses of around 10000 psi in the plate. This is high for glass.

Glass does not behave like structural materials and normal analysis procedures should be used with care. The writer would like to quote some pertinent paragraphs from Reference (5)

"17. Strength. ------ Fracture orginates at a flaw and the nominal strength of the glass is determined by the severity of this flaw. In commercial glassware the weakening flaws are of accidental origin and vary greatly in severity from piece to piece in the same group, consequently there are wide variances in measured values of their breaking stress; ------

Reference (5) also states that data corresponding to other structural materials cannot be compiled for glass; being brittle, there is no yield point, elongation, or reduction of area. "Breaking stress is not an explicit function of composition but of workmanship, that is, the severity of flaw in the particular components under consideration."

"Variances of strength are not only wide, but differ from one product to another. There is no fixed relationship between average and minimum values, so that the minimum breaking stress must be determined individually for each case considered".

From the above it is apparent that confidence cannot be placed in glass that can be placed in accepted structural materials. With this memo the writer has also included a curve from ref. (6) showing effect on stress of minute cracks in a brittle material.

The writer makes the following recommendations:

1. Support impact plate on an energy absorbing material such as foam, to the extent possible, to reduce stresses in the plate to a minimum.

2. Use best available glass.

3. Have a procedure for mounting crystal, wiring, etc., that prevents rought handling of plate.

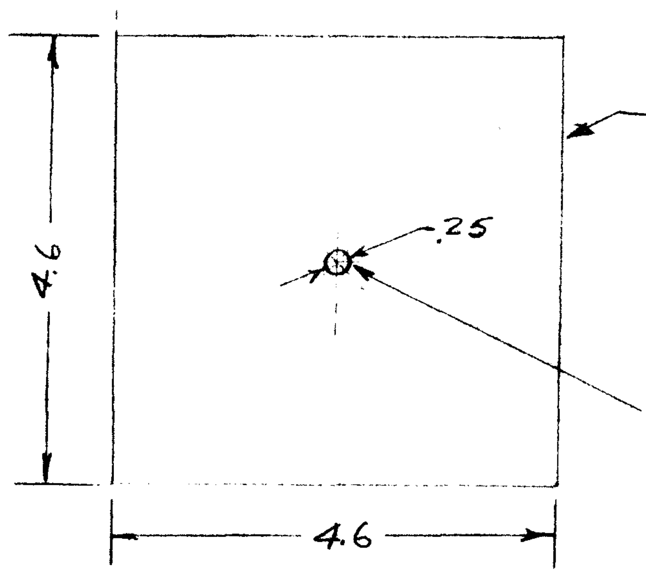
4. Carefully inspect glass microscopically in area of mounting crystal and reject those plates with minute cracks.

J. H. Owens, Jr.

J. H. Owens, Jr.

LUNAR EJECTA AND METEORITE EXPERIMENT
IMPACT PLATE INVESTIGATION

CALCULATED STRESSES & DEFLECTIONS BY CONVENTIONAL STRESS ANALYSIS PROCEDURES FOR MAX. FLIGHT LOAD.



QUARTZ PL. $t = .031$
DWG 2347912

MICROPHONE CRYSTAL
DWG 2347951
DENSITY = 7.6 g/cm³
= .275 LBS/IN³
WT. =
$.6 \times .125^2 \times 3.14 \times .275$
$= .0081$

ASSUME 30 g - DETERMINE STRESS AT CENTER OF PLATE
USING TABLE X - ROARK - "FORMULAS FOR STRESS & STRAIN"
CASE 31

$$m = \frac{1}{\nu} = \frac{1}{.16} = 6.25$$

$$\sigma = \frac{3W}{2\pi m t^2}\left[\log\frac{a}{2r_0}(m+1) + .75m\right]$$

$$= \frac{3 \times 30 \times .0081 \times 10^4}{6.28 \times 6.25 \times 9.6}\left[\log\frac{4.6}{.25}(7.25) + 4.69\right]$$

$$19.3\left[2.9124 \times 7.25 + 4.69\right] = \underline{490 \text{ PSI}}$$ (NEGLECTING WT. OF QUARTZ)

ASSUME σ_{ALLOW} = 10000 PSI (REF. CORNING GLASS HDBK)

$$M.S. = \frac{10000}{490} - 1 = 19.4$$

LUNAR EJECTA AND METEORITE EXPERIMENT

IMPACT PLATE INVESTIGATION

CALCULATED STRESSES AND DEFLECTIONS BY CONVENTIONAL STRESS ANALYSIS PROCEDURES (CONTINUED)

DEFLECTION

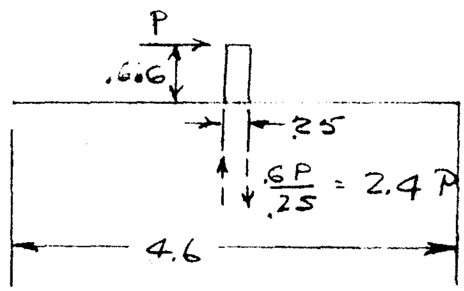
$$y = -\frac{.1391\,Wa^2(m^2-1)}{m^2 E t^3} = -\frac{.1391 \times 30 \times .0081 \times 4.6^2(6.25^2-1)}{6.25^2 \times 10.5\times10^6 \times 3.1^3\times10^{-6}}$$

$= .0069$ ULT.

$.0046''$ LIM.

DETERMINE MAX. LOAD ON SIDE OF CRYSTAL BEFORE IMMINENT CRACKING.

USE OKLAHOMA STATE UNIVERSITY BULLETIN No. 118



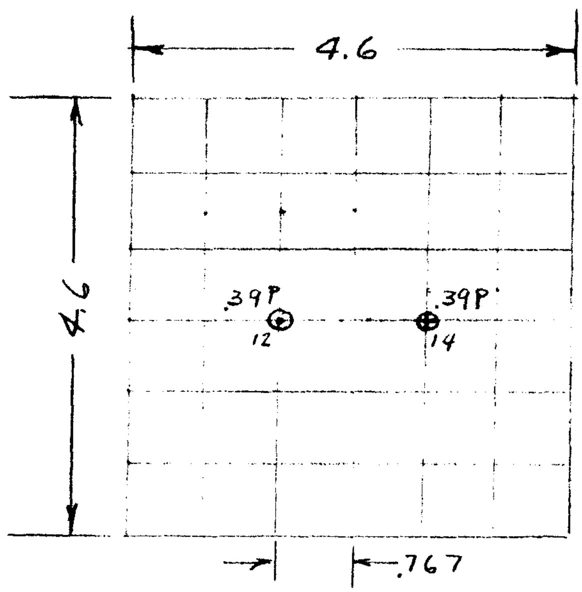
$Q = .394 - .043 = .351$

$M = .351 \times .39P = .137P$ IN LBS/IN

$\sigma_{ALLOW} = 10000$ PSI

$$\frac{6 \times .137P}{.031^2} = 10000$$

$\therefore$ $P = 11.6$ LBS



THIS IS AN APPROXIMATE VALUE. IT IS MARKEDLY AFFECTED BY THE NATURE OF THE SURFACE IN THE VICINITY OF THE CRACK.

LUNAR EJECTA AND METEORITE EXPERIMENT

IMPACT PLATE INVESTIGATION

THERMAL EFFECTS

ASSUME A QUARTZ PLATE .031" THICK $\Delta T = 200°F$

$L_0 = 4.6"$ $\alpha = 7 \times 10^{-7}$ IN/IN/°C $= 7 \times 5/9 \times 10^{-7}$ IN/IN/°F $=$

$= 3.88 \times 10^{-7}$ IN/IN/°F

$$L_{200} = 4.6 + 3.88 \times 10^{-7} \times 200 \times 4.6$$

$$= 4.6 + 3580 \times 10^{-7}$$

DETERMINE R & θ

$$4.6 = \left(R - \frac{.031}{2}\right)\theta$$

$$4.6 + 3580 \times 10^{-7} = \left(R + \frac{.031}{2}\right)\theta$$

$$\frac{4.6}{R - .0155} = \frac{4.6 + 3580 \times 10^{-7}}{R + .0155}$$

$$\cancel{4.6R} + 4.6(.0155) = \cancel{4.6R} + (3580 \times 10^{-7})R - .0155 \times 4.6$$

$$+ (-.0155)(3580 \times 10^{-7})$$

$$(-3580 \times 10^{-7})R = -.14260 - .5549 \times 10^{-7}$$

$$R = 398.3"$$

ASSUME FOR A LENGTH OF .25" PL. IS RESTRAINED FROM MOVEMENT

$$3.88 \times 10^{-7} \times \cancel{.25} \times 200.0 = \frac{\sigma}{10.5 \times 10^6} \times \cancel{.25}$$

$$\sigma = 3.88 \times 10^{-1} \times 200 \times 10.5$$

$$\sigma = 815 \text{ PSI}$$

LUNAR EJECTA AND METEORITE EXPERIMENT

IMPACT PLATE INVESTIGATION

THERMAL EFFECTS

EVALUATE EFFECT OF EPOXY AND GLASS PLATE WITH ΔT = 200° TEMPERATURE CHANGE

$\alpha_{EPOXY} = 39 \times 10^{-6}$ IN/IN/°F
$E = 4.6 \times 10^{5}$
} REF (2) MIL-HDBK17A

$\alpha_{GLASS} = .388 \times 10^{-6}$ IN/IN/°F
$E_{GLASS} = 10.5 \times 10^{6}$
} REF. CORNING GLASS HANDBOOK

ASSUME STRAIN & LOADS EQUAL

$t_{GLASS} = .031 \qquad t_{EPOXY} = .010$

$\sigma_G \times .031 = \sigma_e \times .010 \qquad \sigma_e = 3.1\sigma_G$

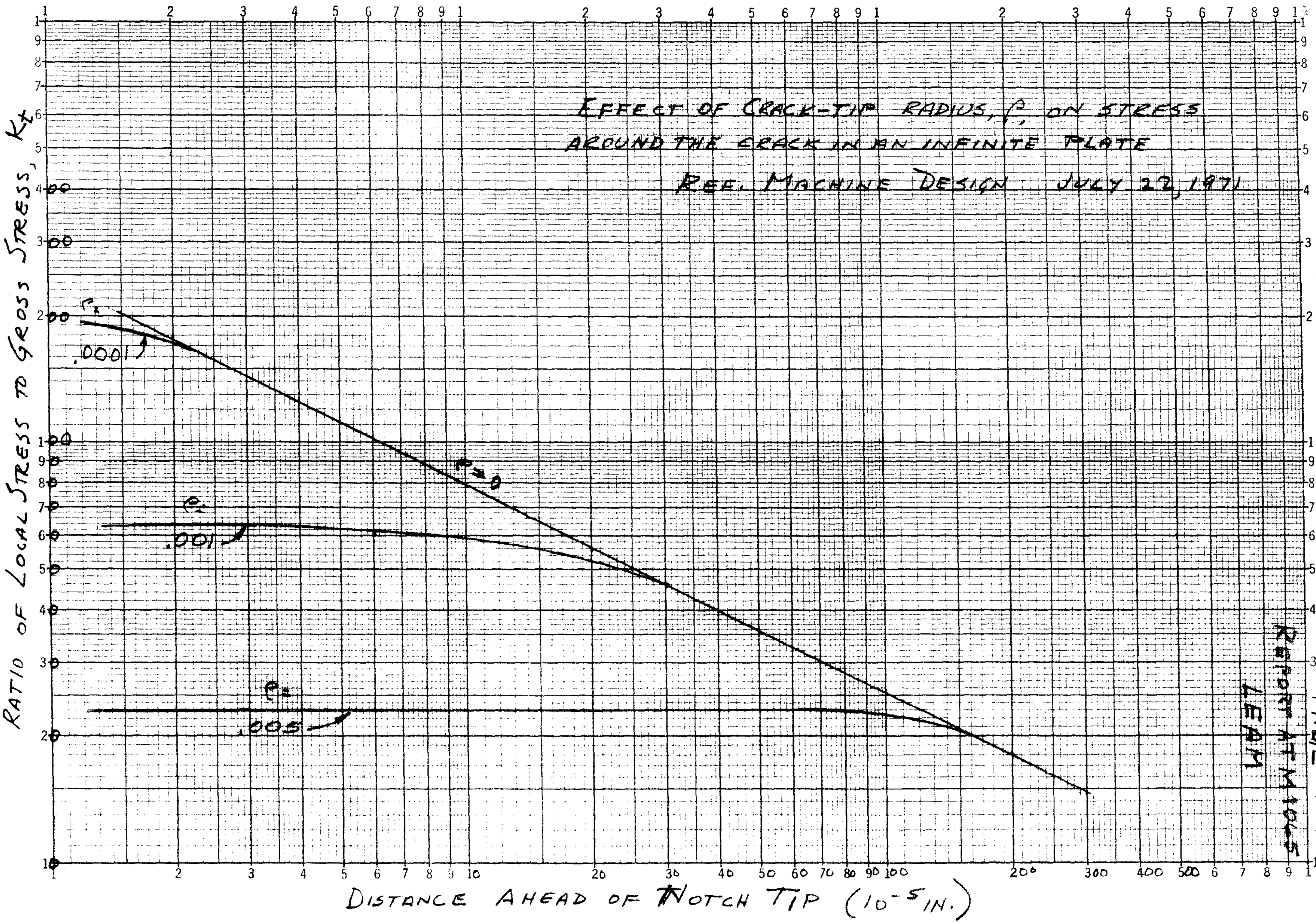
$$\alpha_e \Delta T - \frac{\sigma_e}{E_e} = \alpha_G \Delta T + \frac{\sigma_G}{E_G}$$

$$39 \times 10^{-6} \times 200 - \frac{3.1\sigma_G}{4.6 \times 10^{5}} = .388 \times 10^{-6} \times 200 + \frac{\sigma_G}{10.5 \times 10^{6}}$$

$$38.6 \times 200 \times 10^{-6} = \frac{1}{10^6}(6.72 + .0952)\sigma_G$$

$$\sigma_G = \underline{\underline{1165 \text{ PSI}}}$$

NOTE: THIS SHOWS THAT, MAKING CONSERVATIVE ASSUMPTIONS, STRESSES IN THE GLASS REMAIN SMALL WITH CHANGES IN TEMPERATURE.


EFFECT OF CRACK-TIP RADIUS, ρ, ON STRESS
AROUND THE CRACK IN AN INFINITE PLATE
REF. MACHINE DESIGN JULY 22, 1971
RATIO OF LOCAL STRESS TO GROSS STRESS, Kt
DISTANCE AHEAD OF NOTCH TIP (10^{-5} IN.)
ρ = .0001
ρ = .001
ρ = .005
ρ → 0
1
2
3
4
5
6
7
8
9
10
20
30
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50
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