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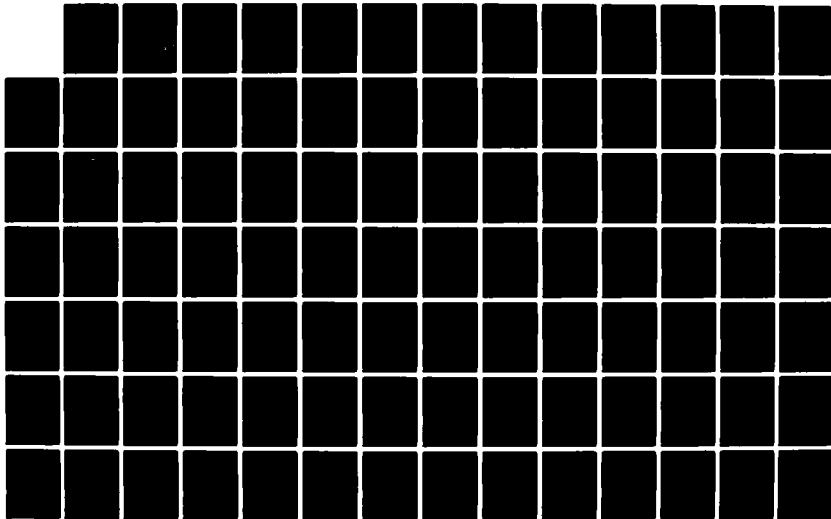
GRAPHITE COMPOSITE LANDING GEAR COMPONENTS VOLUME II
TECHNICAL APPENDICES(I) HERCULES INC MAGNA UT BACCHUS
WORKS L C JENSEN ET AL. JUN 77 AFFDL-TR-77-20-VOL-2
F33615-72-C-1725

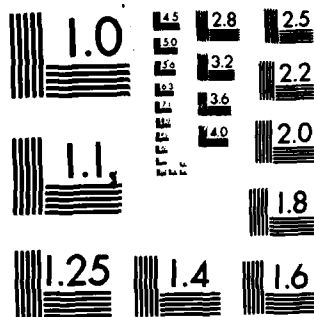
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AD A129206

AFFDL-TR-77-20
VOLUME II

FINAL REPORT GRAPHITE COMPOSITE LANDING
GEAR COMPONENTS
APPENDICES
VOLUME II

HERCULES INCORPORATED, SYSTEMS GROUP
BACCHUS WORKS, MAGNA, UTAH

JUNE 1977

TECHNICAL REPORT AFFDL-TR-77-20, VOLUME II

FINAL REPORT FOR PERIOD FEBRUARY 1973 - FEBRUARY 1977

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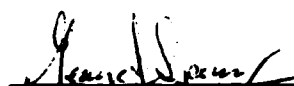
AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This technical report has been reviewed and is approved for publication.


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Vehicle Equipment Division


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Mechanical Branch
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

FOR THE COMMANDER


Ambrose B. Nutt, Director
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

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AIR FORCE/56780/25 October 1977 - 250

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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7. AUTHOR(s) L. C. JENSEN H. L. PRITT		6. PERFORMING ORG. REPORT NUMBER
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11. CONTROLLING OFFICE NAME AND ADDRESS AIR FORCE FLIGHT DYNAMICS LABORATORY/FEM WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project 1369 Task 136903 Work Unit 13690338
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18. SUPPLEMENTARY NOTES THIS FINAL REPORT IS CONTAINED IN TWO VOLUMES VOLUME I TECHNICAL DISCUSSION VOLUME II APPENDICES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
LANDING GEAR OUTER CYLINDER TRUNNION GRAPHITE EPOXY	A37B AIRCRAFT TORQUE ARM ATTACHMENT SIDE BRACE ATTACHMENT COMPOSITE MATERIAL	LANDING GEAR GEOMETRY LANDING GEAR DESIGN LOADS LANDING GEAR FABRICATION LANDING GEAR LAB TEST
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (See Reverse Side)		

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The objectives of this effort were to determine the feasibility of, and the weight and cost savings from the manufacture of a direct replacement landing gear for current Air Force aircraft which is composed of component hardware that is fabricated from graphite epoxy material to the maximum extent possible. Prior to the start of this effort, direct replacement torque arm and side brace components for the A37B aircraft landing gear had been qualified for flight use which were fabricated from epoxy materials to the maximum extent possible. Both of these components were lighter than the existing metallic components. It was projected that the fabrication cost of the side-brace in production quantities would be less than the existing metallic component. Under a separate In-House Work Unit, the graphite epoxy side brace successfully passed extensive laboratory environmental and in-service flight testing. The major task under this effort was the design, fabrication and qualification of an A37B aircraft outer cylinder/trunnion fabricated from graphite epoxy material to the maximum extent possible. After three trunnion design and fabrication iterations, the effort was terminated. Based on current graphite epoxy design and fabrication limitations, it was determined that a successful direct replacement trunnion could not now be fabricated due to existing landing gear compartment and other space limitations. The effort demonstrated that the complex trunnion could be designed and fabricated using an optimum amount of graphite epoxy material with a weight saving of 21 percent in comparison to existing metallic hardware. Potential weight and cost savings exist for the fabrication of new aircraft landing gear trunnions from graphite epoxy material, where the trunnion design is not limited by existing space limitations. Future graphite epoxy material and/or manufacturing improvements could make the fabrication direct replacement trunnion components feasible and profitable.

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FOREWORD

This report was prepared by Hercules Incorporated, Bacchus Works, Magna, Utah under United States Air Force Contract F33615-72-1725, Project 1369, Task 03, Graphite Composite Landing Gear Components. The program was administered by the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, under the direction of Gerald C. Shumaker (AFFDL/FEM).

This is Volume II, Appendices, of the final report, two volumes, covering the work performed from February 28, 1973 to February 1977. Volume I of the report contains the technical discussion. Hercules personnel directly participating on the program were:

Program Manager	L. C. Jensen
Program Engineer	H. L. Pritt
Fabrication Engineer	J. Witzel
Design Supervisor	J. N. Burns
Design Engineer	E. R. Torres
Design Engineer	R. E. Thompson

The report was submitted by the authors for publication as a Technical Report in June 1977.

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APPENDIX A
DESIGN ANALYSIS
OF
THE OUTER CYLINDER/TRUNNION AND ATTACHMENTS

APPENDIX A

PART I

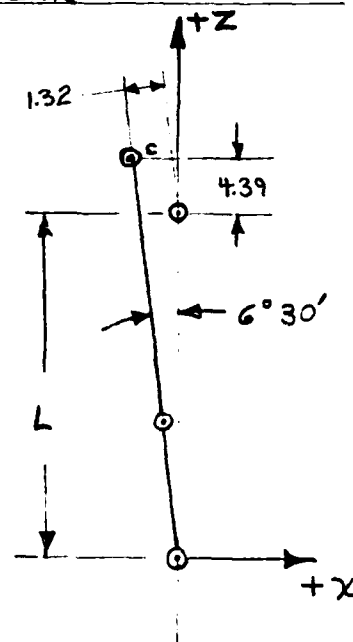
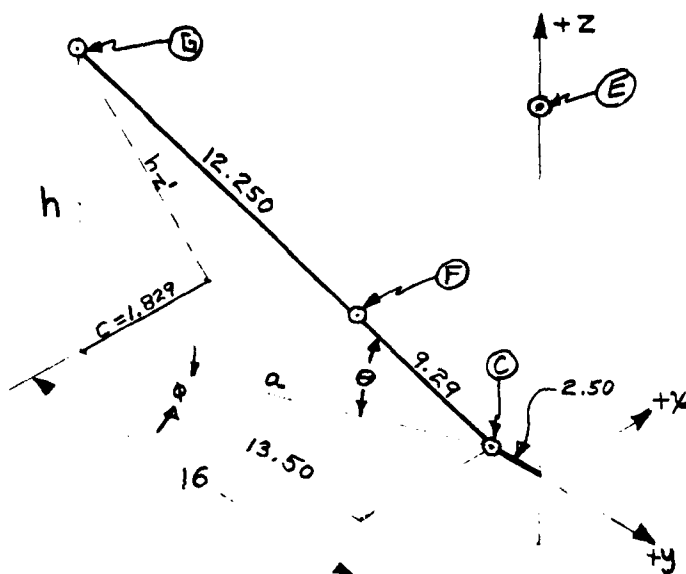
DESIGN ANALYSIS
OF
THE SIDEBRACE ATTACHMENT

HERCULES INCORPORATED
ENGINEERING DEPARTMENT

SKETCH NO. I. 2

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
 BLDG. _____ TITLE A-37 C LANDING GEAR

ORIGINAL SIDE BRACE
GEOMETRY



$$C = \frac{1.32}{\cos 6^{\circ}30'} + \tan 6^{\circ}30' (4.39) = \frac{1.32}{.9936} + .1139 (4.39) = 1.829$$

$$\tan \phi = \frac{1.829}{13.50} = .1355, \phi = 7^\circ 43'$$

$$a = \frac{13.50}{\cos \phi} = \frac{13.50}{.9909} = 13.623$$

$$\cos \theta = \frac{2}{21.54} = .632, \theta = 51^\circ 28'$$

$$h = \sin \theta (21.54) = .7823 (21.54) = 16.851 \text{ m}$$

$$L = 16 - 4.39 = 12.461 \text{ IN}$$

$$h_2' = h + \tan 6'30''(1.829) = 17.059$$

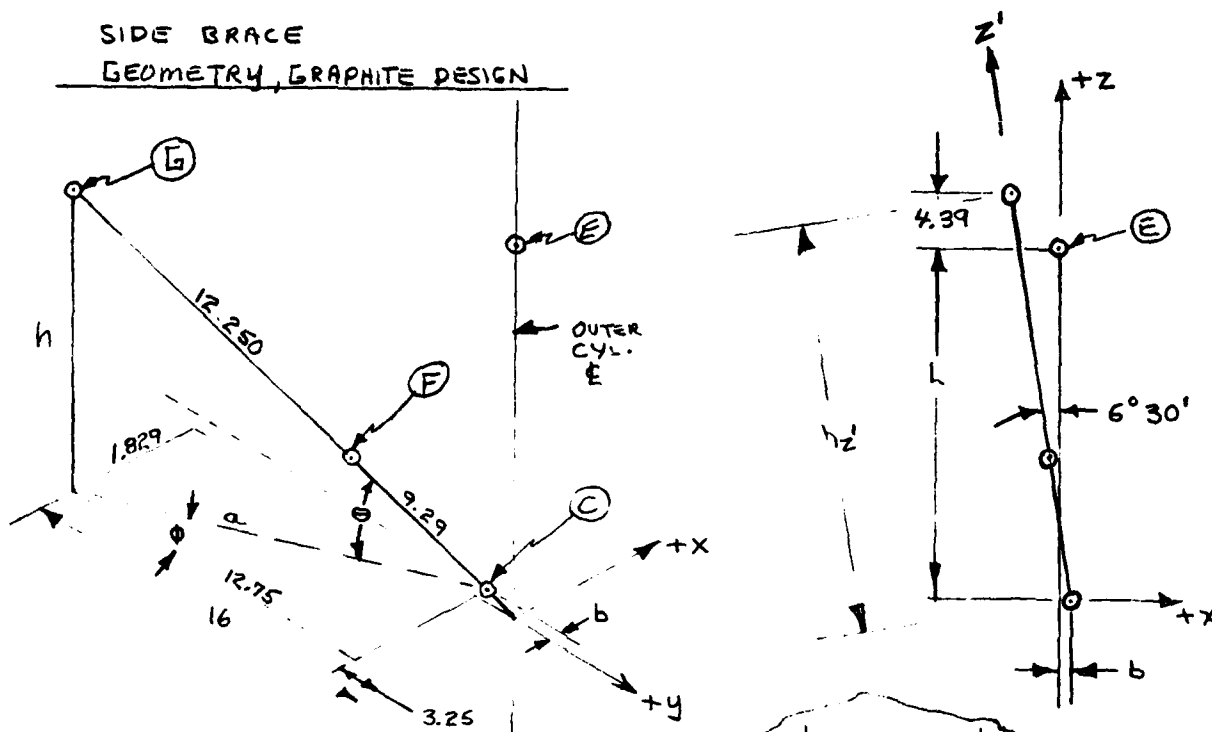
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I. 3

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JNB
BLDG. _____ TITLE A-37 B LANDING GEAR

SIDE BRACE GEOMETRY, GRAPHITE DESIGN



$$g = 16.0 - 3.25 = 12.75"$$

$$h_z = [21.54^2 - g^2]^{1/2} = 17.361"$$

$$h = h_z \cos 6^\circ 30' = 17.361 (.9936) = 17.250$$

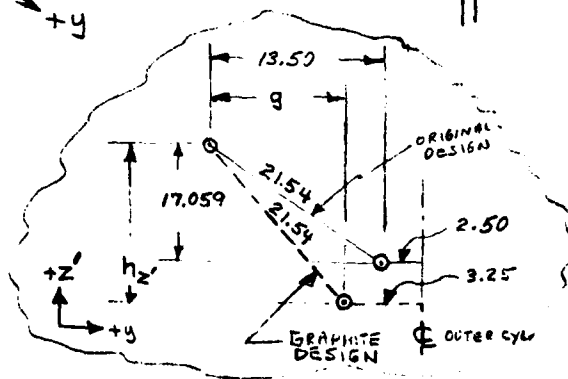
$$L = h - 4.39 = 12.860$$

$$\sin \theta = h/21.54 = .8008, \theta = 53^\circ 12'$$

$$a = 21.54 \cos \theta = 12.903$$

$$\cos \phi = 12.75/a = .9881, \phi = 8^\circ 51'$$

$$b = a \sin \phi - 1.829 = a (.1539) - 1.829 = 0.157 \text{ IN.}$$



REFERENCES

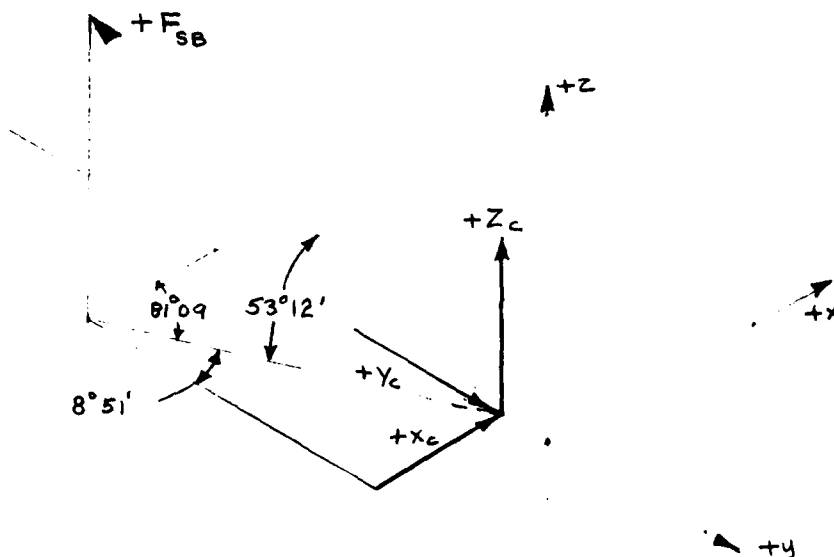
- ① HERCULES INTERNAL REPORT, PHASE I GRAPHITE COMPOSITE GEAR COMPONENTS, CONTRACT # F33615-71-C-1508, DOCUMENT # H4N-12-1-3, 3 MAY 1971
- ② BENDIX THIRD INTERIM REPORT, CONTRACT # F33615-69-C-1508, DATED 14 DEC. 1970
- ③ HERCULES DWG # 3008500433, ORIGINAL DESIGN = 2.5", BENDIX DESIGN 3.12 (2)

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.4

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JGB
BLDG. _____ TITLE A-37B LANDING GEAR

SIDE BRACE
ULT. LOADS



$$F_{sb} = (\cos 81^{\circ}09')(\cos 53^{\circ}12')(-X_c) + (\cos 8^{\circ}51')(\cos 53^{\circ}12')(-Y_c) + \cos 36^{\circ}48'(Z_c)$$

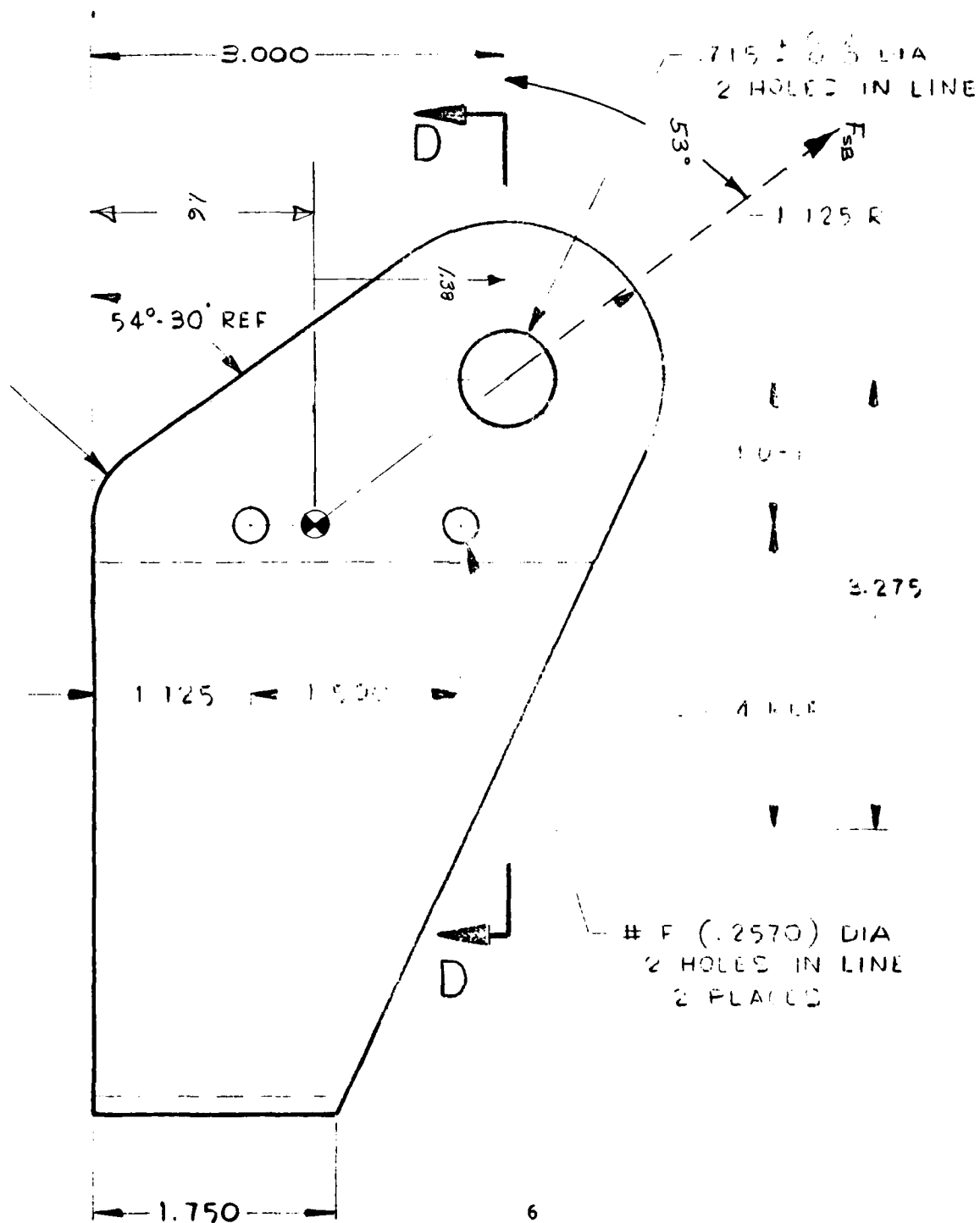
$$= -.092 X_c - .592 Y_c + .8007 Z_c$$

LOAD CONDITION	Z_c	Y_c	X_c	F_{sb}	
1A	-9300	7500	1100	-9838	
1B	-4100	3300	500	-5282	
1C	-7600	6200	900	-9838	
2A	-8900	7230	1000	-11500	
2C	-5600	4600	600	-7262	
3A	9000	-7300	-1000	(+11,619)	← CRITICAL TENSILE LOAD
3B	-22,600	18300	2600	-29,166	
4A	-6,300	5100	700	-8,128	
5A	-6,300	5100	700	-8,128	
6A	-22,700	18,400	2600	(-29,306)	← CRITICAL COMPRESSIVE LOAD

HERCULES INCORPORATED
ENGINEERING DEPARTMENT

SKETCH NO. I.5

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gnb
BLDG. _____ TITLE A-37 B LANDING GEAR

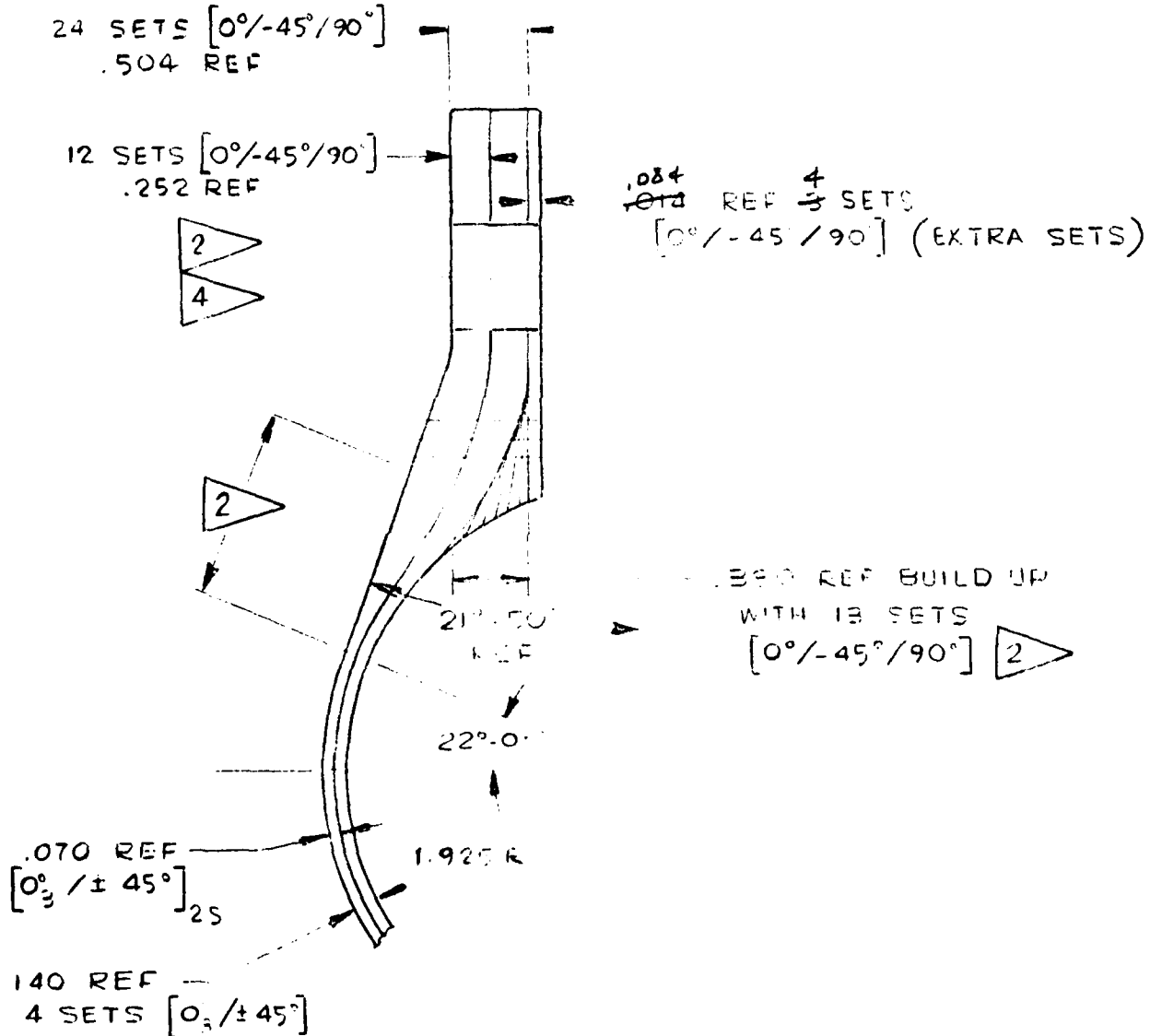


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SKETCH NO. I.6

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BLDG. _____ TITLE _____

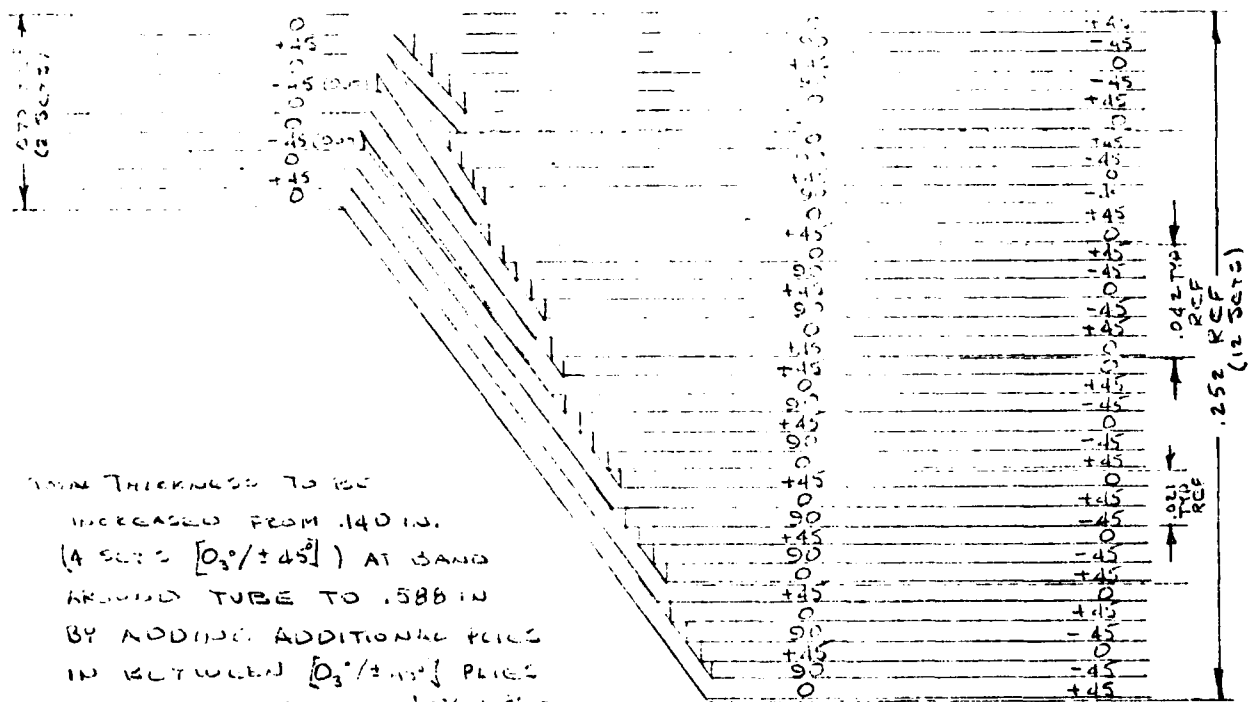


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BIDG.	TITLE		

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$[0^\circ/\pm 45^\circ]$ LAMINATE



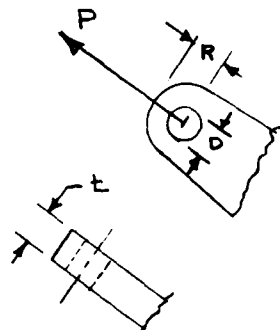
8

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.8

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR g918
BLDG. _____ TITLE A-37B LANDING GEAR

SIDE BRACE
LUG ANALYSIS } TENSILE LOAD



LAY-UP: $[0 \pm 45]_5$ WITH 0° PLY || to P

$$P = 70\% \times F_{SB} = .70 \times 11,619 = 8,133 \text{ \#}$$

$$R = 1.125 \text{ IN}$$

$$D = .717 \text{ IN}$$

$$e = 90\% \times R = 1.013 \text{ IN}$$

$$t = 0.560 \text{ IN}$$

$$S = R - .5D = 1.25 - .359 = .891 \text{ IN}$$

$$S/D = 1.24$$

$$e/D = 1.41$$

$$A_s = 2et = 1.135$$

$$A_{br} = Dt = .402 \text{ IN}^2$$

$$A_t = (2R - D)t = .857 \text{ IN}^2$$

ALLOWABLE BEARING STRESS

USING CURVE ON P. I.9 FOR $e/D = 1.41$

$$\textcircled{1} F_{BR} = 97,000 \text{ PSI}$$

$$F_{BR \text{ ALLOWABLE}} = \textcircled{2} 50\% \times F_{BR} = 48,500 \text{ PSI}$$

ALLOWABLE TENSILE STRESS AT 1-1

$$F_{tu} = \frac{F_{BR \text{ ALL}}}{2(S/D - 0.5)} = \frac{48,500}{2(1.24 - .5)} = 32,800 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F_{su} = \frac{F_{BR \text{ ALL}}}{2(e/D - 0.5)} = \frac{48,500}{2(1.41 - .5)} = 26,600 \text{ PSI}$$

① CURVE ON PAGE I.10 INDICATES $F_{BR} = 75,000 \text{ PSI}$ FOR $D/t = 1.28$

② FACTOR TO ACCOUNT FOR FATIGUE AND UNCERTAINTIES IN F_{BR} VALUES

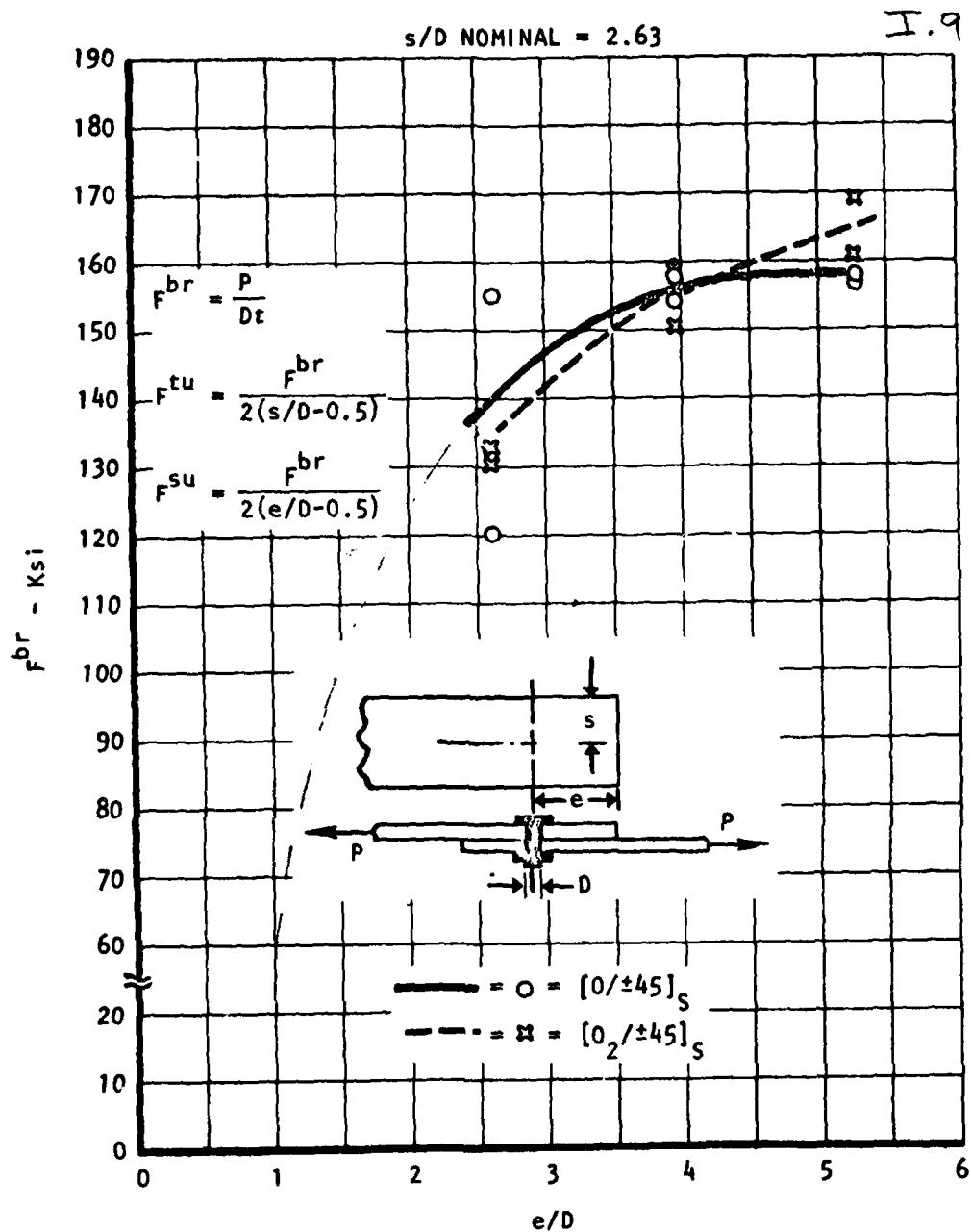


Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

10

REF : ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN, VOL. IV : MATERIAL AND BASIS ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY, NORTH AMERICAN ROCKWELL / L.A. DIVISION, REPORT # AFML-TR-70-58, SEPT. 1972

JANUARY 1971

Graphite/epoxy data on equivalent bearing strength F_{br} versus D/t , for various laminate layup orientations of Narmco 5206, Type II, are presented in Figures 6.2.2.23 and 6.2.2.24, which were obtained from Reference 6.8. The design curves shown represent the lower bound data and are valid for the parameter range designated. Countersunk fastener joint data are presented in paragraph 6.2.2.1.2.

6.2.2.1.1.4 Elevated-Temperature Effects - The strength reduction in boron/epoxy test data for temperatures up to 375°F are shown in Figure 6.2.2.25 from References 6.2 and 6.25. The shearout, net-tension, and bearing temperature correction curves shown should be considered applicable only for the laminate orientations designated.

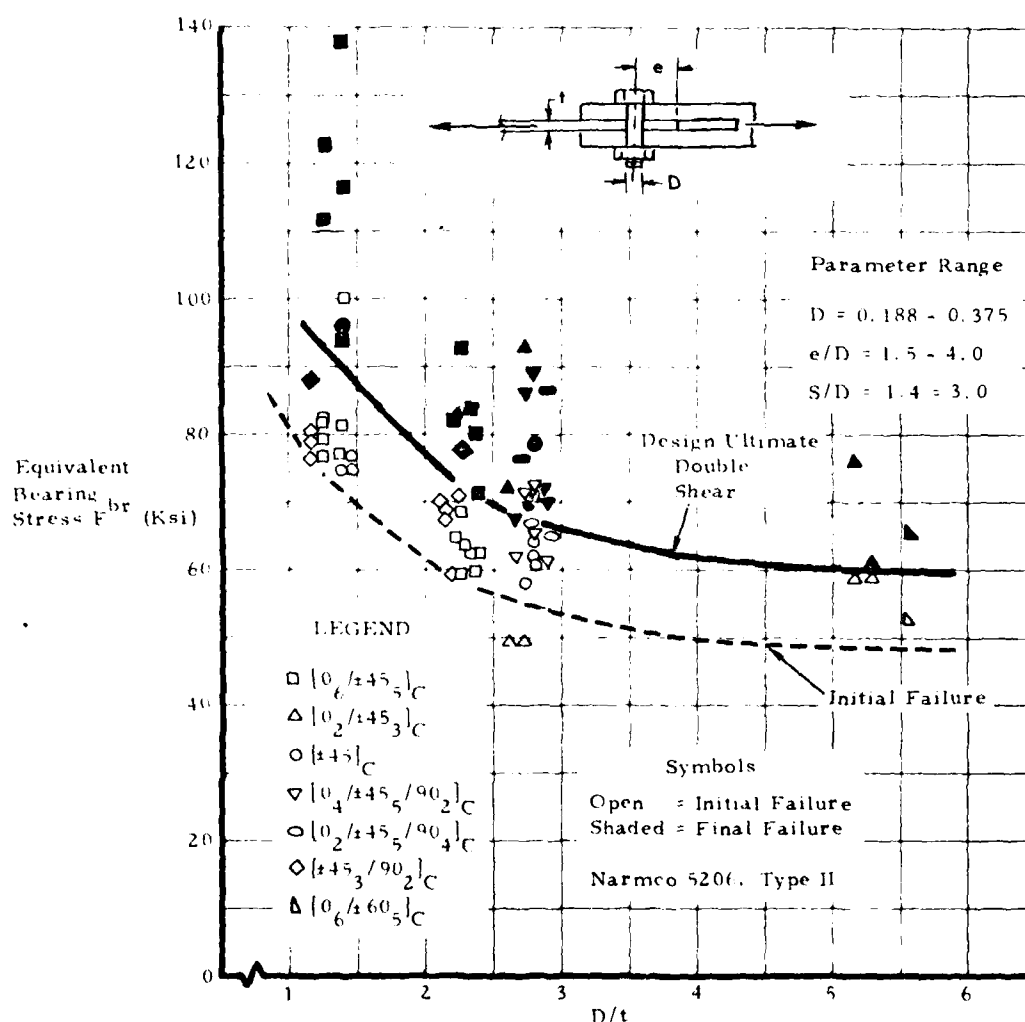


FIGURE 6.2.2.23 GRAPHITE/EPOXY MECHANICAL JOINT STRENGTH - DOUBLE SHEAR

TAKEN FROM AIR FORCE DESIGN GUIDE

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.11

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gob
BLDG. _____ TITLE A-37B LANDING GEAR

SIDE BRACE
LUG ANALYSIS, CON'T

STRESSES

$$F_{BR} = \frac{P}{A_{br}} = \frac{8,133}{.402} = \underline{\underline{20,200 \text{ PSI}}}$$

$$m.s. = \frac{48,500}{20,200} - 1 = \underline{\underline{+1.40}}$$

$$F_t = \frac{P}{A_t} = \frac{8,133}{.857} = \underline{\underline{9,500 \text{ PSI}}}$$

$$m.s. = \frac{32,800}{9,500} - 1 = \underline{\underline{+2.46}}$$

$$F_s = \frac{P}{A_s} = \frac{8,133}{1.135} = \underline{\underline{7,170 \text{ PSI}}}$$

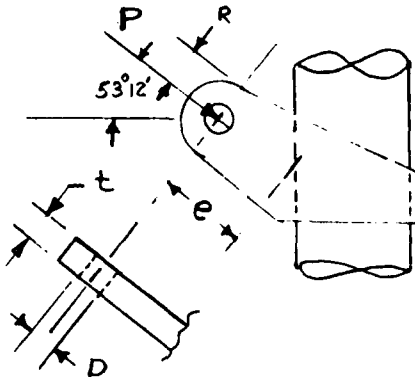
$$m.s. = \frac{26,600}{7,170} - 1 = \underline{\underline{+2.72}}$$

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SKETCH NO. I.12

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEAR

SIDE BRACE } COMPRESSIVE LOAD
LUG ANALYSIS



LAY UP: $[0 \pm 45]_3$ WITH 0° PLYS || to P

$$P = 70\% (-F_{B0}) = .7 (29,306) = 20,514$$

$$D = .717$$

$$e = 1.8$$

$$t = 0.56$$

$$R = 1.125$$

$$S = R - .5D = .891$$

$$S/D = 1.24$$

$$e/D = 2.51$$

$$A_{br} = Dt = .402$$

$$A_t = (2R - D)t = .857$$

$$A_s = 2et = 2.02$$

ALLOWABLE BEARING STRESS

USING CURVE ON P. I.9 FOR $e/D = 2.51$

$$F_{BR} = 138,000 \text{ PSI}$$

$$F_{BR_{ALL}} = 50\% \times 138,000 = 69,000 \text{ PSI}$$

ALLOWABLE TENSILE STRESS

$$F_{t_{ALL}} = \frac{F_{BR_{ALL}}}{2(S/D - 0.5)} = \frac{69,000}{1.48} = 46,600 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F_{s_{ALL}} = \frac{F_{BR}}{2(e/D - 0.5)} = \frac{69,000}{4.02} = 17,200 \text{ PSI}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.13

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gnd
BLDG. _____ TITLE A-37B LAMPING GEAR

SIDE BRACE
LUG ANALYSIS, CON'T

STRESSES

$$F_{BR} = \frac{P}{A_{br}} = \frac{20,514}{.402} = \underline{\underline{51,200 \text{ PSI}}}$$

$$m.s. = \frac{69,000}{51,200} - 1 = \underline{\underline{+0.35}}$$

$$F_t = \frac{P}{A_t} = \frac{20,514}{.857} = \underline{\underline{23,900 \text{ PSI}}}$$

$$m.s. = \frac{46,600}{23,900} - 1 = \underline{\underline{+0.95}}$$

$$F_s = \frac{P}{A_s} = \frac{20,514}{2.02} = \underline{\underline{10,150 \text{ PSI}}}$$

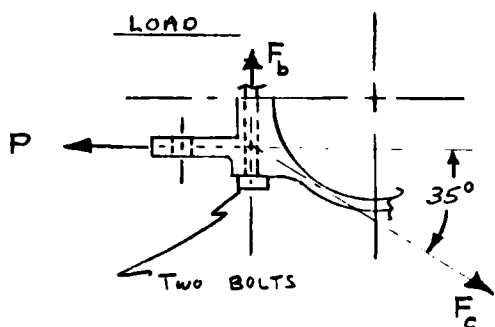
$$m.s. = \frac{17,200}{10,150} - 1 = \underline{\underline{+0.70}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.14

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gab
BLDG. _____ TITLE A-37B LANDING GEAR

SIDE BRACE ATTACHMENTS BOLTS (TENSILE LOAD)



$$\text{MAX } +P = 70\% \times F_{se} = .7 (11,619) = 8133 \#$$

$$F_c = \frac{+P}{\cos 35^\circ} = \frac{8133}{.8192} = 9929 \#$$

$$F_b = +P \tan 35^\circ = (8133)(.7002) = 5,695 \#$$

BOLT & NUT TYPE

BOLT : NAS 1271-48 (SEE P. I.16 & I.17)

TENSILE LOAD, MAX = 5820 LBS

NUT : FNT 20-428 (SEE P. I.18)

TENSILE LOAD = 7270 LBS

MARGIN OF SAFETY ON 1/4-28 BOLT

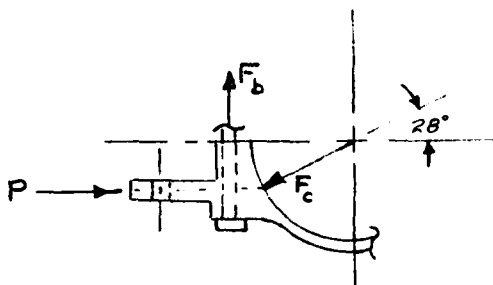
$$\text{m.s.} = \frac{2 \times 5820}{5,695} - 1 = \underline{\underline{+1.04}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I,15

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR g. g. b.
BLDG. _____ TITLE _____

SIDE BRACE ATTACHMENT BOLTS (COMPRESSIVE LOAD)



$$\text{MAX } P = 70\% \times F_{SB} = .7 (29,303) = 20,514 \#$$

$$F_c = \frac{P}{\cos 28^\circ} = \frac{20,514}{.883} = 23,200 \#$$

$$F_b = P \tan 28^\circ = 20,514 (.5317) = 10,900 \#$$

MARGIN OF SAFETY FOR 1/4-28 BOLT

$$m.s. = \frac{2 \times 5820}{10,900} - 1 = \underline{\underline{+0.07}}$$

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SPS-N-59715 REVISION 2 REDRAWN

REVISED AND 12/10/64 (3) 8-8-66 (4) 4-24-67 (5) 2-7-68 (6) 7-12-68

TOOL MARKS AND DISTORTION AT TOP OF NUT DUE TO LOCKING FEATURE PERMISSIBLE.

COUNTERSINK, COUNTERBORE, OR RADIUS RELIEF TO THREAD WITHIN THE LIMITS OF P DIAMETER

PART NUMBER	(1) THREAD SIZE	A MAX.	B MIN.	C MIN.	H MAX.	P MAX.	S MIN.	V MIN.	W		(2) X	(3) Y	AXIAL STRENGTH LBS. MIN.	WEIGHT MAXIMUM LBS. 100
									MAX.	MIN.				
FNT20-1032	.190-32 UNF-3B	.350	.320	.277	.220	.220	.060	.020	.251	.43	.033	.002	4,000	.15
FNT20-439	.250-28 UNF-3B	.438	.408	.347	.303	.303	.100	.027	.311	.305	.033	.002	7,370	.27
FNT20-524	.312-24 UNF-3B	.51	.501	.419	.325	.347	.120	.042	.376	.347	.044	.002	11,600	.50
FNT20-634	.375-24 UNF-3B	.619	.611	.515	.415	.415	.152	.077	.431	.410	.045	.002	17,600	.85
FNT20-723	.437-20 UNF-3B	.720	.720	.611	.500	.473	.183	.078	.504	.513	.065	.003	23,700	1.45
FNT20-820	.500-20 UNF-3B	.828	.799	.703	.600	.475	.199	.092	.627	.616	.066	.003	32,000	2.08
FNT20-918	.562-18 UNF-3B	.918	.909	.775	.680	.597	.210	.100	.670	.674	.068	.003	40,600	2.76
FNT20-1018	.625-18 UNF-3B	1.050	1.050	.815	.740	.670	.250	.110	.752	.741	.068	.003	51,200	3.56

(1) THREADS: BEFORE LUBRICATION PER MIL-S 8179.
 (2) BEARING SQUARENESS: BEARING SURFACE TO BE SQUARE WITH PITCH DIAMETER WITHIN X WHEN CHECKED AT A POINT MIDWAY BETWEEN THE I.D. AND O.D. OF THE BEARING SURFACE.
 (3) BEARING FLATNESS: BEARING SURFACE TO BE FLAT TO CONCAVE WITHIN Y T.I.R. WHEN CHECKED IN ACCORDANCE WITH SPS-G-1013.

MATERIAL: TITANIUM ALLOY PER AMS 4928.

LUBRICANT: DRY FILM LUBRICANT.

FLUORESCENT PENETRANT INSPECT 100% PER SPS-N-269.

BREAK SHARP CORNERS.

DIMENSIONS IN INCHES.

DIMENSIONS TO BE MET PRIOR TO LUBRICATION.

SURFACE TEXTURE: USAS B46.1 UNLESS OTHERWISE SPECIFIED THE SURFACE TEXTURE SHALL NOT EXCEED 125 MICROINCHES.

PERFORMANCE: SEE PROCUREMENT SPECIFICATION.

DESIGN AND USAGE LIMITATIONS: THESE NUTS ARE DESIGNED TO DEVELOP THE TENSILE STRENGTH OF BOLTS AND SCREWS WITH AN ULTIMATE TENSILE STRENGTH OF 200 KSI BASED ON THE TENSILE STRESS AREA OF THE EXTERNAL THREAD. THESE NUTS ARE DESIGNED TO BE USED ON CLASS JA EXTERNAL THREADS WITHIN THE LIMITATIONS OF MS J3528. THESE NUTS ARE RECOMMENDED FOR USE ON EWB T815 BOLTS.

THIS STANDARD TAKES PRECEDENCE OVER DOCUMENTS REFERENCED HEREIN. REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATIONS FOR BID.

PART NUMBERS OTHER THAN LISTED ON THIS DRAWING SHALL NOT BE USED.

STANDARD

TOLERANCES: ———— AND ———— UNLESS OTHERWISE NOTED * INDICATES LATEST CHANGE

STANDARDS AND SPECIFICATIONS: SPS-N-269, CLASS II

FED. IDENT. CODE NO. 56878

CUSTOMER: JENKINTOWN, PENNA.

TITLE: NUT, FLEXLOC, DOUBLE HEXAGON, SELF-LOCKING, TITANIUM 750F, 200 KSI, FLANGED

DRAWN BY: W. A. B. DATE: 3/15/63

APPROVED: DATE: 3/15/63

PART NUMBER: FNT 20

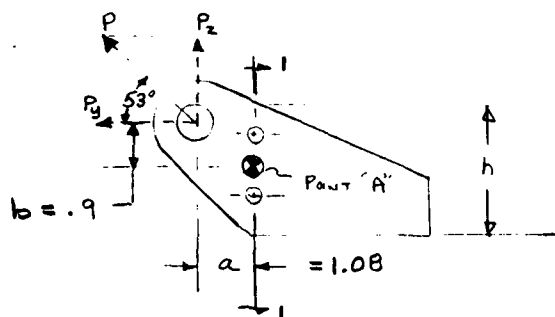
HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.19

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR g n b
BLDG. _____ TITLE _____

SIDE BRACE ATTACHMENT ANALYSIS

STRESSES AT SECTION 1-1



$$h = 3.3 \text{ in}$$

$$z = \text{PART THICKNESS} = .560$$

LAY UP: $[0, +45, 90]$ WITH 0° PLY
|| to P_y LOAD. PROPERTIES
SHOWN IN P. I. 21 .

LOADS

$$P = 70\% \times F_{SB} = .7 (11,619) = 8,133 \#$$

$$P_2 = P \sin 53^\circ = 8133 (.7986) = 6,495 \#$$

$$P_y = P \cos 53^\circ = 8133 (.6018) = 4,894 \#$$

SHEAR STRESS

$$\tau = \frac{3}{2} \frac{P_2}{A} = 1.5 \frac{(6,495)}{z h} = \frac{9743}{(.56)(3.3)} = \underline{\underline{5,260 \text{ PSI}}}$$

DESIGN ALLOWANCES

BASED UPON $\tau_{ult} = 5,260$

$$\tau_{limit} = \frac{\tau_{ult}}{1.2} = 4,390 \text{ PSI (USE 5,000)}$$

AND FROM CURVE ON PAGE I. 21

PROPERTY	LIMIT	ULT
τ	5000	7000
F_{xe}	30,000	36,000
F_{xc}	40,000	48,000
F_{yt}	10,000	12,000
F_{yc}	20,000	24,000

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.20

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ggb
BLDG. _____ TITLE _____

BENDING AND NORMAL STRESSES

$$F_N = \frac{P_0}{A} = \frac{4,894}{t h} = \frac{4,894}{1.85} = 2,640 \text{ PSI}$$

$$F_b = \frac{M c}{I} = \frac{6 m}{t h^2} = \frac{6 [P_2 a - P_0 b]}{.56 (3.3)^2}$$

$$= .985 [6495(1.05) - 4894(.9)] = 2,560 \text{ PSI}$$

$$F_t = 2,640 \pm 2,560 = \underline{\underline{+5,200 \text{ PSI}}}, \quad 80 \text{ PSI}$$

$$m.s. = \frac{F_{xt}}{5200} - 1 = \underline{\underline{+5.93}}$$

2525 DESIGN PROPERTIES (77° F)
 FOR
 2002 AS GRAPHITE EPOXY LAMINATE [0°/±45°]
 55 % FIBER VOL.

ELASTIC CONSTANTS

$$E_x = 11.03 \times 10^6 \text{ PSI}$$

$$E_y = 2.45 \times 10^6 \text{ PSI}$$

$$\mu_{xy} = 0.65$$

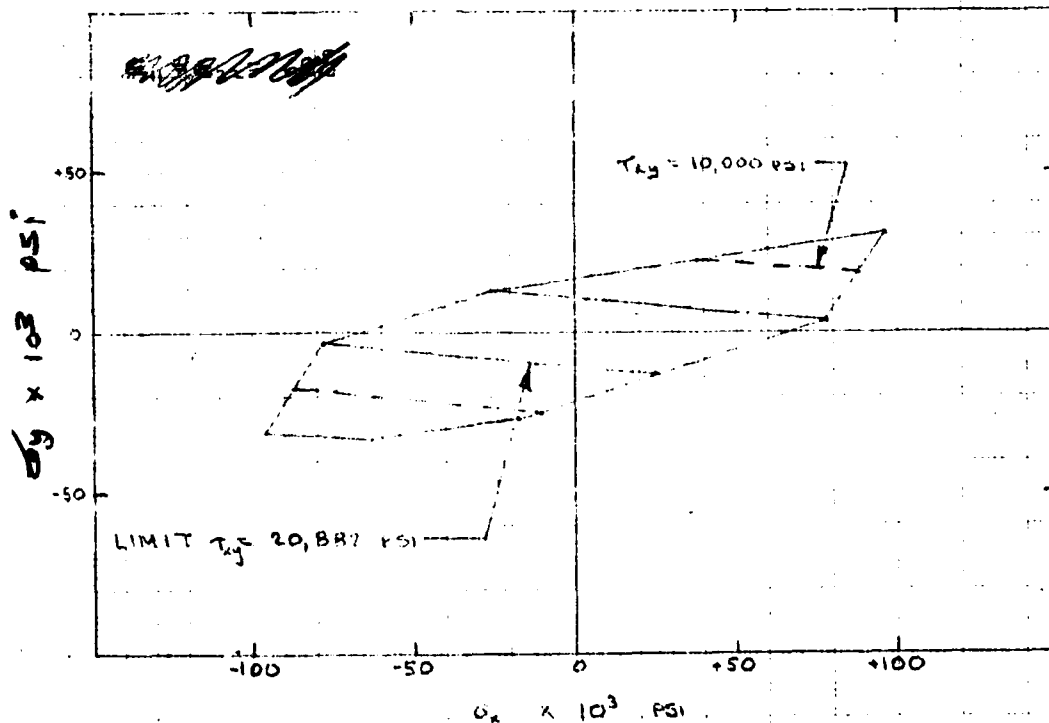
$$G_{xy} = 2.11 \times 10^6 \text{ PSI}$$

THERMAL COEFFICIENTS

$$\alpha_x = -0.345 \text{ IN/IN/°F} \times 10^{-6}$$

$$\alpha_y = +4.116 \text{ IN/IN}$$

"LIMIT" INTERACTION CURVE



DESIGN PROPERTIES (77°F)
 FOR
 2002 A5 ($G_{11} = G_{22} = .65\%$) / G100 GRAPHITE FIBER VOL.
 $[0^\circ/+45^\circ/90^\circ]$, SAME AS $[0^\circ/+45^\circ]$ WITH $\phi = +45^\circ$
 QUASI-ORTHOTROPIC

ELASTIC CONSTANTS

$$E_x = 6.70 \times 10^6 \text{ PSI}$$

$$E_y = 6.70 \times 10^6 \text{ PSI}$$

$$\nu_{xy} = 0.087$$

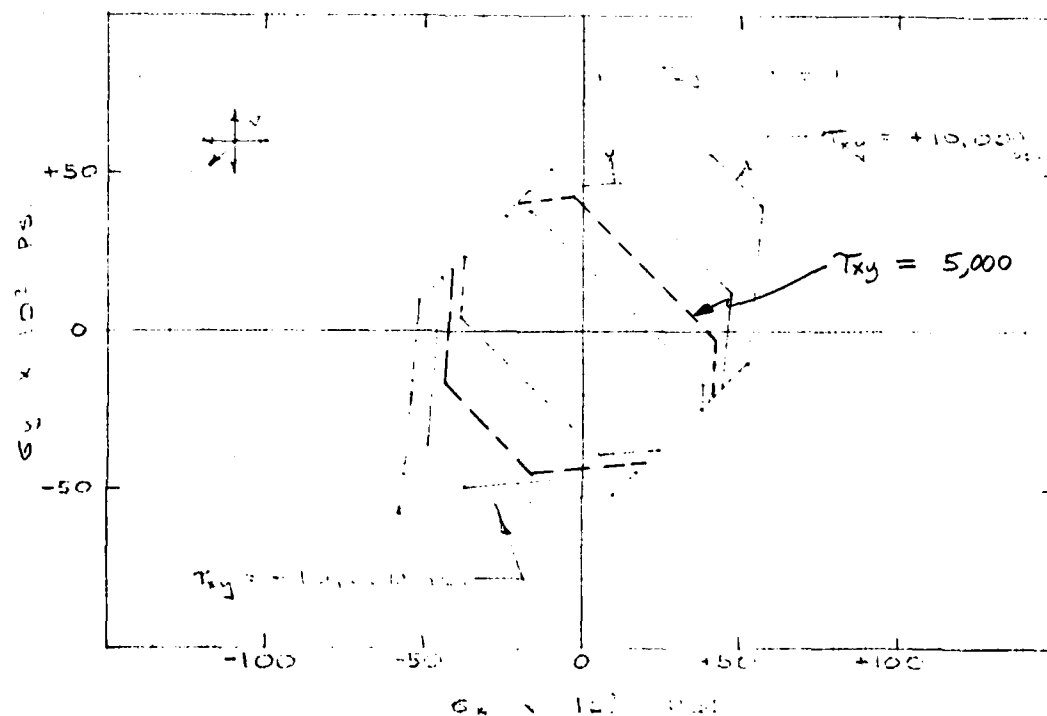
$$G_{xy} = 1.49 \times 10^6 \text{ PSI}$$

THERMAL COEFFICIENTS

$$\alpha_x = 1.123 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

$$\alpha_y = 1.123 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

INTERACTION CURVE

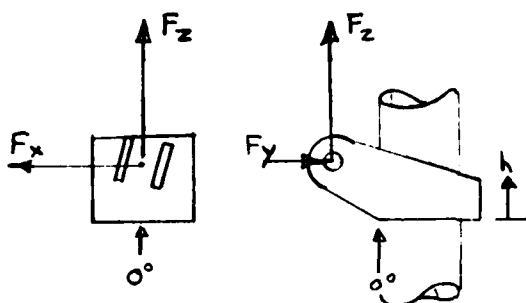


HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.22

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37 B LANDING GEAR

SIDE BRACE ATTACHMENT
SHEAR STRESSES IN BOND
TO TUBE } TENSILE LOAD, COND. 3A



$$\begin{aligned} F_z &= 9000 \text{ *} \\ F_x &= -1000 \text{ *} \\ F_y &= -7300 \text{ *} \end{aligned}$$

h = HEIGHT AT 0° = 3.0 IN

ULT. ALLOWABLE SHEAR = 4750 PSI AT
R.T. FOR PHYSOL'S
EA 9309

SHEAR DUE TO F_z @ 0°

$$\begin{aligned} V_{max} &= F_z C_{vp} & C_{vp} &= .5 \text{ FROM CURVE ON P. I.23} \\ &= 9000 (.5) = 4500 \text{ */IN} \end{aligned}$$

$$\tau_z = \frac{V_{max}}{h} = \frac{4500}{3} = 1500 \text{ PSI at } 0^\circ$$

SHEAR DUE TO F_x @ 0°

$$V_{max} = \frac{4 F_x}{\pi R} = \frac{4 (1000)}{\pi (2)} = 638 \text{ */IN}$$

$$\tau_x = \frac{638}{3} = 212 \text{ PSI}$$

COMBINED SHEAR @ 0°

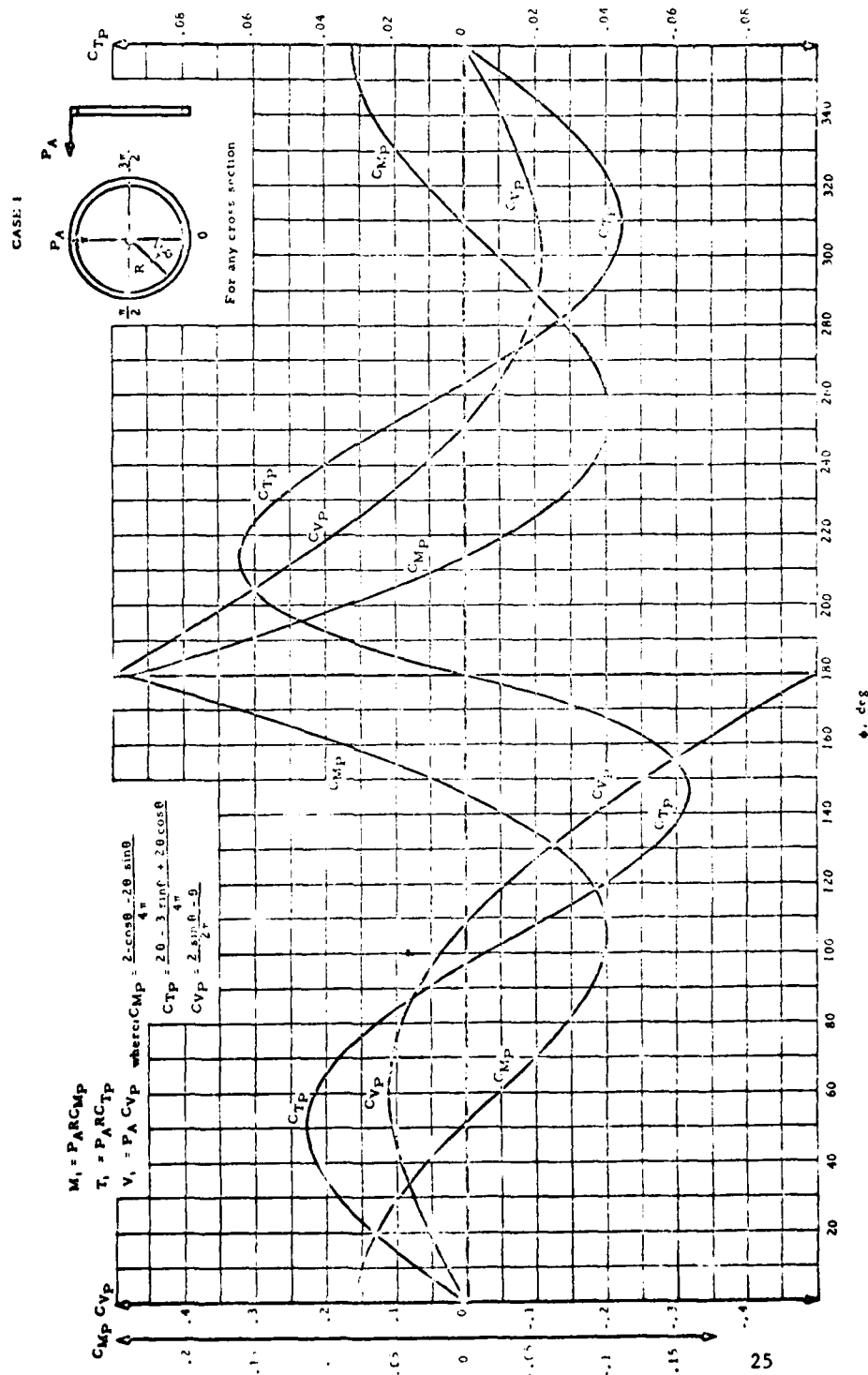
$$\begin{aligned} \tau_T &= [\tau_x^2 + \tau_z^2]^{1/2} = [(212)^2 + (1500)^2] \\ &= \underline{\underline{1510 \text{ PSI}}} \end{aligned}$$

$$M.S. = \frac{4750}{1500} - 1 = \underline{\underline{+2.17}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. **I.23**

PLANT _____ PROJECT NO. _____ DATE **2-73** AUTHOR **gmb**
BLDG. _____ TITLE **A-37 B LANDING GEAR**



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I, 24

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37 B LANDING GEAR

SIDE BRACE ATTACHMENT
SHEAR STRESSES IN BOND
TO TUBE } COMPRESSIVE LOAD, COND. 6A

SEE FIGURE P. I.22

$$F_z = -22,700$$

$$F_x = 2600$$

$$F_y = 10,400$$

$$h = 3.0$$

$$\text{ULT. SHEAR ALLOWABLE} = 4750 \text{ PSI} \\ \text{EA-9309}$$

SHEAR DUE TO F_z

$$V_{\max y} = F_z C_{vp} = 22,700 (1.5) = 11,350 \text{ #/IN}$$

$$\tau_y = \frac{V_{\max y}}{h} = \frac{11,350}{3.5} = 3,240 \text{ PSI}$$

SHEAR DUE TO F_x

$$V_{\max x} = \frac{4 F_x}{\pi R} = \frac{4 (2600)}{\pi (2)} = 1650 \text{ #/IN}$$

$$\tau_x = \frac{1650}{h} = \frac{1650}{3.5} = 470 \text{ PSI}$$

COMBINED SHEAR

$$\tau_T = [\tau_x^2 + \tau_y^2]^{\frac{1}{2}} = [(3240)^2 + (470)^2]^{\frac{1}{2}}$$

$$\tau_T = \underline{\underline{3280 \text{ PSI}}}$$

$$\text{m.s.} = \frac{4750}{3280} - 1 = \underline{\underline{+0.45}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I.25

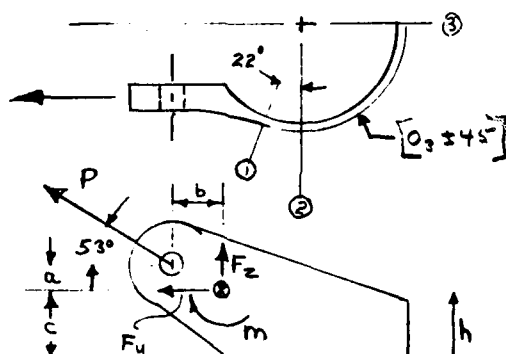
PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gpc
BLDG. _____ TITLE _____

SIDE BRACE ATTACHMENT STRESSES IN BAND

FROM P. I.26
WT. ALLOWABLES $[0.3 \pm 45]$

$$\sigma_x = 72,000 \quad \sigma_y = 12,000$$

$$\tau_{xy} = 20,000 \quad \text{INTERLAMINAR SHEAR} = 12,000$$



$$h_0 = 3.7$$

$$h_1 = 3.1 \quad t_1 = .140$$

$$h_2 = 2.7 \quad t_2 = .140$$

$$h_3 = 1.75 \quad t_3 = .140$$

$$a = 1.38$$

$$b = 1.08$$

$$P = 70\% F_{SB}$$

$$+P = 70\% (11,619) = +8,133 \#$$

$$-P = 70\% (29,306) = -20,514 \#$$

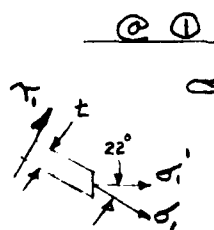
$$C = 1.6$$

STRESSES DUE TO $+P = 8133$

$$F_y = P \cos 53^\circ = 4895 \#$$

$$F_z = P \sin 53^\circ = 6495 \#$$

$$M = a F_y - b F_z = -260 \text{ in} \#$$



$$\sigma_1 = \frac{\sigma_1'}{\cos 22^\circ} = 1.078 \sigma_1'$$

$$t_1' = \frac{t_1}{\cos 22^\circ} = \frac{.140}{.927} = .151$$

$$\sigma_1 = 1.078 \left[\frac{F_y}{t_1' h_1} + \frac{6M}{t_1' h_1^2} \right] = 1.078 [10,459 + 1075]$$

$$\sigma_1 = 12,433 \text{ PSI}$$

$$\tau_1 = \cos 22^\circ \sigma_1' = \cos^2 22^\circ \sigma_1 = .859 (12,433) = 10,683 \text{ PSI}$$

$$M.S. = \frac{12,000}{10,680} - 1 = \underline{\underline{+0.123}}$$

DESIGN PROPERTIES (77°F)

FOR

AS/2002 GRAPHITE/.688% ULT. RESIN [0°/±45°]

55% FIBER VOL.

QUASI-ORTHOTROPIC

ELASTIC CONSTANTS

$$E_x = 11.03 \times 10^6 \text{ PSI}$$

$$E_y = 2.45 \times 10^6 \text{ PSI}$$

$$\mu_{xy} = 0.65$$

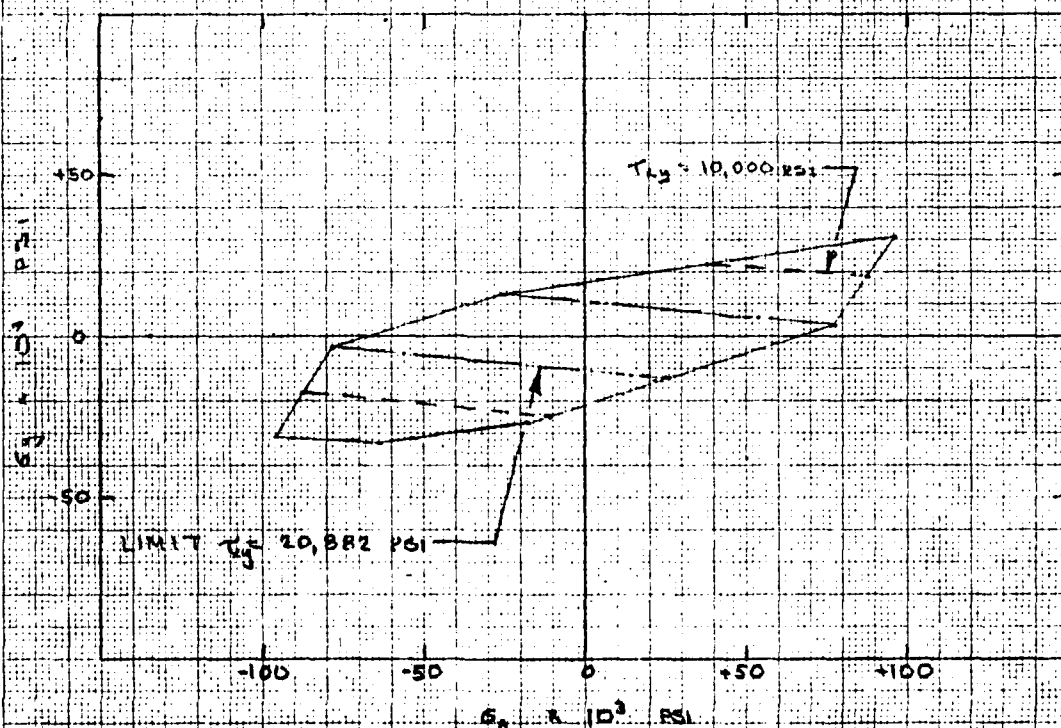
$$G_{xy} = 2.11 \times 10^6 \text{ PSI}$$

THERMAL COEFFICIENTS

$$\alpha_x = -0.345 \text{ IN/IN/°F} \times 10^{-4}$$

$$\alpha_y = +4.116 \text{ IN/IN}$$

"LIMIT" INTERACTION CURVE



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I, 27

PLANT _____ PROJECT NO. _____ DATE 273 AUTHOR gnc
BLDG. _____ TITLE _____

AT (2)

$$\begin{aligned}\sigma_2 &= \frac{F_y}{t_2 h_2} + \frac{6m}{t_2 h_2^2} + \frac{6[F_y](\frac{h_2^3}{2} - c)}{t_2 h_2^2} \\ &= \frac{4895}{(.140)(2.7)} + \frac{6(-260)}{(.140)(2.7)^2} + \frac{6[-1224]}{(.140)(2.7)^2} \\ &= 12,950 \pm 1529 \mp 7,196 = \underline{\underline{21,674 \text{ PSI}}} \\ \text{m.s. } &\frac{72,000}{21,674} - 1 = \underline{\underline{+2.32}}\end{aligned}$$

$$\gamma_2 = 0.0$$

AT (3)

$$\begin{aligned}\sigma_3 &= \frac{F_y}{t_3 h_3} + \frac{6m}{t_3 h_3^2} + \frac{6[F_y](\frac{h_3^3}{2} - c)}{t_3 h_3^2} \\ &= \frac{4895}{.245} + \frac{6(-260)}{.429} + \frac{6[4895(-.725)]}{.429} \\ &= 19,980 \mp 3636 \mp 49,634 \\ &= \underline{\underline{73,250 \text{ PSI}}}\end{aligned}$$

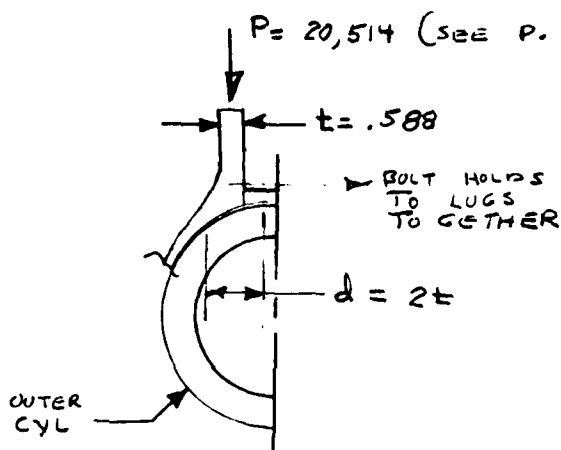
$$\text{m.s.} = \frac{72,000}{73,250} - 1 = \underline{\underline{-.017}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. I. 28

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR J. P. S.
 BLDG. _____ TITLE _____

SIDE BRACE ATTACHMENT
 STRESSES IN BAND DUE
 TO $-P = 20,514$



ASSUMPTION: BOLTS HOLD THE
 TWO LUGS TOGETHER AND
 THAT THE LOAD IS
 TRANSFERRED TO THE
 OUTER CYLINDER OVER
 DIMENSION d

$$\sigma = -\frac{F_y}{dh} \pm \frac{6m}{dh^2} = \frac{4895}{(1.18)(3.6)} \pm \frac{6(260)}{(1.18)(3.6)^2}$$

$$= -1152 \pm 102$$

$$= -1254 \text{ PSI} \quad , \quad -1050 \text{ PSI}$$

M.S. = HIGH

APPENDIX A
PART II

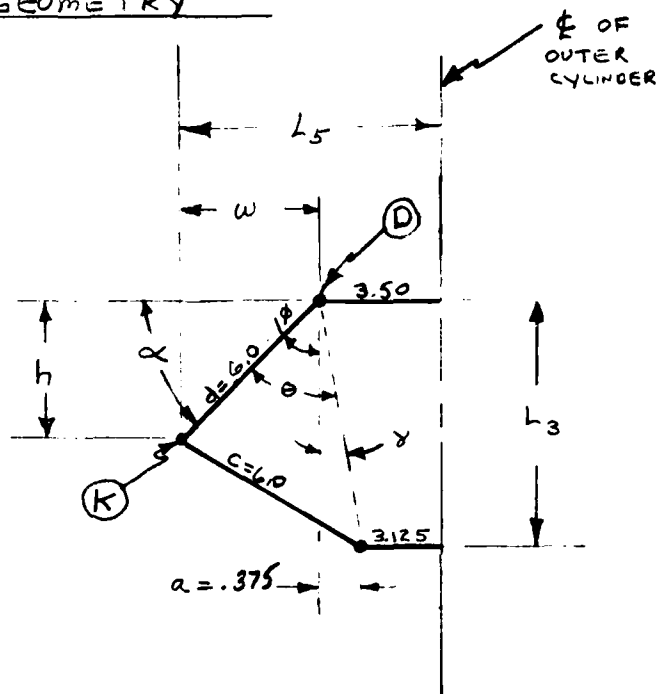
DESIGN AND ANALYSIS
OF
THE TORQUE ARM ATTACHMENT

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-1

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR g m B
BLDG. _____ TITLE A-37-B LANDING GEAR

TORQUE ARM GEOMETRY



$$b = [(L_3)^2 + a^2]^{1/2}$$

$$\tan \gamma = a / L_3$$

$$\cos \theta = b / 2c = b / 12$$

$$\phi = \theta - \gamma$$

$$\alpha = 90 - \phi$$

$$w = d \cos \alpha = 6 \cos \alpha$$

$$h = d \sin \alpha = 6 \sin \alpha$$

DIM.	FULLY EXTENDED	LANDING	STATIC	FULLY COMPRESSED
L_3	11.62	7.62	5.22	3.62
b	11.626	7.629	5.233	3.639
γ	1.848	2.817	4.109	5.194
θ	14.34	50.524	64.145	72.347
ϕ	12.49	47.707	60.036	67.153
α	77.51	42.293	29.964	22.847
w	1.299	4.438	5.198	5.529
h	5.858	4.038	2.997	2.330
L_5	4.799	7.938	8.698	9.029

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-2

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR JAB
BLDG. _____ TITLE A-37 B LANDING GEAR

TORQUE ARM
LOADS

CRITICAL LOADS (PER BENDIX REPORT)

LANDING ~ LOAD CONDITION 2C , $Y_R = +9700 \#$

STATIC ~ LOAD CONDITION 5A , $Y_R = +8200 \#$

CRITICAL LOADS FOR GRAPHITE DESIGN

THE ABOVE LOADS WERE DEVELOPED BY
BENDIX FOR L_5 VALUES (SEE P.) OF

$$L_5 = 8.0 , \text{LANDING}$$

$$L_5 = 8.74 , \text{STATIC}$$

THE L_5 VALUES FOR THE GRAPHITE GEAR
ARE

$$L_5 = 7.938 , \text{LANDING}$$

$$L_5 = 8.698 , \text{STATIC}$$

AND THEREFORE RESULTING IN THE FOLLOWING
DESIGN LOADS

$$\text{LANDING} \sim Y_R = \frac{8.0}{7.938} \times 9700 = \underline{\underline{9,776 \#}}$$

$$\text{STATIC} \sim Y_R = \frac{8.74}{8.698} \times 8200 = \underline{\underline{8,240 \#}}$$

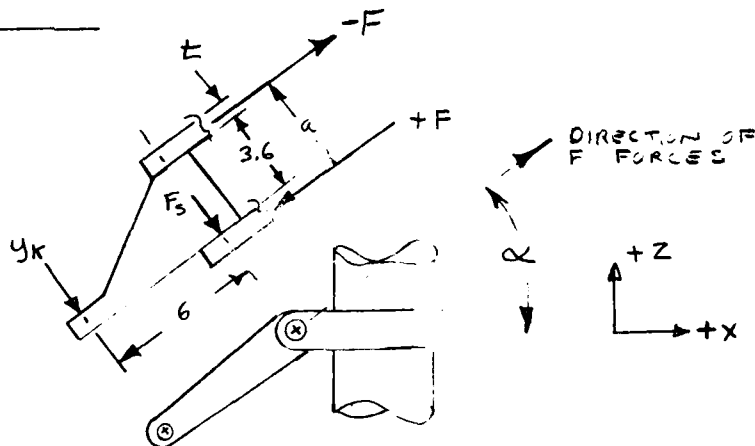
HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. D-3

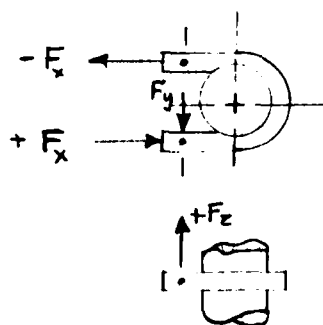
PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____
BLDG. _____ TITLE _____

TORQUE ARM ATTACHMENT LOADS

$$\begin{aligned} t &= .609 \text{ (ASSUMED)} \\ a &= 3.6 + t = 4.209 \\ m &= 6 Y_K \\ m &= Fa \\ F &= \frac{6 Y_K}{a} = 1.425 Y_K \end{aligned}$$



CONDITION	Y_K	F	F_s	α
LANDING (2C)	9776	13,931	9776	42.3
STATIC (5A)	8240	11,742	8240	30.0

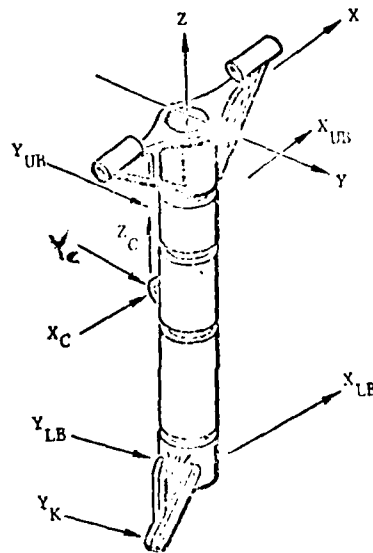


	2C LANDING	5A STATIC
$F_x = F \cos \alpha =$	10,303	10,168
$F_z = F \sin \alpha =$	9,375	5,871
$F_y = F_s =$	9,776	8,240

TABLE I

II-4

ULTIMATE LOADS APPLIED TO OUTER CYLINDER



OUTER CYLINDER

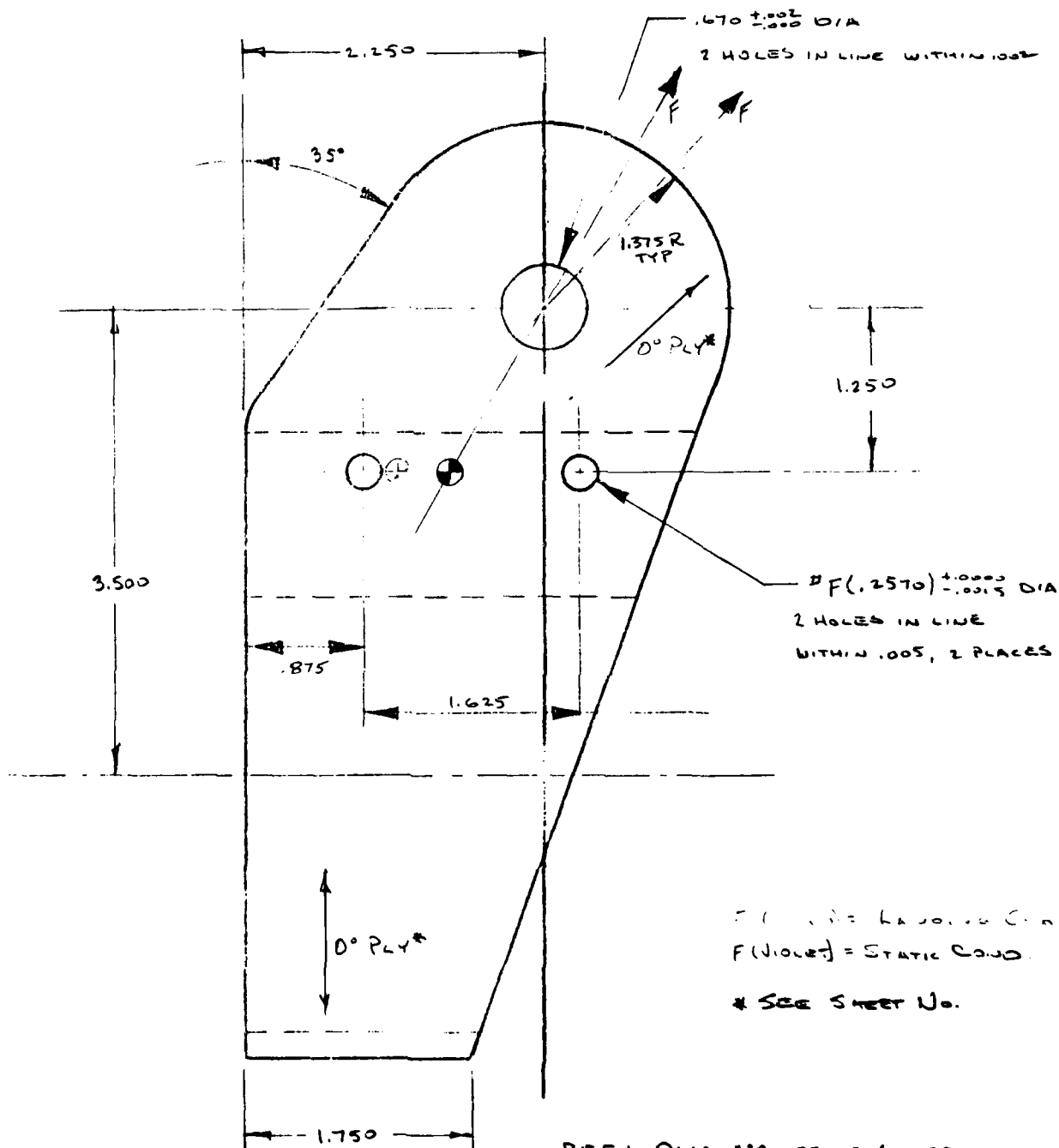
Load Conditions				X_{LB}	Y_{LB}	Y_K	X_C	Z_C	Y_C	X_{UB}	Y_{UB}
Landing Conditions	2 Pt. Level Landing	Max Vert	1A	-9500	-15300	5200	1100	-9300	7500	3000	10100
		Spin-up	1B	12100	3900	-6800	500	-4100	3300	-4800	2900
		Spring Back	1C	-16200	-18200	9100	900	-7600	6200	6400	9100
	Tail Down Landing	Max Vert	2A	-16000	-19400	9000	1000	-8900	-7230	6400	10400
		Spring Back	2C	-14900	-17000	9700	600	-5600	4600	4500	7200
	Drift Landing	Right	3A	-1400	6100	300	-1000	9000	-7300	500	-1800
		Left	3B	-1400	-21000	1600	2600	-22600	18300	500	13300
Static Conditions	Braked Roll		4A	14700	1300	-6100	700	-6300	5100	-7500	4800
	Reversed Brake		5A	-17900	-14000	8200	700	-6300	5100	8300	5800
	Right Turn		6A	-1800	-19100	1700	2600	-22700	18400	500	11600

Note: Loads in pounds.

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-5

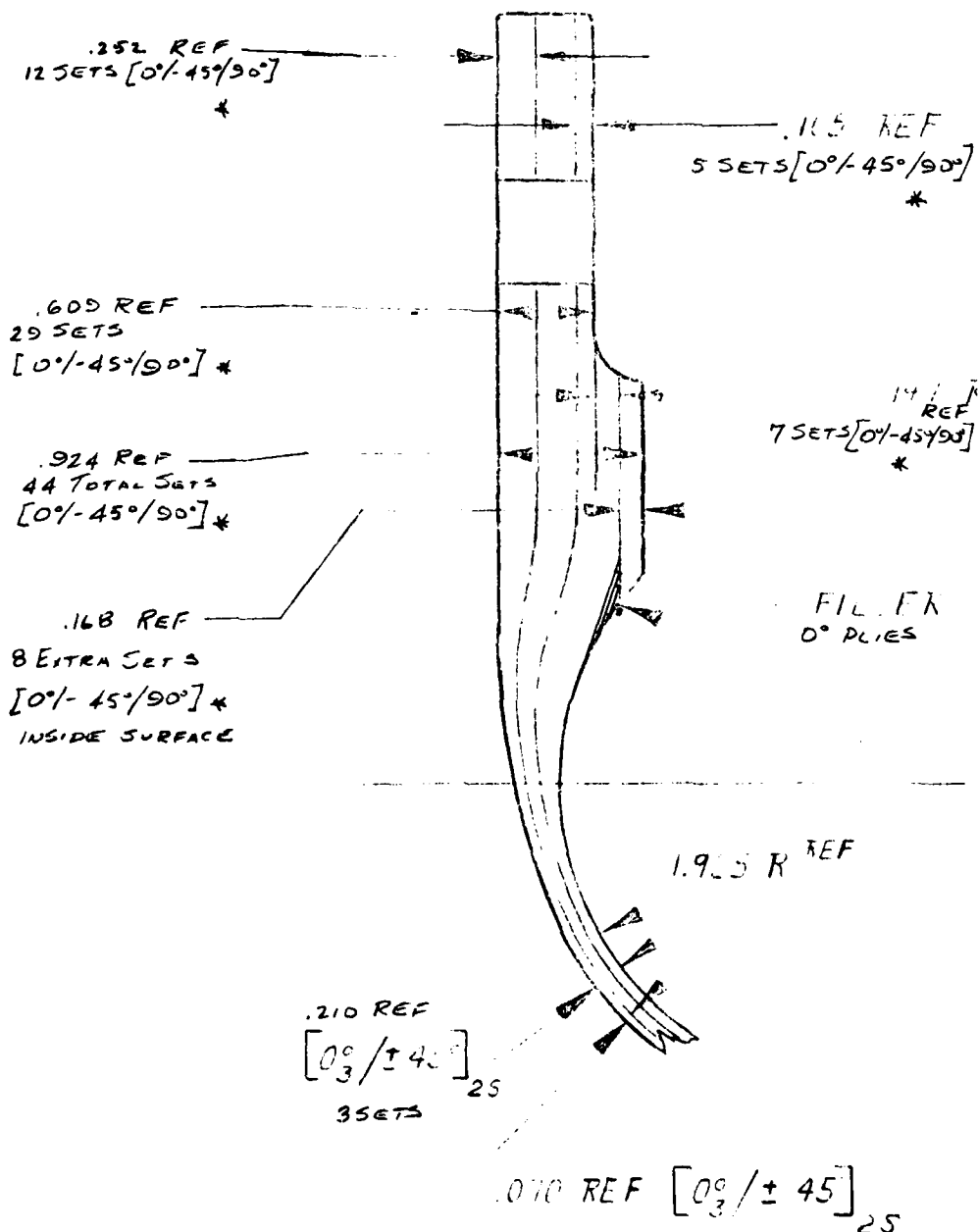
PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LAJOG GEAR - TORQUE ARM ATTACH



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-6

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR RRT
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACH



* SEE NEXT SHEET

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-1

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BIDG. _____ TITLE A-37 B LANDING GEAR - TORQUE ARM ATTACH

PLY ORIENTATION
AT BAND

ACTUAL PLY
ORIENTATION
AS SHOWN ON DWG
NO. 83008500432

PLY ORIENTATION
FOR LUGS WITH
RESPECT TO LOAD

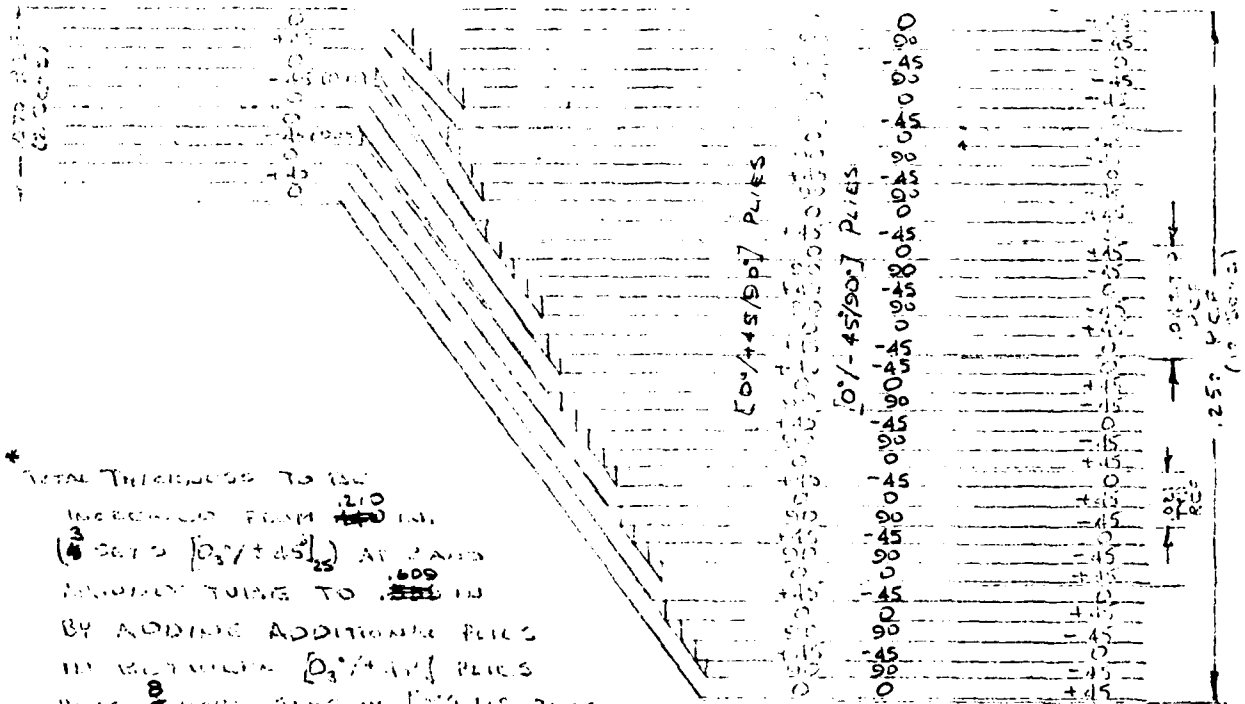
PLY ORIENTATION
FOR LUGS WITH
RESPECT TO LOAD

$[0_3/\pm 45]$ LAMINATE

R/L
LUG

L/R
LUG

$[0_3/\pm 45]$ LAMINATE



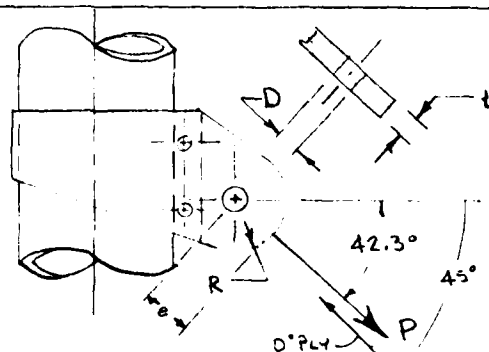
* TOTAL THICKNESS TO BE
INCREASED FROM ~~0.180~~ IN.
TO 0.210 IN. AT BAND
BY ADDING ADDITIONAL PLYS
IN BETWEEN $[0_3/\pm 45]$ PLYS
PLUS 8 MORE SETS OF $[0_3/\pm 45]$ PLYS
(PLY ORIENTATION). THE PLY ORIENTATION WAS SET UP WITH 0°
PLY PARALLEL TO ± 45° WITH RESPECT TO THE CIRCUMFERENTIAL
PLIES. THE ANALYSIS PURPOSES, DWG NO 83008500432 (FIG.)
CALLS OUT THE $[0_3/\pm 45]$ AS EITHER $[0_3/\pm 45/90]$ OR $[0_3/-45/90]$ IN
ORDER TO BE CONSISTENT WITH THE NOMENCLATURE OF THE $[0_3/\pm 45]$
PLY.

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-B

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR EET
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACH

TORQUE ARM ATTACHMENT LUG ANALYSIS - TENSILE LOAD LANDING (2C) LOAD CONDITION - CRITICAL



P DIRECTION CAN BE + OR -;
HOWEVER, DIRECTION SHOWN
IS CRITICAL CONDITION.

$$A_{br} = D \cdot t = .67 \times .609 = .408$$

$$A_t = (2R - D)t = (2 \times 1.375 - .67) \cdot .609$$

$$A_t = 1.265$$

$$A_s = 2et = 2 \times 1.333 \times .609 = 1.623$$

LAY UP: $[0^\circ/\pm 45^\circ]$ WITH 0° PLY
AS SHOWN

$$P = F = 13,960 \#$$

$$R = 1.375 \text{ IN.}$$

$$D = .67 \text{ IN.}$$

$$e = [R^2 - (\frac{D}{2})^2]^{1/2} = [(1.375)^2 - (\frac{.67}{2})^2]^{1/2} = 1.333$$

$$t = .609 \text{ IN.}$$

$$s = R - .50 \times D = 1.375 - .335 = 1.040 \text{ IN.}$$

$$s/D = \frac{1.040}{.67} = 1.552$$

$$e/D = \frac{1.333}{.67} = 1.991$$

$$D/t = \frac{.67}{.609} = 1.10$$

ASSUMING GRAPHITE TO STEEL MECH JOINT SINGLE LAP BEARING LOAD
USING CURVE ON PG 233, REF 1, FOR $s/D = 2.63$.

ALLOWABLE

$$F_{br} = 123,180 \text{ PSI.}$$

BEARING

STRESS

$$F_{br}^{\text{ALLOWABLE}} = 50\% \times F_{br} = .5 \times 123,180 = 61,590 \text{ PSI.}$$

THIS FACTOR ACCOUNTS FOR FATIGUE AND
UNCERTAINTIES IN F_{br} VALUES F_{br} IN CURVE ON
PG 62.45, REF 1 IS HIGHER ($F_{br} = 74,000 \text{ PSI, DOUBLE SHEAR,}$
 $D/t = 1.10$).

REF 1: ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN,
VOL II: MATERIAL & BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/
EPOXY, NORTH AMERICAN ROCKWELL / L.A. DIVISION, REPORT NO.

AFML-TR-70-58, SEPT 172.

2. AIR FORCE DESIGN GUIDE. 39

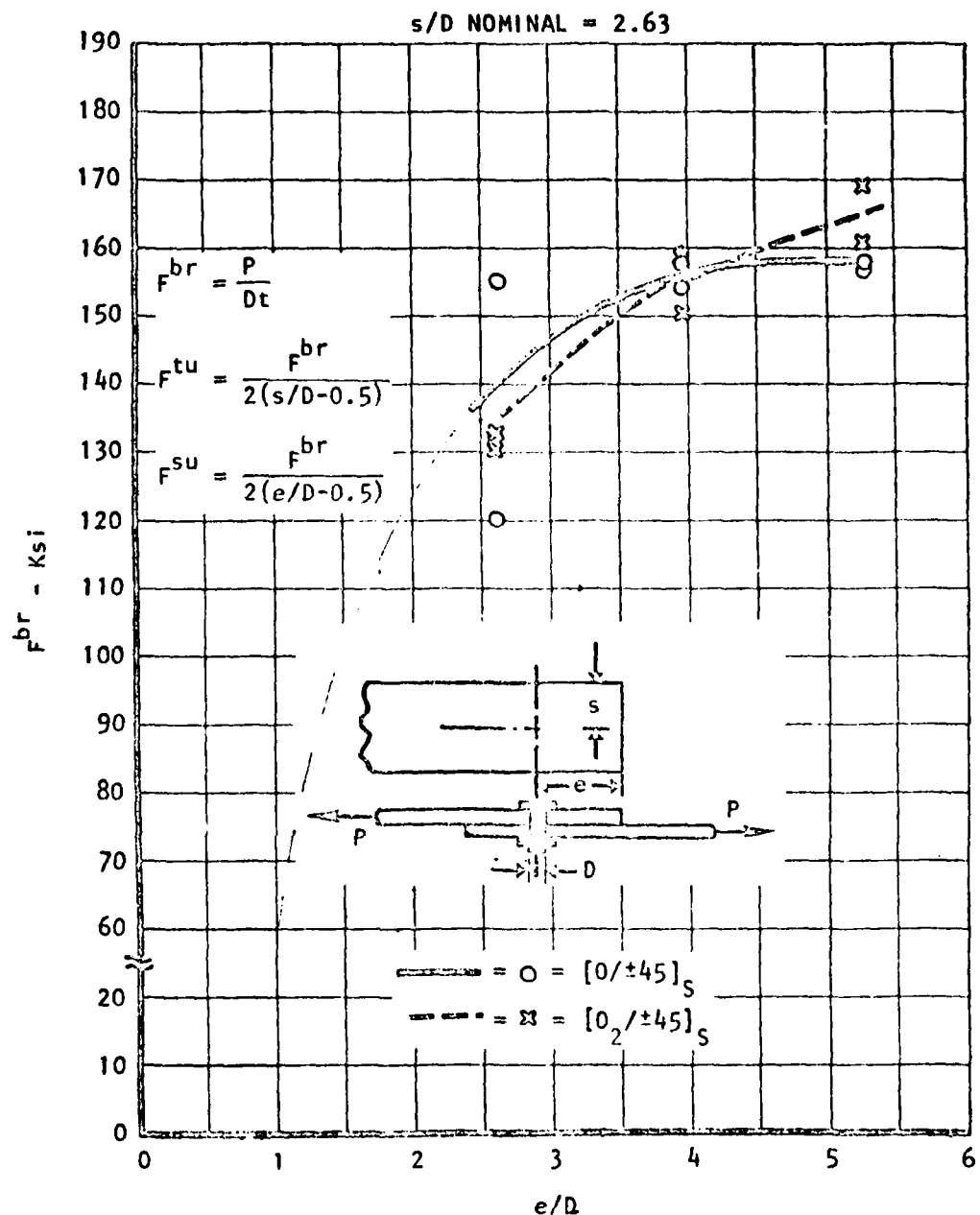


Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

REF: ADVANCED COMPOSITE DATA FOR AIRCRAFT STRUCTURAL DESIGN, VOL. II: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPoxy, NORTH AMERICAN ROCKWELL / L.A. DIVISION, REPORT # AFML-TR-70-58, SEPT. 1972

Graphite/epoxy data on equivalent bearing strength F_{br} versus D/t , for various laminate layup orientations of Narmco 5206, Type II, are presented in Figures 6.2.2.23 and 6.2.2.24, which were obtained from Reference 6.3. The design curves shown represent the lower bound data and are valid for the parameter range designated. Countersunk fastener joint data are presented in paragraph 6.2.2.1.2.

6.2.2.1.1.4 Elevated-Temperature Effects - The strength reduction in boron/epoxy test data for temperatures up to 375°F are shown in Figure 6.2.2.25 from References 6.2 and 6.25. The shearout, net-tension, and bearing temperature correction curves shown should be considered applicable only for the laminate orientations designated.

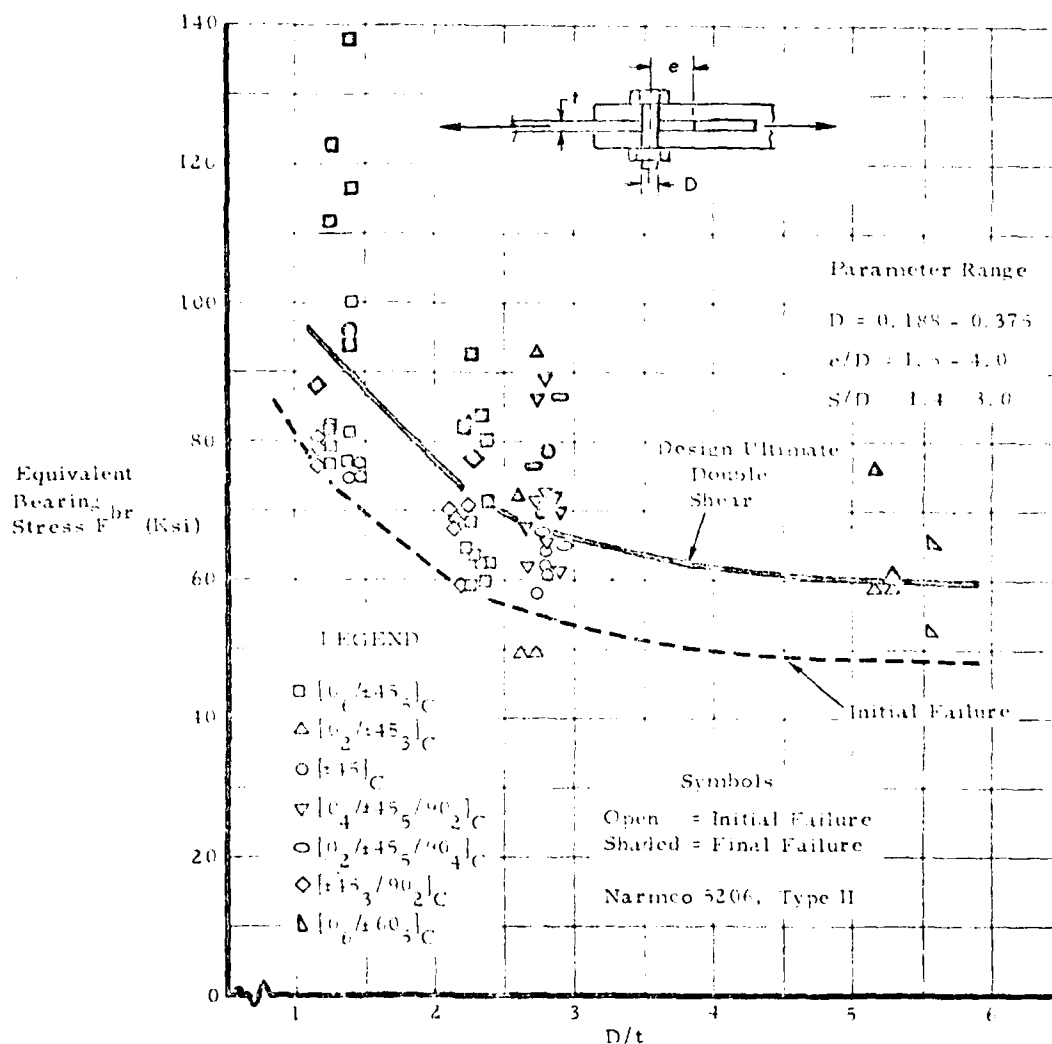


FIGURE 6.2.2.23. GRAPHITE/EPOXY MECHANICAL JOINT STRENGTH - DOUBLE SHEAR

TAKEN FROM AIR FORCE DESIGN GUIDE

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-11

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR EFT

BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

LUG ANALYSIS - TENSION, CONT'D

ALLOWABLE TENSILE STRESS

$$F_{\text{allowable}}^{\text{tu}} = \frac{F_{\text{br}}}{2(S/D - 0.5)} = \frac{61,590}{2(1.552 - .5)} = 29,300 \text{ PSI}$$

ALLOWABLE SHEAR TEAR-OUT STRESS

$$F_{\text{allowable}}^{\text{su}} = \frac{F_{\text{br}}}{2(G/D - .5)} = \frac{61,590}{2(1.991 - .5)} = 21,670 \text{ PSI}$$

CALCULATED STRESSES AND MARGINS OF SAFETY

$$F_{\text{calc}}^{\text{br}} = \frac{P}{A_{\text{br}}} = \frac{13,960}{.408} = 34,200 \text{ PSI}$$

BEARING

$$M.S. = \frac{61,590}{34,200} - 1 = +1.801$$

TENSILE

$$F_{\text{calc}}^{\text{tu}} = \frac{P}{A_{\text{t}}} = \frac{13,960}{1.265} = 11,030 \text{ PSI}$$

$$M.S. = \frac{29,300}{11,030} - 1 = +1.656$$

TEAR-OUT SHEAR

$$F_{\text{calc}}^{\text{su}} = \frac{P}{A_{\text{s}}} = \frac{13,960}{1.623} = 8590 \text{ PSI}$$

$$M.S. = \frac{21,670}{8590} - 1 = +1.523$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

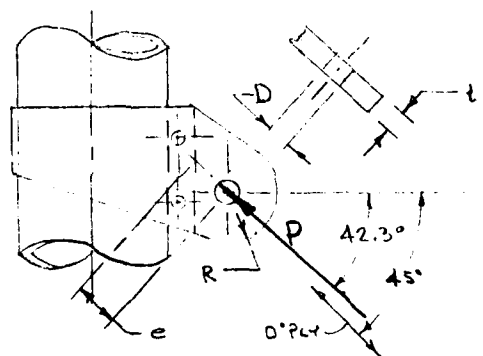
SKETCH NO. II-12

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR E.R.T
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMT

LUG ANALYSIS, COMPRESSIVE LOAD

LANDING (2C) LOAD CONDITION - CRITICAL

MAGNITUDE AND ANGLE ARE SAME AS FOR TENSILE LOAD
EXCEPT DIRECTION IS OPPOSITE TO THAT SHOWN ON
PG



P DIRECTION CAN BE + OR -;
HOWEVER, DIRECTION SHOWN
IS CRITICAL CONDITION.

LAY UP: $[0^\circ/\pm 45^\circ]_3$ WITH
0° PLY AS SHOWN

$$P = -F = -13,960^{\circ}$$

$$R = 1.375 \text{ IN.}$$

$$D = .67 \text{ IN}$$

$$e = \frac{.950 + 2.420}{2} = 1.685 \text{ IN}$$

$$t = .609 \text{ IN}$$

$$S = R - .5 \times D = 1.375 - .335 = 1.040 \text{ IN}$$

$$s/D = \frac{1.040}{.67} = 1.552$$

$$e/D = \frac{1.685}{.67} = 2.516$$

$$D/t = \frac{.67}{.609} = 1.10$$

$$A_{br} = D \times t = .67 \times .609 = .408$$

$$A_2 = (2R - D)t = (2 \times 1.375 - .67) \times .609 = 1.265$$

$$A_3 = 2et = 2 \times 2.516 \times .609 = 3.065$$

ALLOWABLE BEARING STRESS

USING CURVE ON PG

FOR $e/D = 2.516$, ASSUMING
COMPRESSIVE LOADING

$$F_{br \text{ allowable}} = \frac{F_{br \text{ curve}}}{2} = \frac{-138,000}{2} = -69,000 \text{ PSI}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-13

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

LUG ANALYSIS, COMPRESSIVE LOAD (CONT'D)

ALLOWABLE COMPRESSIVE STRESS

$$F_{cu} = \frac{F_{br}^{all}}{2(3/0-.5)} = \frac{-69,000}{2(1.552-.5)} = -32,795 \text{ PSI}$$

ALLOWABLE SHEAR TEAR OUT STRESS

$$F_{su} = \frac{F_{br}^{all}}{2(2/0-.5)} = \frac{-69,000}{2(2.516-.5)} = -17,117 \text{ PSI (MAKE IT -10,000 PSI FOR INTERLAMINAR SHEAR)}$$

CALCULATED STRESSES AND MARGINS OF SAFETY — COMPRESSIVE LOADS

BEARING

$$F_{br}^{calc} = \frac{-13,960}{.408} = -34,200 \text{ PSI}$$

$$M.S. = \frac{-69,000}{-34,200} - 1 = +1.017$$

COMPRESSION

$$F_{cu}^{calc} = \frac{-13,960}{1.265} = -11,030 \text{ PSI}$$

$$M.S. = \frac{-32,795}{-11,030} - 1 = +1.973$$

INTERLAMINAR SHEAR

$$F_{br}^{calc} = \frac{-13,960}{3.065} = -4555 \text{ PSI}$$

$$M.S. = \frac{-10,000}{-4,555} - 1 = +1.195$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

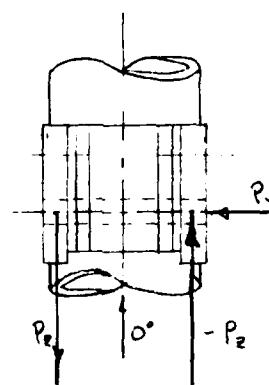
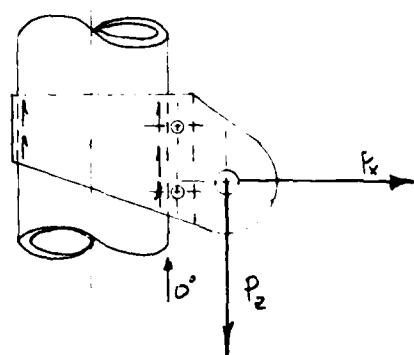
SKETCH NO. II-14

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT SHEAR STRESSES IN BOND TO TUBE

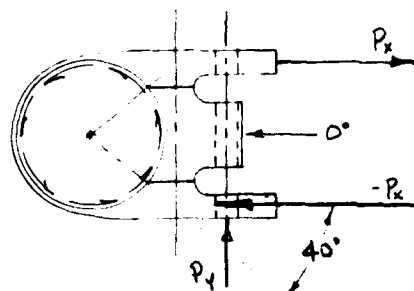
CRITICAL LOAD CONDITION:

	2C LANDING	5A STATIC
$P_x = 10,303 \text{ #}$		10,168
$P_z = 9,375$		5,871
$P_y = 9,776$		8,240



LANDING COND
IS WORST IN EA.
CASE 5 WILL
THEREFORE BE
ANALYZED.

H = MEDIAN HEIGHT
= 2.4 IN



ULT. ALLOWABLE SHEAR = 4750 PSI
(MT R.T. FOR HYSOL'S EA #9300)

0° FOR P_z WILL BE ASSUMED
TO BE 40° FROM ACTUAL 0°
SO AS TO BE EFFECTIVE ON
CLAMP. IT MAY NOT BE EF-
FECTIVE ON MIDDLE BLOCK.

FOR P_x , CASE B, FIG. , P_0 APPLIES AND FOR P_z ,
CASE 1, FIG. , P_0 APPLIES.

REF: ENG'G ANALYSIS - ANALYTICAL TECHNIQUES, VOL. I, APR. 1966

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-15

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LANDING GEAR-TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT SHEAR STRESSES IN BOND TO TUBE

SHEAR DUE TO P_z AT 40° (0°)

$$V_{MAX} = P_z C_{UP} =$$

$C_{UP} = .50$, FROM CASE 1 CURVE

$$= 9375 \times .5 = 4688 \text{ #/IN}$$

$$H_{40^\circ} = 2.92''$$

$$\tau_z = \frac{V_{MAX}}{H_{40^\circ}} = \frac{4688}{2.92} = 1605 \text{ PSI}$$

SHEAR DUE TO P_x AT 90°

$$V_{MAX} = P_x \times K_Q = 10,303 \times .32$$

$K_Q = .32$, FROM CASE B CURVE

$$V_{MAX} = 3,297 \text{ #/IN}$$

$$H_{90^\circ} = 2.45''$$

$$\tau_x = \frac{V_{MAX}}{H_{90^\circ}} = \frac{3,297}{2.45} = 1346 \text{ PSI}$$

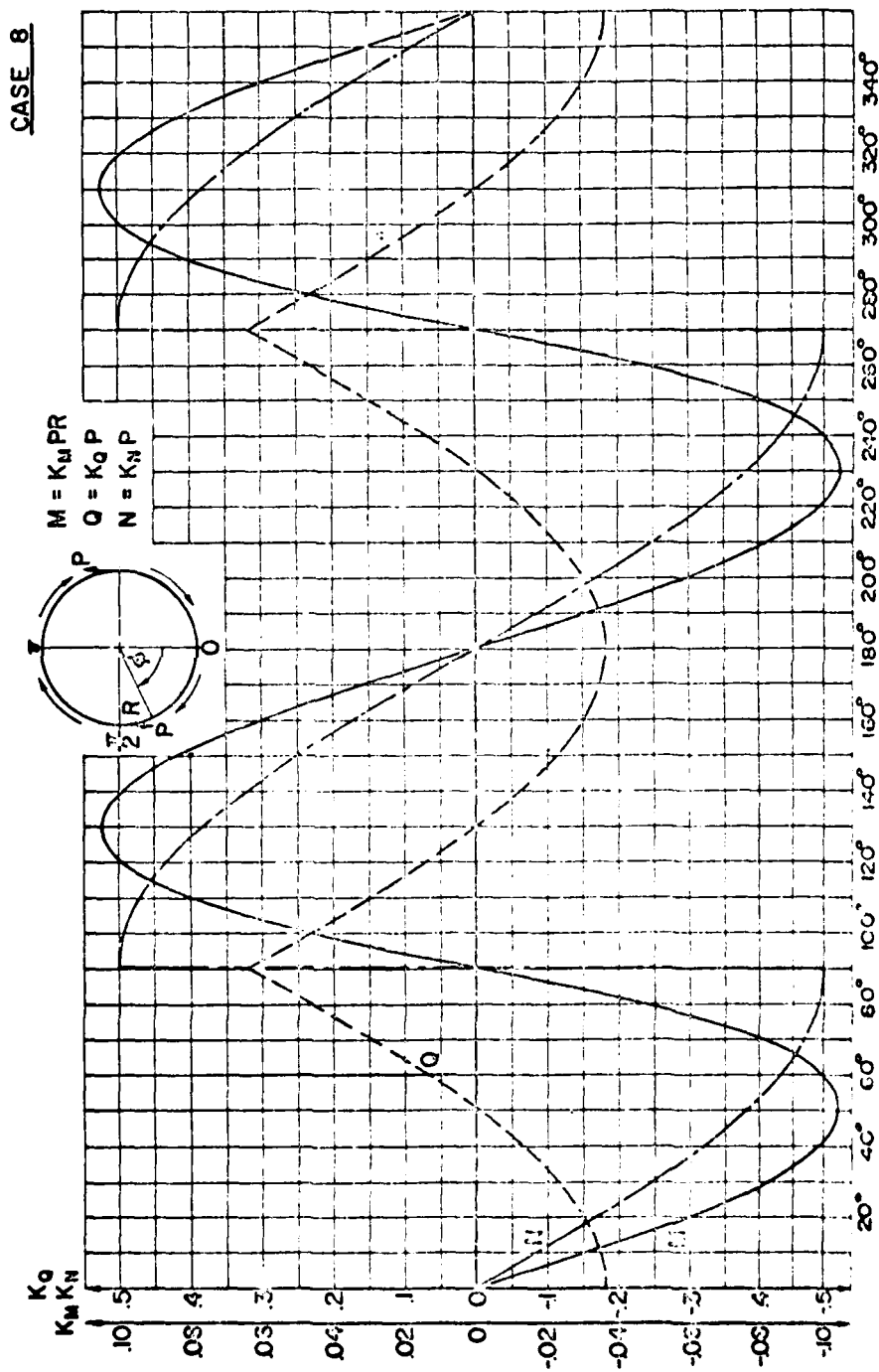
COMBINED SHEAR (ASSUMING BOTH SHEAR STRESSES IS AT THE SAME POINT)

$$\tau_{xz} = \left[(1346)^2 + (1605)^2 \right]^{1/2} = 2092 \text{ PSI}$$

$$M.S. = \frac{4750}{2092} - 1 = +1.271$$

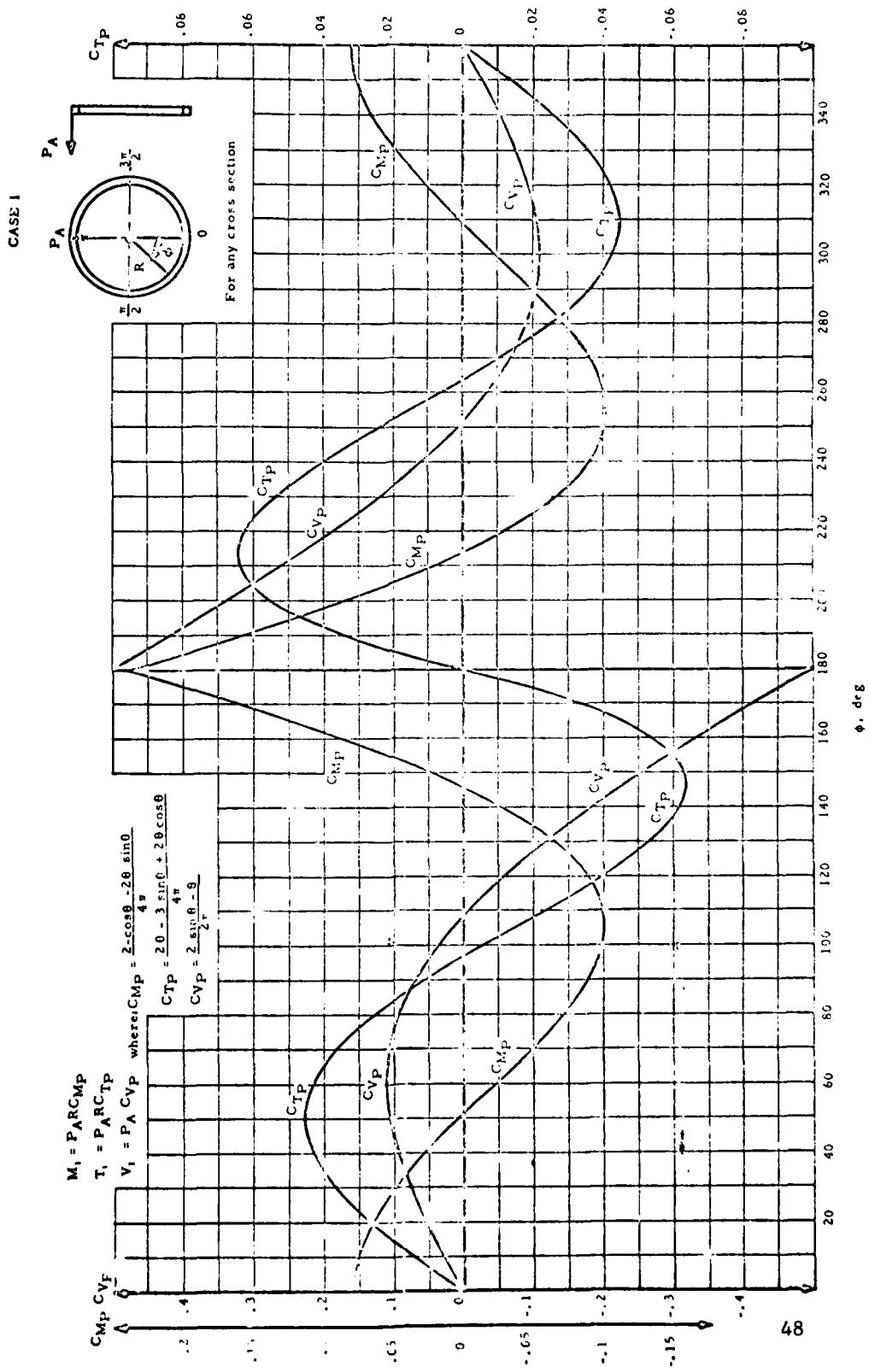
Section B 6
15 September 1961
Page 24

B 6.1.1 In-Plane Load Cases (Cont'd)



B 6.1.2 Out-of-Plane Load Cases (Cont'd)

Section B6
July 9, 1964
Page 58.1



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-18

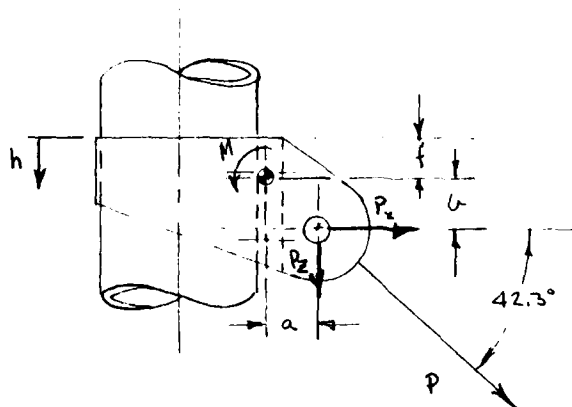
PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT

BLDG. _____ TITLE A-37B LANDING GEAR-TORQUE ARM ATTACHMENT

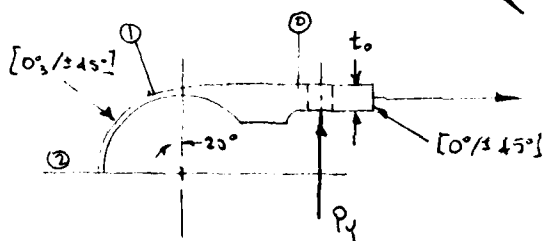
TORQUE ARM ATTACHMENT
STRESSES IN BAND

ULT. ALLOWABLES FOR $[0^\circ/\pm 45^\circ]$
LAY-UP

$$\begin{aligned} \sigma_x &= 72,000 \text{ PSI} & \sigma_y &= 12,000 \text{ PSI} \\ \tau_{xy} &= 20,000 & \text{INTERLAMINAR SHEAR} &= 12,000 \text{ PSI} \end{aligned}$$



$$\begin{aligned} h_0 &= 3.28 \text{ IN.} & P &= F = 13,931 \text{ LBS} \\ h_1 &= 2.21 \text{ IN.} & P_1 &= 10,303 \text{ LBS} \\ h_2 &= 1.75 \text{ IN.} & P_2 &= 9,375 \text{ LBS} \\ a &= 1.250 \text{ IN.} & P_4 &= 9,776 \text{ LBS} \\ u &= 1.138 \text{ IN.} & t_0 &= .609 \\ f &= 1.112 \text{ IN.} & h_0 &= 3.35 \text{ IN.} \\ & & t_1 = t_2 &= .210 \text{ IN.} \end{aligned}$$


SHEAR STRESS AT (O) DUE TO P_4

$$e = [(1.375)^2 - (.677)^2] = 1.197 \text{ IN.}$$

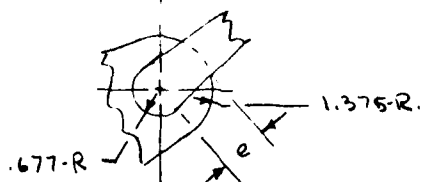
$$\tau_y = \frac{P_4}{\pi r + 2e} = \frac{9776}{\pi(.677) + 2(1.197)}$$

$$\tau_y = 2,162 \text{ PSI}$$

ULTIMATE ALLOWABLES FOR $[0^\circ/\pm 45^\circ]$
 $\phi = 60^\circ$

$$\begin{aligned} \sigma_x &= 52,000 \text{ PSI} & \sigma_y &= 14,000 \text{ PSI} \\ \tau_{xy} &= 20,000 \text{ PSI} \end{aligned}$$

INTERLAMINAR SHEAR = 12,000 PSI


SHEAR STRESSES AT (O) DUE TO P_2

$$\tau_z = \frac{P_2}{h_0 t} = \frac{9375}{3.35 \times .609} = 4,595 \text{ PSI}$$

COMBINING BOTH SHEAR STRESSES AT (O) - $(\tau_y + \tau_z)$

$$\tau_{yz} = \sqrt{\tau_y^2 + \tau_z^2} = [(2,162)^2 + (4,595)^2]^{1/2}$$

$$\tau_{yz} = 5,075 \text{ PSI}$$

$$M.S. = \frac{20,000}{5,075} - 1 = +2.941$$

DESIGN PROPERTIES (T/F)
 FOR 60% FINE VIB.
 AIR CURED 2002/04/04 U.S. P.S.W.

II-19

	<u>0°/345°</u>	<u>0°/345°</u>	<u>0°/345°</u>	<u>0°/345°</u>	<u>0°/345°</u>
ρ_{comp}	8.45	11.01	11.81	7.15	14.38
$\rho_{\text{g, comp}}$	5.52	2.45	2.71	3.01	1.66
ρ_{g}	0.30	0.05	0.03	0.11	0.53
$\rho_{\text{g, comp}}$	2.11	2.11	1.87	3.03	1.26

THEORETICAL

CHANGES

$\Delta \rho_{\text{g, comp}} / \rho_{\text{g, comp}} \times 10^6$	+0.369	-0.345	-0.352	-0.274	-0.231
$\Delta \rho_{\text{g}} / \rho_{\text{g}} \times 10^6$	+1.250	+4.116	+4.712	+2.471	+7.466

THEORETICAL

FOR

$\rho_{\text{comp, P-1}} \times 10^3$	58,400	66,110	72,000	41,000	83,500
$\rho_{\text{comp, P-2}} \times 10^3$	58,400	66,110	72,000	41,000	83,500
$\rho_{\text{g, comp, P-1}} \times 10^3$	37,950	16,850	18,410	20,700	11,400
$\rho_{\text{g, comp, P-2}} \times 10^3$	37,950	21,300	20,070	23,170	15,470
$\rho_{\text{g, P-1}} \times 10^3$	21,050	21,050	19,200	30,420	12,580

DESIGN PROPERTIES (77°F)
 FOR
 AS/2002 GRAPHITE/.688% ULT. RESIN [0°/±45°]
 60% FIBER VOL.
 QUASI - ORTHOTROPIC

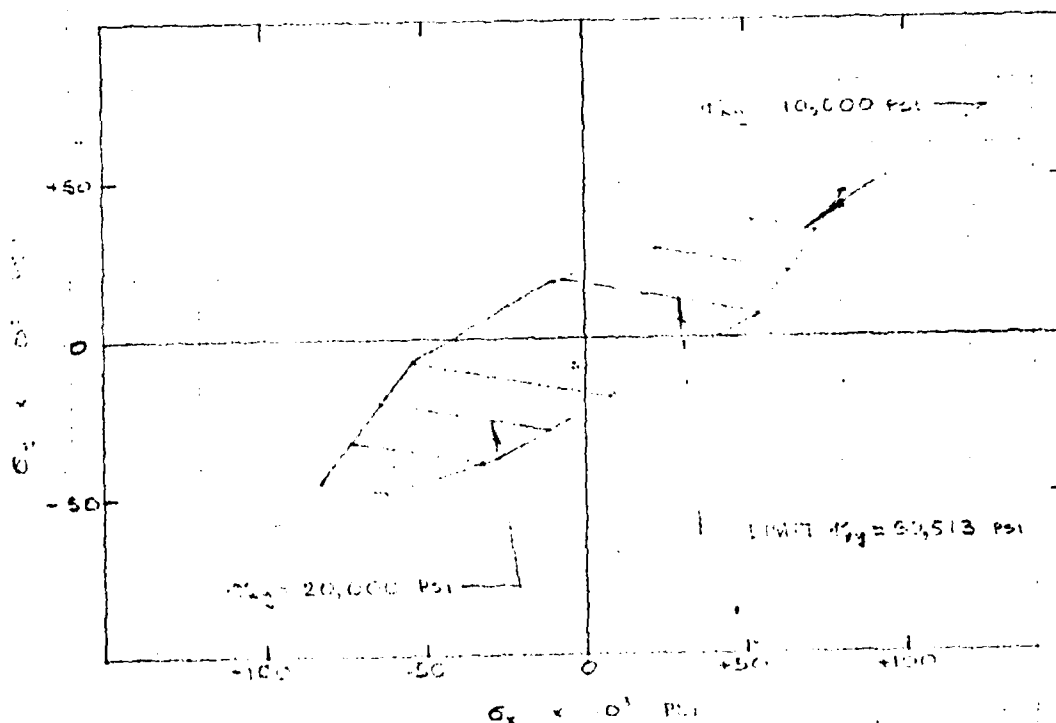
ELASTIC CONSTANTS

$$\begin{aligned} E_x &= 7.15 \times 10^6 \text{ PSI} \\ E_y &= 3.01 \times 10^6 \text{ PSI} \\ \nu_{xy} &= 0.71 \\ G_{xy} &= 3.09 \times 10^6 \text{ PSI} \end{aligned}$$

THERMAL COEFFICIENTS

$$\begin{aligned} \alpha_x &= -0.274 \text{ in/in/°F} \times 10^{-6} \\ \alpha_y &= +2.471 \text{ in/in/°F} \times 10^{-6} \end{aligned}$$

"LIMIT" INTERACTION CURVE



MECHANICAL PROPERTIES (T/F)
 FOR
 AS / 2002 GRAPHITE / 685 % VOL. RESIN [$G_{32} / \pm 45^\circ$]
 60 % FIBER VOL.
 Q-VALUE - ORTHOTROPIC

ELASTIC CONSTANTS

$$E_x = 11.03 \times 10^6 \text{ PSI}$$

$$E_y = 2.45 \times 10^6 \text{ PSI}$$

$$\nu_{xy} = 0.45$$

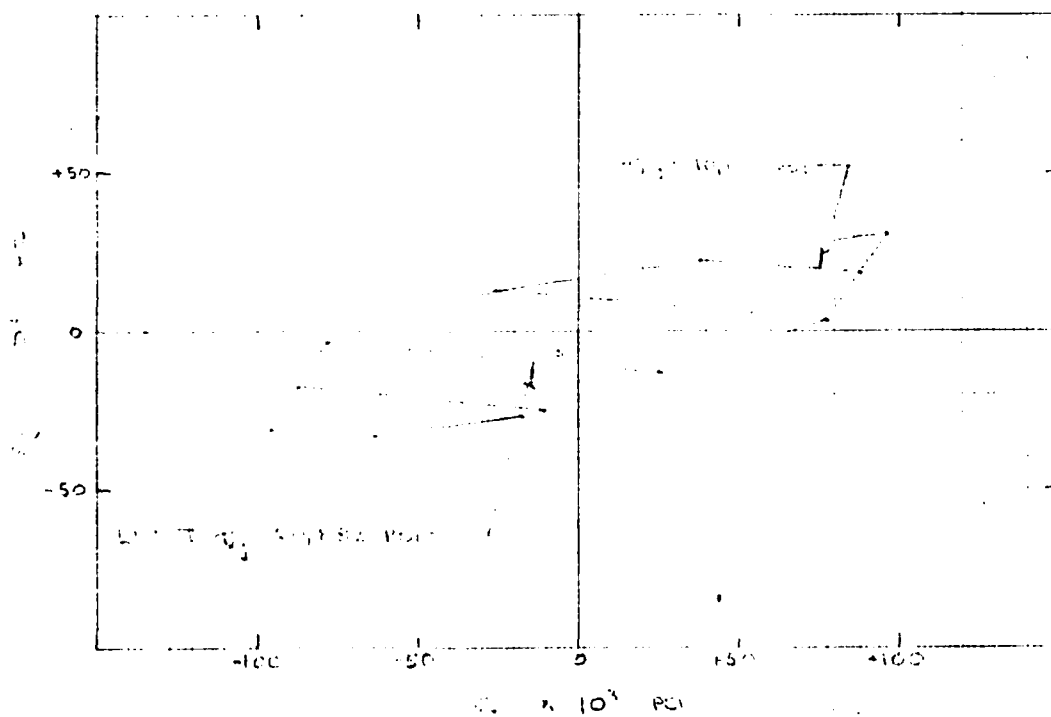
$$G_{xy} = 2.11 \times 10^6 \text{ PSI}$$

THERMAL COEFFICIENTS

$$\alpha_x = -0.345 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

$$\alpha_y = +4.116 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

THERMAL INTERACTION CURVE



DESIGN PROPERTIES (77°F)
 FOR
 2002 AG ($G_{11} = G_{22} = .60\%$) / 60% GRAPHITE FIBER VOL.
 [0°/45°] WITH $\phi = 1.6$
 QUASI-ORTHOTROPIC

Elastic Properties

$$E_x = 7.23 \times 10^6 \text{ PSI} \quad \nu_{xy} = 0.294$$

$$E_y = 3.07 \times 10^6 \text{ PSI} \quad G_{xy} = 2.95 \times 10^5 \text{ PSI}$$

Thermal Coefficients

$$\alpha_x = -0.155 \text{ in/in/°F} \times 10^{-6} \quad \alpha_y = 12.4115 \text{ in/in/°F} \times 10^{-6}$$

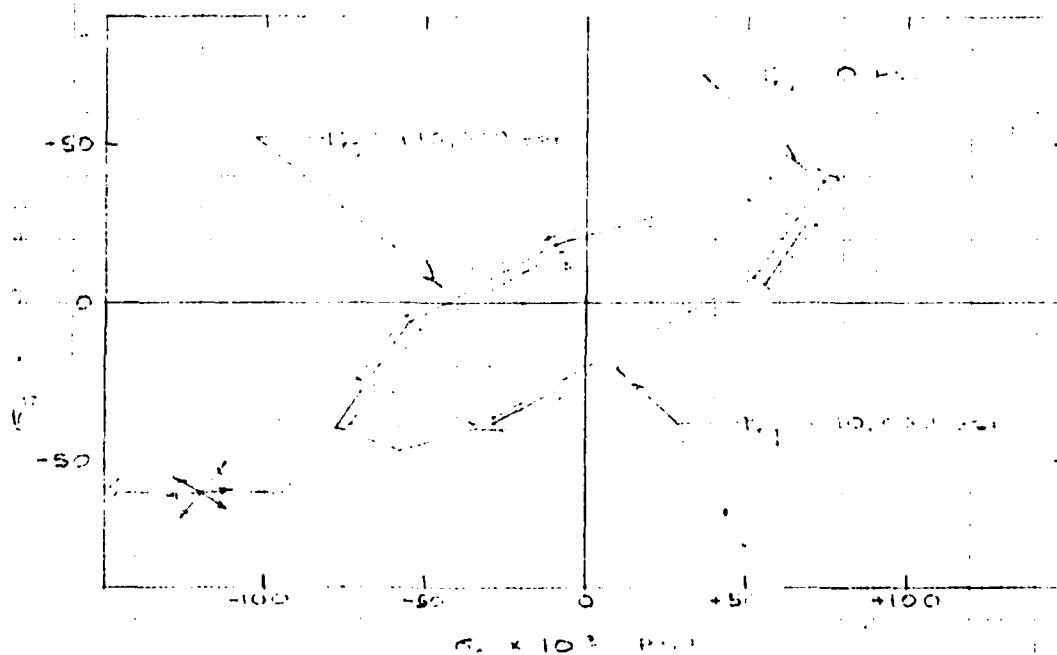
Limit Strengths

$$\sigma_{xL} = 43,010 \text{ PSI} \quad \sigma_{yL} = 21,030 \text{ PSI}$$

$$\sigma_{xU} = 43,130 \text{ PSI} \quad \sigma_{yU} = 23,570 \text{ PSI}$$

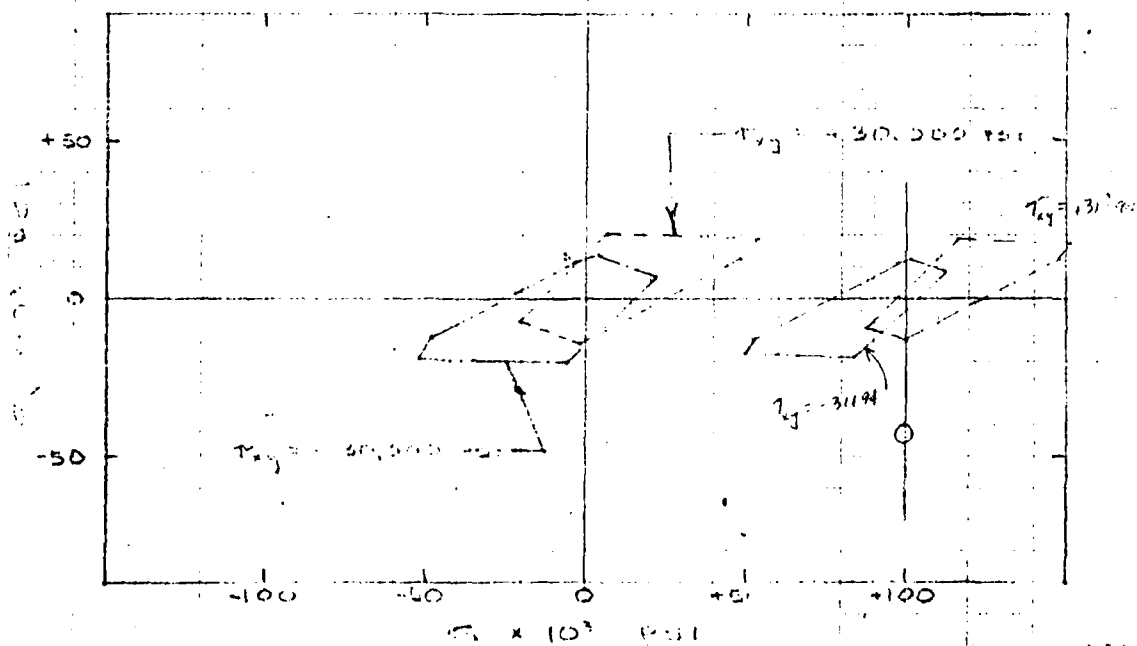
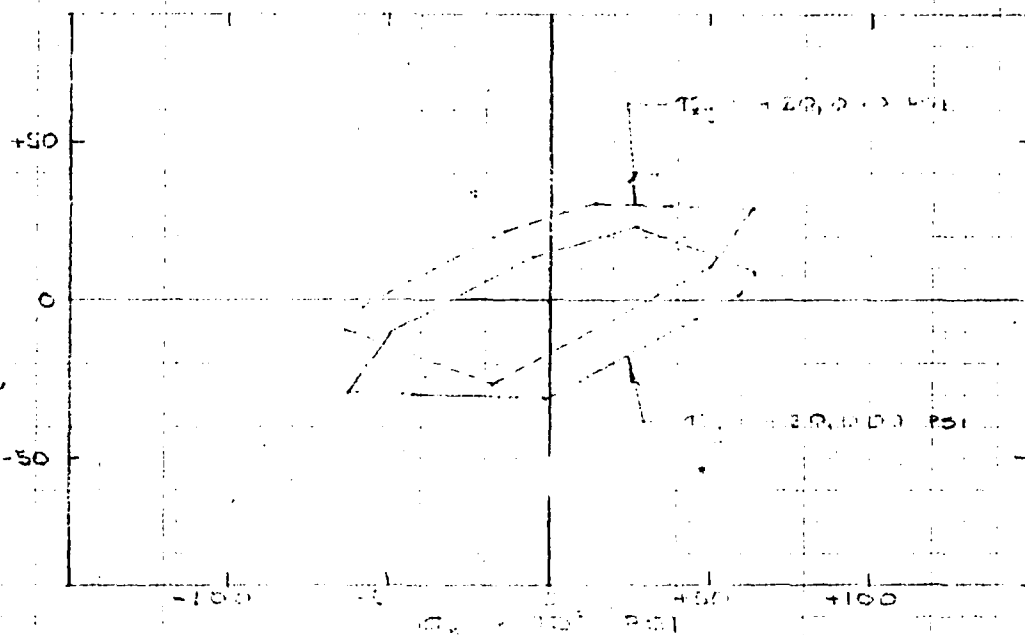
$$\tau_{xy} = 31,510 \text{ PSI}$$

Interaction Diagrams



2002 AS ($\epsilon_1 = \epsilon_2 = .69\%$) / 60% CARBON FIBER VOL.
 [$0^\circ / \pm 45^\circ$] WITH $\phi = 16^\circ$
 (SHEET 2)

INTERACTION CURVES



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-24

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR E.R.T.
BLDG. _____ TITLE A-373 LANDING GEAR - TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT

STRESSES IN BAND

STRESSES AT (0) DUE TO P_1 & P_2

$$a_o = .93 \text{ in}; b_o = .84"; t_o = .609"; h_o = 3.35 \text{ in.}$$

$$\sigma_z = \frac{P_z}{t_o \times h_o} = \frac{10,303}{.609 \times 3.35} = 5,050 \text{ PSI}$$

$$I_o = \frac{t_o h_o^3}{12} = \frac{.609(3.35)^3}{12} = 1.90796 \text{ in}^4$$

$$c_o = h_o - f_o = 3.35 - 1.30 = 2.05 \text{ in.}$$

$$M_o = -b_o \times P_1 + P_2 \times a_o = -.84 \times 10,303 + .93 \times 9375 = +64.23 \text{ IN-LBS}$$

$$\sigma_{bz_o} = \frac{M_o c_o}{I_o} = \frac{64.23 \times 2.05}{1.908} = 69.0 \text{ PSI}$$

COMBINING BOTH STRESSES AT (0)

$$\sigma_{to} = \sigma_z + \sigma_{bz_o} = 5,050 + 69 = 5,119 \text{ PSI}$$

$$M.S. = \frac{51,000}{5,119} - 1 = +9.174$$

STRESSES AT (1) DUE TO P_1 & P_2

$$M_o = -P_1 \times b + P_2 \times a = -10,303 \times 1.138 + 9375 \times 1.250 =$$

$$M_o = -6.1 \text{ IN-LBS}$$

$$I_1 = \frac{.210(2.21)^3}{12} = .18880 \text{ in}^4$$

$$c_1 = \frac{h_1}{2} = \frac{2.21}{2} = 1.105 \text{ in}$$

BENDING STRESSES AT (1)

$$\sigma_{b_1} = \frac{M c}{I} = \frac{6.1 \times 1.105}{.19} = \mp 35.5 \text{ PSI}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-25

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR E.R.
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT
STRESSES AT BANG
STRESSES AT (1)

TENSILE STRESSES AT (1)

$$\sigma_{e1} = \frac{P_k}{t_1 \times h_1} = \frac{10,303}{.210 \times 2.21} = +22,200 \text{ PSI}$$

BENDING STRESSES DUE ECCENTRICITY AT (1)

$$\sigma_{be1} = \frac{P_k \left(\frac{h_1}{2} - f \right) \times C_1}{I_1} = \frac{10,303 \left(\frac{2.21}{2} - 1.112 \right) \times 1.105}{.1889}$$

$$\sigma_{be1} = +422.2 \text{ PSI}$$

TOTAL TENSILE STRESSES AT (1)

$$\sigma_{t1} = \sigma_b + \sigma_{e1} + \sigma_{be1} = 35.5 + 22,200 + 422.2$$

$$\sigma_{t1} = 22,658 \text{ PSI}$$

$$M.S. = \frac{72,000}{22,658} - 1 = +2.178$$

STRESSES AT (2)

$$I_2 = \frac{.21 (1.75)^3}{6} = .10712 \times 10^3$$

BENDING AT (2)

$$\sigma_{b2} = \frac{6.1}{.107} = +57 \text{ PSI}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-26

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT

STRESSES AT BAND

STRESSES AT (2)

TENSILE AT (2)

$$\sigma_{t2} = \frac{10,303}{.210 \times 1.75} = +28,035 \text{ PSI}$$

ECCENTRICITY AT (2)

$$\sigma_{e2} = \frac{10,303 \left(\frac{1.75}{2} - 1.112 \right)}{.1072} = \mp 22,778 \text{ PSI}$$

TOTAL TENSILE STRESSES AT (2)

$$\sigma_{t2} = \sigma_{b2} + \sigma_{e2} + \sigma_{b2} = \mp 57 + 28,035 \mp 22,778$$

$$\sigma_{t2} = +50,870 \text{ PSI}$$

$$M.C. = \frac{72,000}{50,870} - 1 = +.415$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II-27

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR ERT
BLDG. _____ TITLE A-37B LANDING GEAR - TORQUE ARM ATTACHMENT

TORQUE ARM ATTACHMENT

SUMMARY OF MARGINS OF SAFETY

LUG LOADS

TENSION	BEARING	M.S. = +1.801
	TENSILE	M.S. = +1.656
	TEAR-OUT SHEAR	+1.523

COMPRESSION

BEARING	+1.017
COMPRESSION	+1.973
INTERLAMINAR SHEAR	+1.195

BAND LOADS

BONDING TO TUBE (SHEAR)	+1.271
-------------------------	--------

STRESSES AT (0)

SHEAR	+2.841
TENSION	+9.174

STRESSES AT (1)

TENSION	+2.178
---------	--------

STRESSES AT (2)

TENSION	+ .415
---------	--------

APPENDIX A
PART III
DESIGN ANALYSIS
OF
THE OUTER CYLINDER/TRUNNION

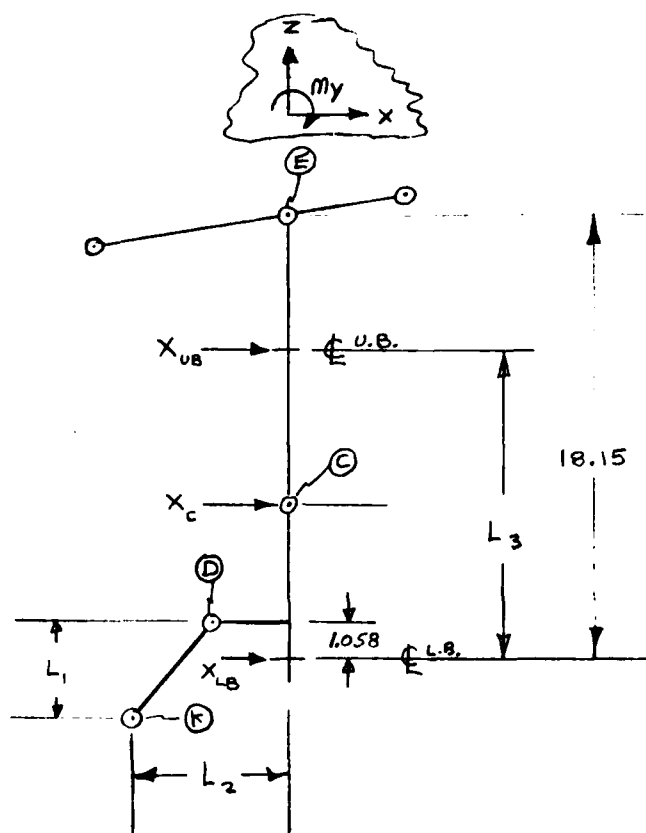
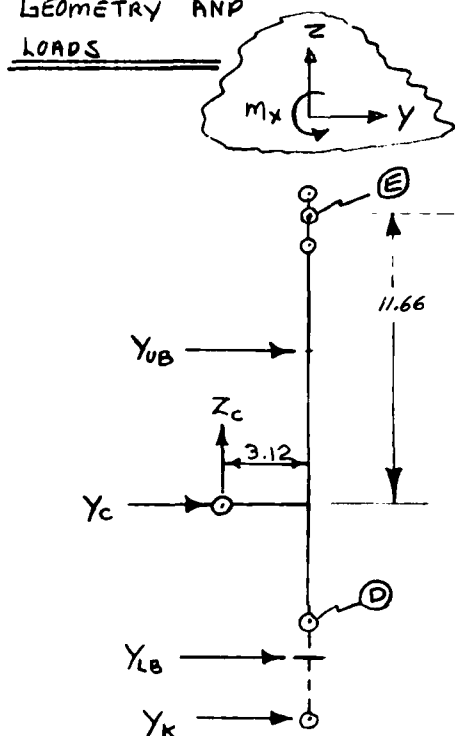
HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-1

SKETCH NO. _____

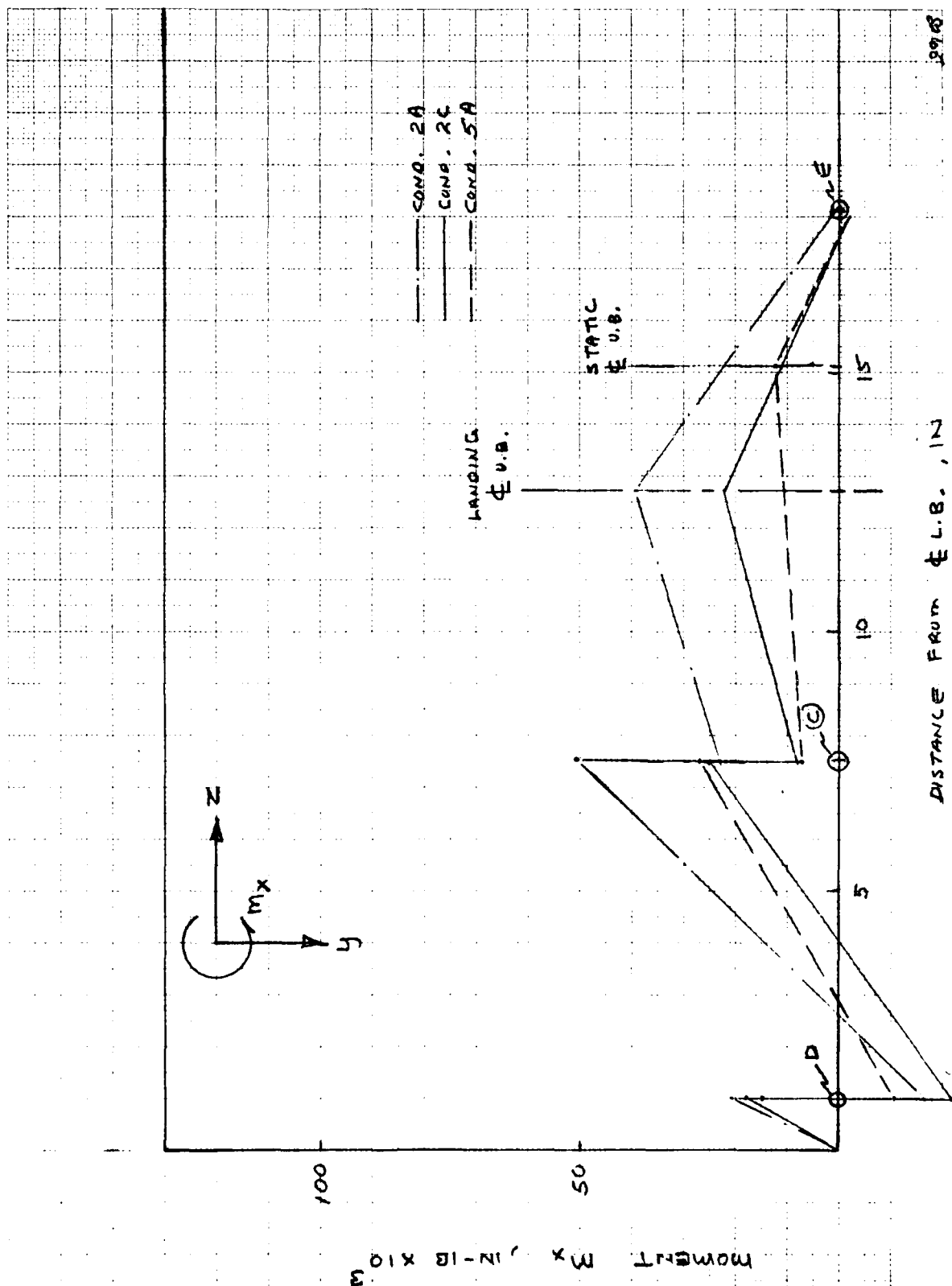
PLANT BACCHUS PROJECT NO. _____ DATE _____ AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEAR

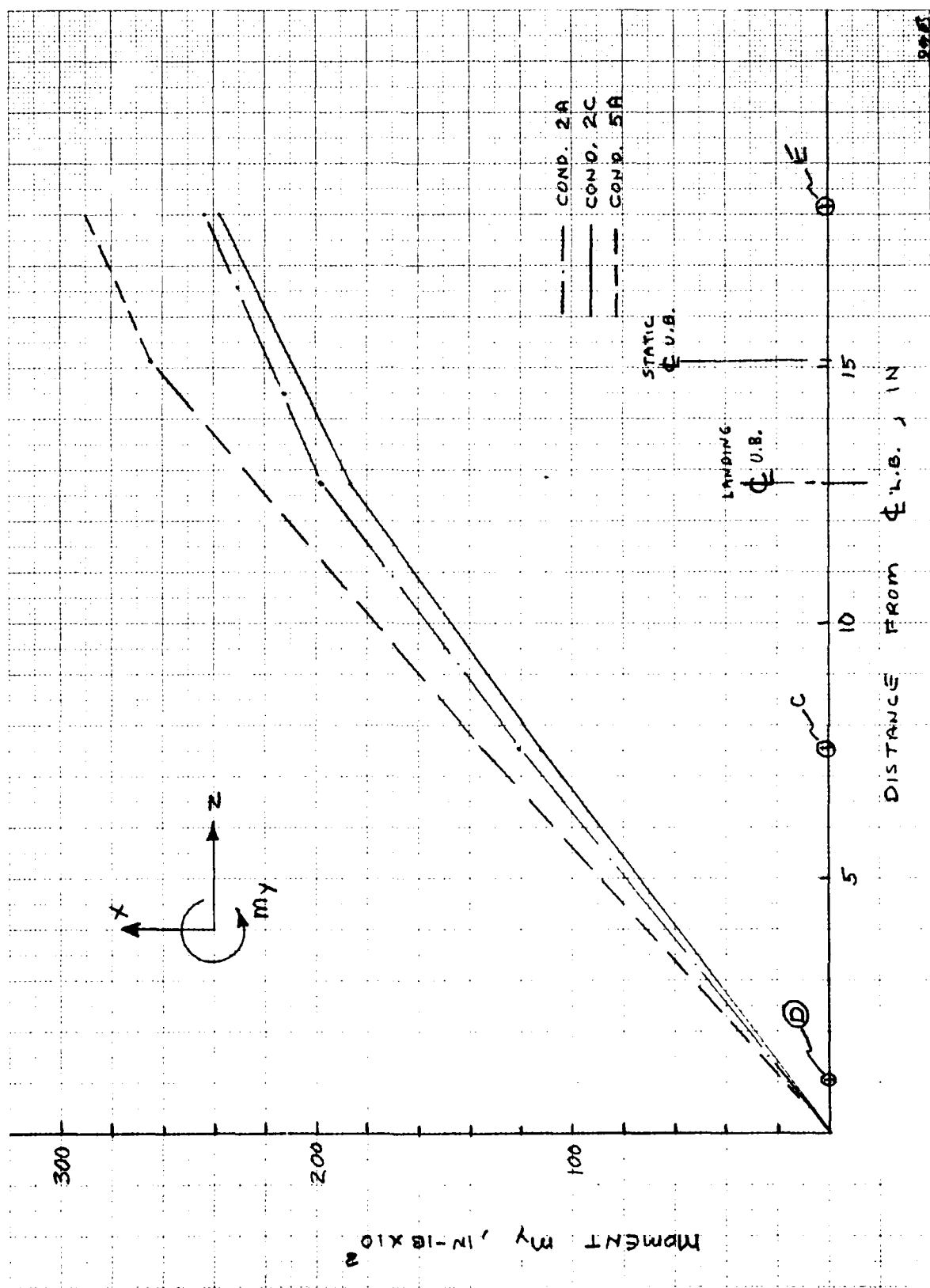
OUTER CYLINDER GEOMETRY AND LOADS

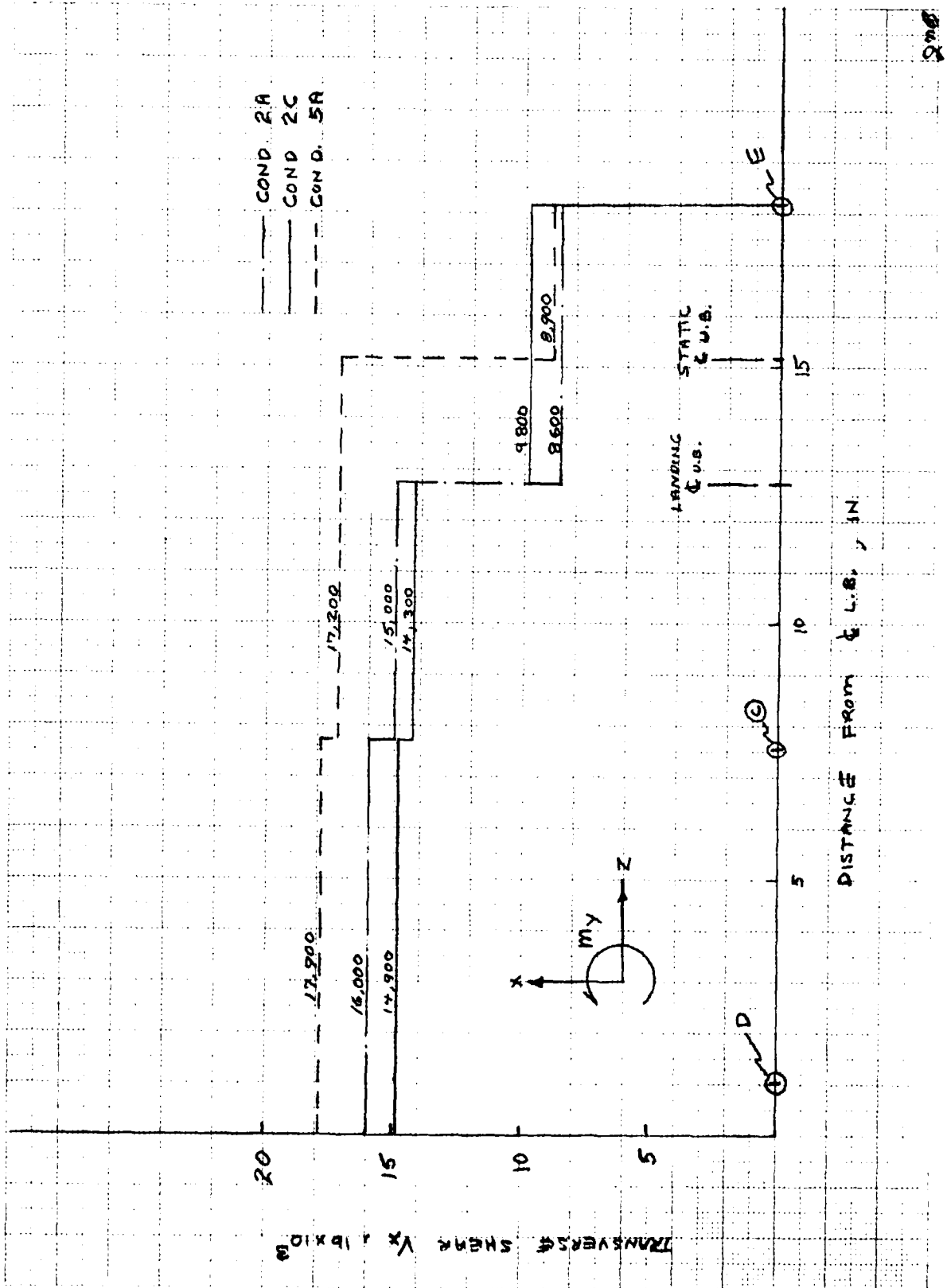


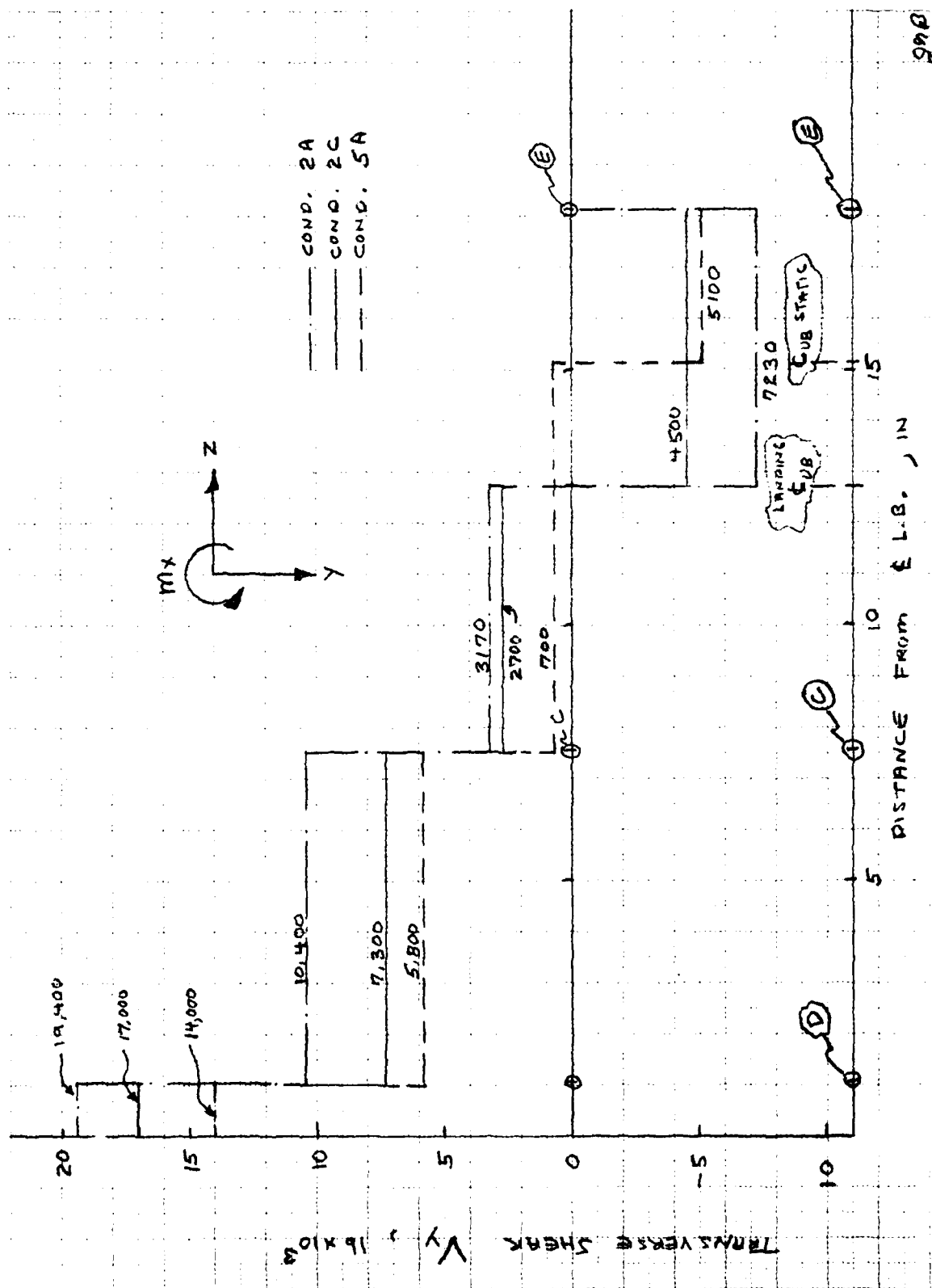
	STATIC	LANDING
L ₁	3.118	4.128
L ₂	8.000	8.740
L ₃	15.120	12.720

Load Condition			X _{LB}	Y _{LB}	Y _K	X _C	Z _C	Y _C	X _{U.B}	Y _{U.B}
2 Pt. Level Landing	Max. Vert.	1A	-9500	-15300	5200	1100	-9300	7500	3900	10100
	Spin-up	1B	12100	3900	-6800	500	-4100	3300	-4800	2900
	Spring Back	1C	-16200	-18200	9100	900	-7600	6200	6400	9100
Tail Down Landing	Max. Vert.	2A	-16000	-19400	9000	1000	-8900	+7230	6400	10400
	Spring Back	2C	-14900	-17000	9700	600	-5600	4600	4500	7200
Drift Landing	Right	3A	-1400	6100	300	-1000	9000	-7300	500	-1800
	Left	3B	-1400	-21000	1600	2600	-22600	18300	500	13300
Braked Roll		4A	14700	1300	-6100	700	-6300	5100	-7500	4800
Reverse Brake		5A	-17900	-14000	8200	700	-6300	5100	8300	5800
Right Turn		6A	-1800	-19100	1700	2600	-22700	18400	500	11600



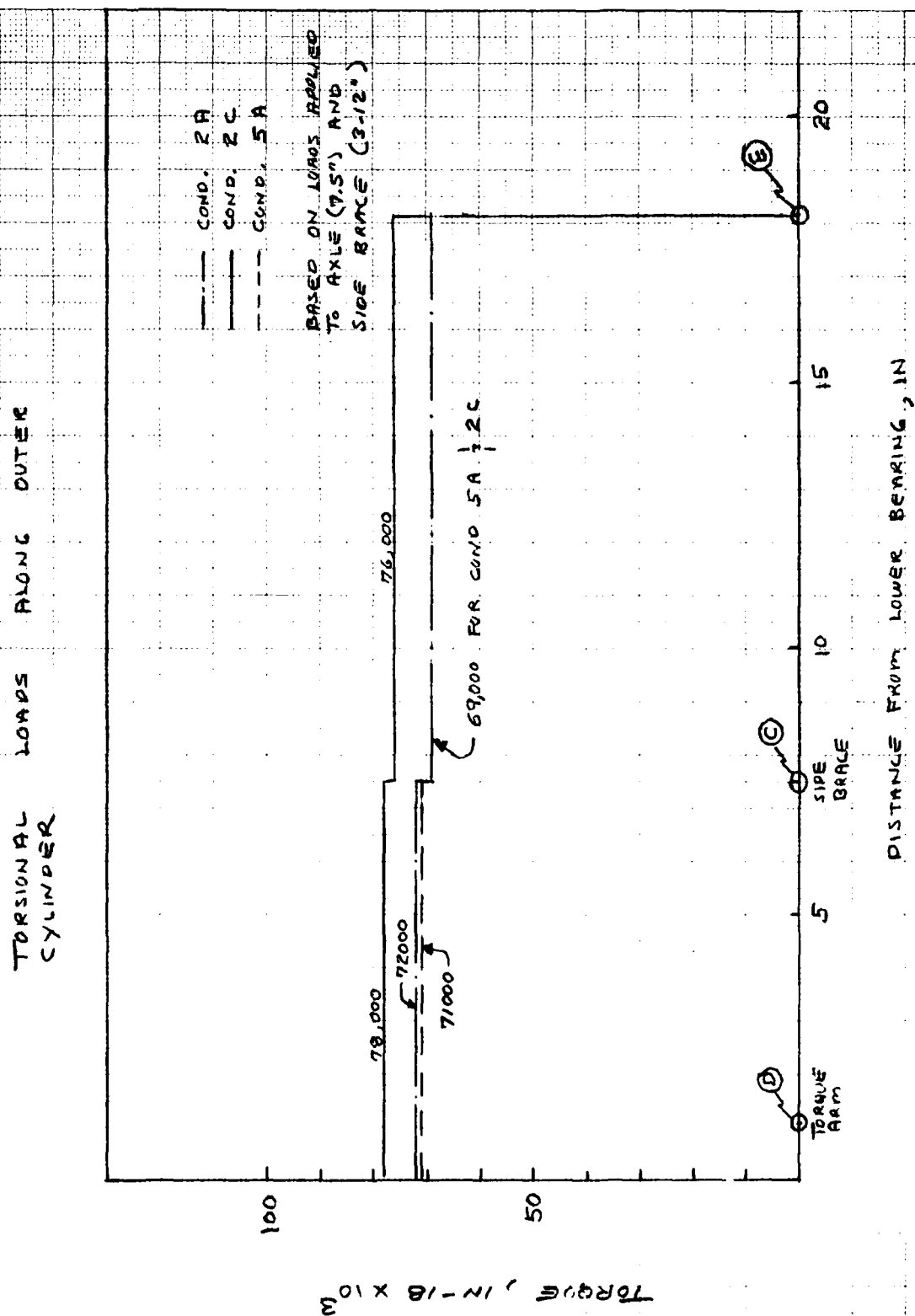






II-5

990



TORQUE, IN-LB X 10⁶

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-7

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gnb

BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER ANALYSIS LOCATIONS

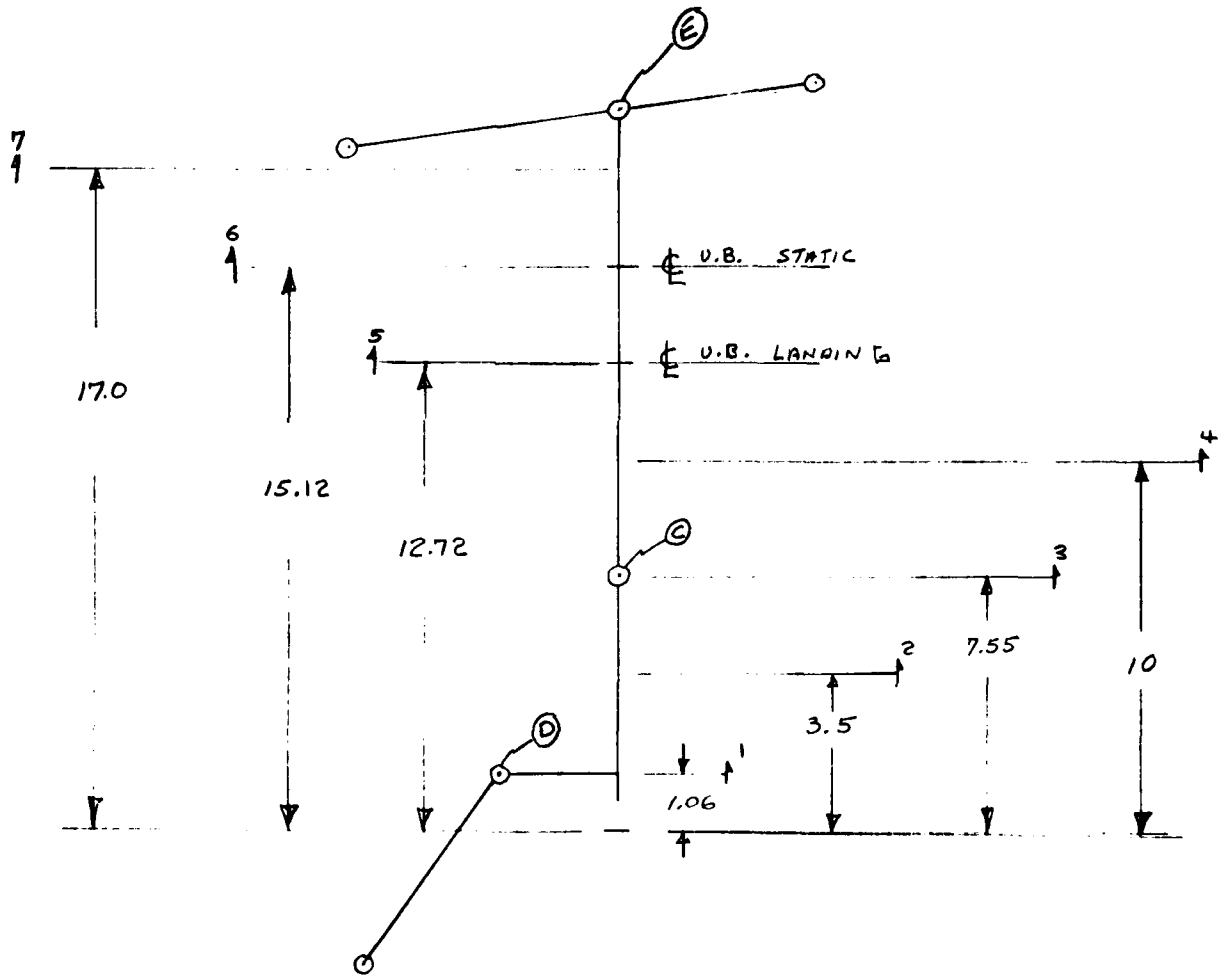


TABLE
 ULTIMATE LOADS⁽¹⁾ USED TO DESIGN THE OUTER CYLINDER/TRUNNION

Location ⁽²⁾	F ₂	M _x	M _y	M _{ecs}	V _x	V _y	V _{res}	τ
1	0	22,000	16,000	27,200	17,900	10,400	20,700	78,000
2	0	9,000	62,000	62,700	17,900	10,400	20,700	78,000
3	-8900	51,000	135,000	144,000	17,900	10,400	20,700	78,000
4	-8900	31,000	176,000	178,500	17,200	3,170	17,500	76,000
5	-8900	39,000	223,000	226,500	17,200	7,230	18,650	76,000
6	-8900	22,000	264,000	265,000	17,200	7,230	18,650	76,000
7	-8900	9,000	281,000	281,000	9,800	7,230	12,150	76,000

(1) Maximum values from ^{P. III-2} Figures ^{P. III-6} through A regardless of load condition; all load conditions lumped together. This will provide a slightly conservative analysis.

(2) SEE PAGE III-7

OUTER CYLINDER/TRUNNION
LOADS AT ATTACHMENT
TO A-37 B AIRCRAFT

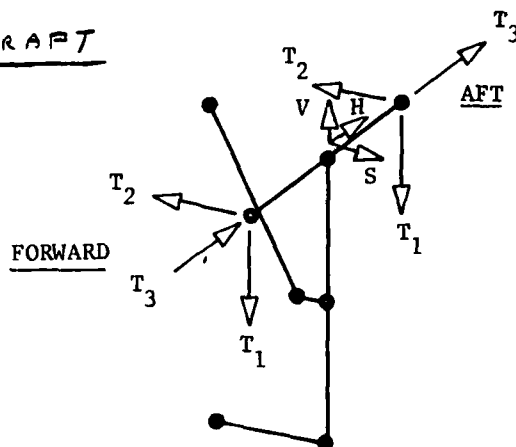


Figure IV.16. Trunnion Reaction Loads in H,S,V System

TABLE IV.17

TRUNNION REACTION LOADS IN H,S,V SYSTEM FOR BALL JOINTS

Case	Forward			Aft		
	T ₁ Lbs	T ₂ Lbs	T ₃ Lbs	T ₁ Lbs	T ₂ Lbs	T ₃ Lbs
1A	13,066	5970	3866	-6,958	1547	0
1B	-14,404	-2965	0	17,088	6267	-8124
1C	21,255	7816	8313	-16,254	-1661	0
2A	21,259	8146	7965	-15,403	-938	0
2C	22,379	7630	9393	-18,675	-3071	0
3A	-6,308	5066	17	-8,418	6657	0
3B	9,354	-495	26	7,135	-1771	0
4A	-17,884	-2251	0	22,017	7338	-8444
5A	24,253	7309	8363	-20,120	-2222	0
6A	-4,196	5432	-14	-6,732	6709	0
7	1,851	3394	-2173	5,648	5836	0

NOTE: LOADS APPLY AT CENTER OF AIRCRAFT
ATTACHMENT BUSHING.

OUTER CYLINDER / TRUNNION
LOADS AT ATTACHMENT
TO A 37 B AIRCRAFT

III = 10

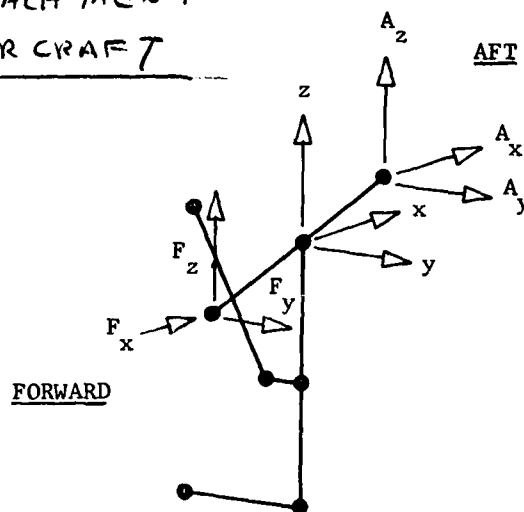


Figure IV.18. Trunnion Reaction Loads

TABLE IV.19
 TRUNNION REACTION LOADS IN THE x,y,z SYSTEM FOR BALL JOINTS

Cond	F_x Lbs	F_y Lbs	F_z Lbs	A_x Lbs	A_y Lbs	A_z Lbs
1A	5,320	-5,970	-12,544	-787	-1,547	6,913
1B	-1,630	2,965	14,311	-6,137	-6,267	-17,897
1C	10,665	-7,816	-20,177	-1,840	16,612	16,149
2A	10,320	-8,146	-20,217	-1,743	938	15,303
2C	11,865	-7,630	-21,171	-2,114	3,071	18,553
3A	-697	-5,066	6,269	-953	-6,657	8,363
3B	1,084	495	-9,290	807	1,771	-7,089
4A	-2,024	2,251	17,769	-5,897	-7,338	-22,831
5A	11,054	-7,309	-23,150	-2,277	2,222	19,990
6A	-488	-5,432	4,167	-762	-6,709	6,688
7	-1,949	-3,394	-2,085	639	-5,836	-5,611

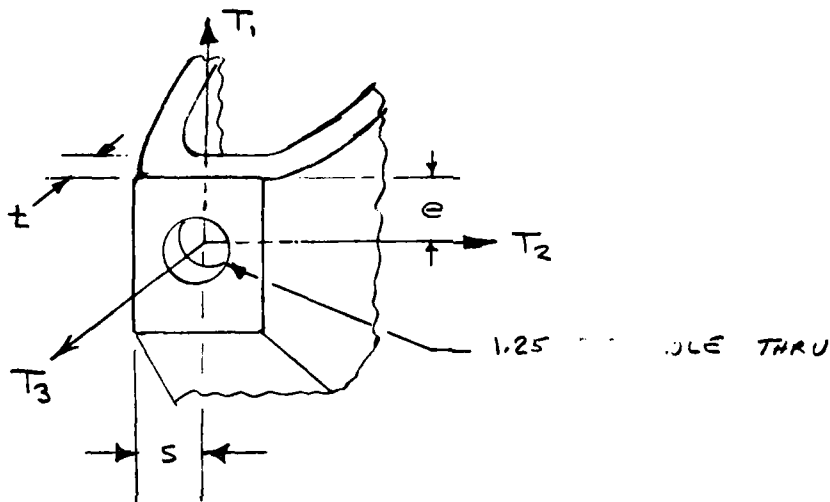
HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-11

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTH: MB
BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYL. / TRUNNION
GEAR / AIRCRAFT
ATTACHMENT LUGS, AFT.



LOADS

LOAD	COND. 4A ①	COND. 5A ②
T ₁	27,323	-24,969
T ₂	-9,106	2,755
T ₃	-8,444	0

$$F_{MAX} = \sqrt{T_1^2 + T_2^2} = \sqrt{(27,323)^2 + (-9,106)^2}$$

$$= 28,800 \#$$

① VALUES ARE LARGER THAN SHOWN IN LOADS TABLE BECAUSE THEY APPLY AT THE TRUNNION BUSHING RATHER THAN AT THE AIRCRAFT BUSHING.

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-12
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37B LANDING GEAR

BEARING ALLOWABLES (SEE CURVE ON NEXT PAGE)

e/p	F_{BR}	$\textcircled{1}$ 50% F_{BR}
2.5	135,000	67,500
2.0	125,000	62,500
1.5	100,000	50,000
4.0	155,000	77,500

SHEAR ALLOWABLES

$$\tau_{ALL} = \frac{F_{BR}}{2(e/p - .5)}$$

e/p	50% F_{BR}	τ_{ALL}
2.5	67,500	16,900
2.0	62,500	20,800
1.5	50,000	25,000
4.0	77,500	11,000

TENSILE ALLOWABLES

$$F_{ALL} = \frac{F_{BR}}{2(s/p - .5)}$$

s/p	50% F_{BR}	F_{ALL}
4.0	77,500	11,000
2.5	67,500	16,900
2.0	62,500	20,800
1.5	50,000	25,000

① REDUCED BY 50% TO ACCOUNT FOR FATIGUE AND UNCERTAINTIES IN F_{BR} VALUES.

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. III-13

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEAR

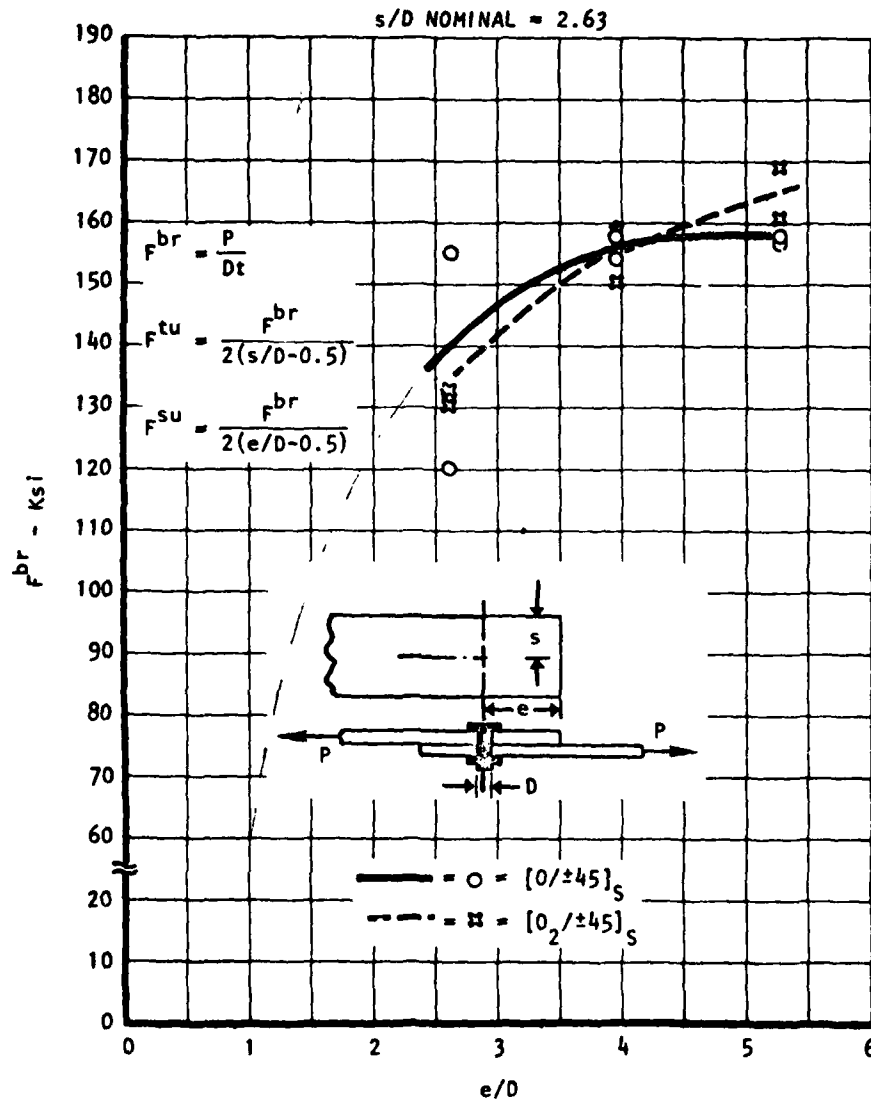


Figure 140. Graphite/Epoxy to Steel Mechanical Joint Single Lap Bearing Strength Versus e/D at Room Temperature (Type AS/3002, Batch) Protruding Head Fastener

HERCULES INCORPORATED
ENGINEERING DEPARTMENTSKETCH NO. III-14PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEARt req for BEARING

$$\sigma_B = \frac{F}{Dt} = \frac{28,800}{1.25t} = \frac{23,000}{t}$$

$$t = \frac{23,000}{F_{BR}}$$

e/d	F _{BR}	t
4.0	77,500	.297
2.5	67,500	.340
2.0	62,500	.368
1.5	50,000	.460

← SELECTED DESIGN

t req for SHEAR

$$\tau = \frac{F}{A_s} = \frac{F}{2et} \quad t = \frac{F}{2e\tau_{all}}$$

$$t = \frac{28,800}{2e\tau_{all}} = \frac{14,400}{e\tau_{all}}$$

e/d	D	e	τ_{all}	t
4.0	1.25	5.00	11,000	.262
2.5	↓	3.13	16,900	.273
2.0	↓	2.50	20,800	.281
1.5	↓	1.88	25,000	.307

← SELECTED DESIGN

t req for TENSION

$$\sigma_T = F/A = F/(2S-D)t = 28,800/(2S-1.25)t$$

S/d	σ_{all}	S	2S-1.25	t
4.0	11,000	5.0	8.75	.299
2.5	16,900	3.13	5.01	.340
2.0	20,800	2.50	3.75	.37
1.5	25,000	1.88	2.51	.46

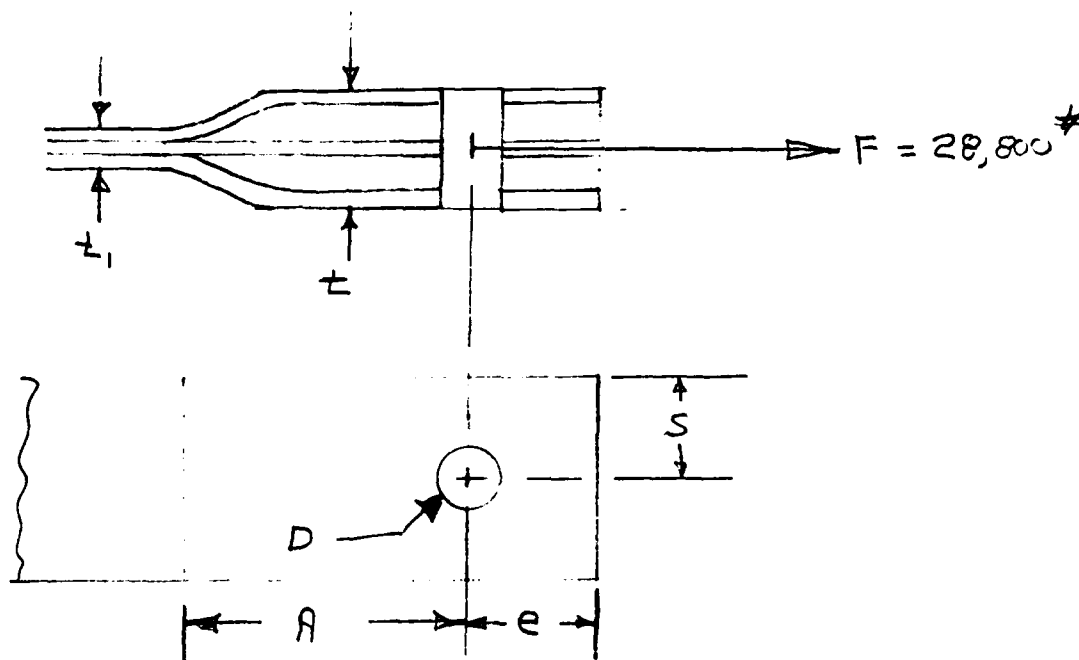
← SELECTED DESIGN

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-15
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37B LANDING GEAR

REQ. LENGTH OF REINFORCEMENT (TRUNNION LUGS)



$$\sigma_T @ t = \frac{F}{(2S-D)t} = \frac{28,800}{(2S-D)t} =$$

$$\tau = k \frac{F'}{A} = \frac{k}{2SA} \left(\frac{t-t_1}{t} \sigma_T \right) = \frac{2}{2SA} \left(\frac{t-t_1}{t} \times \sigma_T \right)$$

$$\tau = \frac{1}{SA t} \left[(t-t_1) \sigma_T \right]$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-16

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JNB
BLDG. _____ TITLE A-37B LANDING GEAR

REQ LENGTH OF REINFORCEMENT (TRUNNION LUGS)

$$\begin{aligned} \text{LET } T_{\text{ALLOWABLE}} &= 6,000 \text{ PSI} \\ e/d &= 2.0 & d &= 1.25, e = 2.5 \\ s/d &= 2.0 & b &= 1.25, s = 2.5 \\ t &= 0.4 \end{aligned}$$

$$\sigma_T = \frac{28,800}{(2s-d)t} = \frac{28,800}{[(2)(2.5)-1.25] \cdot .4} = 19,200 \text{ PSI}$$

$$A_{\text{req}} = \frac{L}{stT_{\text{ALL}}} [(t-t_1)\sigma_T] = \frac{1}{(2.5)(.4)(6000)} [(.4-t_1)19,200]$$

$$A_{\text{req}} = 1.67 \times 10^{-4} [(.4-t_1)19,200]$$

$$t_1 = \frac{14,400}{\sigma_{T_{\text{ALLOW.}}} s} = \frac{14,400}{(50,000)(2.5)} = .115$$

$$A_{\text{req}} = 1.67 \times 10^{-4} [(.4-.115)19,200]$$

$$= 1.67 \times 10^{-4} [5472] = \underline{.91 \text{ IN}}$$

USE MIN. LENGTH = 1.0 IN

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-17
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEAR

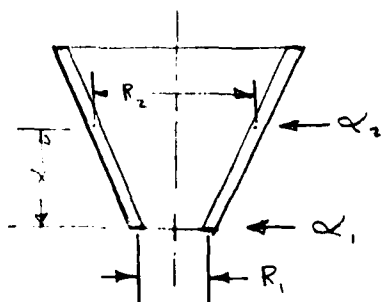
OUTER CYLINDER WINDING PATTERN

ASSUMPTION

ELLIPSE PORTION OF OUTER CYLINDER.
WILL BE APPROXIMATED BY A CONE HAVING
CIRCUMFERENTIAL DISTANCES EQUAL TO THE
ELLIPSE CIRCUMFERENTIAL DISTANCES.

SECTION	ELLIPSE APEN @ $t=.1$	EQUIVALENT CONE DIA. @ 0	$P/2 = R$
3	1.054	3.36	1.64
4	1.139	3.62	1.81
5	1.594	5.08	2.54
6	2.018	6.43	3.22
7	2.176	6.95	3.47

CONE WINDING ANGLES AND THICKNESSES

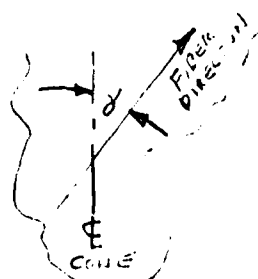


$$R_1 \sin \alpha_1 = R_2 \sin \alpha_2$$

$$\alpha_2 = \text{ARC-SIN} \left(\frac{R_1 \sin \alpha_1}{R_2} \right)$$

$$t_2 R_2 \cos \alpha_2 = t_1 R_1 \cos \alpha_1$$

$$\frac{t_2}{t_1} = \frac{R_1 \cos \alpha_1}{R_2 \cos \alpha_2}$$



$$C = \frac{A}{\pi t} = \frac{A}{.2146}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-18

SKETCH NO.

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____
BLDG. _____ TITLE _____

OUTER CYLINDER
WINDING PATTERN

WINDING ANGLES

$$\cos 80^\circ = .1736$$

$$\cos 70^\circ = .342$$

$$\cos 65^\circ = .423$$

$$\cos 60^\circ = .5$$

$$\cos 50^\circ = .6428$$

SECTION	R_1/R_2	α_2 FOR					α_2
		$\alpha_1 = 80$	$\alpha_1 = 70$	$\alpha_1 = 65$	$\alpha_1 = 60$	$\alpha_1 = 50$	
3-3	1.0	80.0	70.0	65.0	60.0	50.0	-
4-4	.928	66.1	60.7	57.2	53.5	45.3	-
5-5	.861	40.6	38.4	36.2	34.0	30.4	13.1
6-6	.522	30.9	29.4	28.2	27.0	23.6	10.3
7-7	.484	28.5	27.1	26.0	24.8	21.8	9.5

WALL THICKNESSES

t_2/t_1 FOR

SECTION	$\alpha_1 = 80$	$\alpha_1 = 70$	$\alpha_1 = 65$	$\alpha_1 = 60$	$\alpha_1 = 50$
3-3	1.0	1.0	1.0	1.0	1.0
4-4	.4	.65	.72	.78	.85
5-5	.15	.27	.35	.40	.49
6-6	.106	.20	.25	.29	.37
7-7	.10	.19	.23	.27	.34

TABLE
OUTER CYLINDER SECTION PROPERTIES

Section (3)	b_1	d_1	$\frac{t = .1}{A^{(1)}} \frac{(2)}{I}$	$\frac{t = .2}{A^{(1)}} \frac{(2)}{I}$	$\frac{t = .3}{A^{(1)}} \frac{(2)}{I}$	$\frac{t = .4}{A^{(1)}} \frac{(2)}{I}$				
3-3	3.25	3.25	1.054	1.479	2.17	3.24	3.348	5.31	4.59	7.73
4-4	3.25	3.80	1.139	2.09	2.34	4.52	3.605	7.35	4.93	10.60
5-5	3.25	6.70	1.594	7.65	3.25	16.14	4.97	25.54	6.75	35.89
6-6	3.25	9.40	2.018	17.32	4.10	36.13	6.24	56.48	8.45	78.47
7-8	3.25	10.4	2.176	22.25	4.41	46.25	6.72	72.09	9.08	99.84

(1) $A = \frac{\pi}{4} (bd - b_1 d_1) = \frac{\pi}{4} [(b_1 + 2t)(d_1 + 2t) - b_1 d_1]$

(2) $I = \frac{\pi}{64} [bd^3 - b_1 d_1^3] = \frac{\pi}{64} [(b_1 + 2t)(d_1 + 2t)^3 - b_1 d_1^3]$

(3) See figure. PAGE III-17

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-20

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER
STRESSES DUE TO

8900^{lb} AXIAL LOAD
AT SECTION 3-3

$$\sigma_A = \frac{F}{A} = \frac{F}{\pi d t}$$

$$t = \frac{F}{\pi d \sigma_{ALL}} = \frac{8900}{\pi d (40,000)} = \frac{.071}{d}$$

SECTION ⁽¹⁾	d	t
1-1	3.35	N/A
2-2	3.55	N/A
3-3	3.55	.0200
4-4	3.62	.0196
5-5	5.08	.0140
6-6	6.43	.0110
7-7	6.95	.0102

(1) SEE PAGE III-7

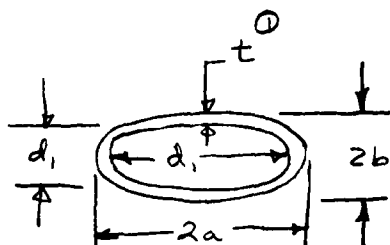
HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-21
SKETCH NO.

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37B LANDING GEAR

OUTER CYLINDER

TORSIONAL STRESSES
FOR SHAPE SHOWN



$$S = \frac{T}{2\pi t (a - \frac{1}{2}t)(b - \frac{1}{2}t)}$$

$$= \frac{T}{\pi t (d_1 + t)(d_2 + t)}$$

SECTION #	b ₁	d ₁	S/T			
			t=.1	t=.2	t=.3	t=.4
3-3	3.25	3.25	.284	.134	.084	.050
4-4		3.80	.244	.115	.073	.052
5-5		6.70	.140	.067	.043	.031
6-6		9.40	.100	.048	.031	.022
7-7		10.4	.090	.044	.028	.020

SECTION #	S FOR T = 78,000 IN-LB			
	t=.1	t=.2	t=.3	t=.4
3-3	22,152	10,452	6,552	4,680
4-4	19,032	8,970	5,694	4,056
5-5	10,920	5,226	3,354	2,418
6-6	7,800	3,744	2,418	1,716
7-7	7,020	3,432	2,184	1,560

① t = THICKNESS ⊥ TO OUTER CYLINDER/TRUNNION E LINES
SEE PAGE III-7 80

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-22

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37B LANDING GEAR

OUTER CYLINDER
IN-PLANE SHEAR
DUE TO TRANSVERSE
SHEAR LOAD

$$\tau = \frac{2V}{A}$$

SECTION	V	FOR $t = .1"$	
		A	τ
3-3	20,700	1.05	39,429
4-4	~~17,500~~ 17,500	1.14	30,702
5-5	18,650	1.59	23,459
6-6	18,650	2.02	18,466
7-7	12,150	2.18	11,147

SECTION	$t = .2"$		$t = .3"$		$t = .4"$	
	A	τ	A	τ	A	τ
3-3	2.17	19,600	3.35	12,350	4.59	9040
4-4	2.34	15,000	3.61	9,700	4.93	7100
5-5	3.25	11,500	4.97	7,550	6.75	5530
6-6	4.10	9,120	6.24	5,990	8.45	4410
7-7	4.41	5,520	6.72	3,620	9.08	2690

① SEE PAGE III-7

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-23
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____

BLDG. _____ TITLE _____

OUTER CYLINDER/TRUNNION
IN-PLANE SHEAR STRESS
COMBINED TORSIONAL
TRANSVERSE SHEAR LOADS

$$\tau_T = V + T$$

①

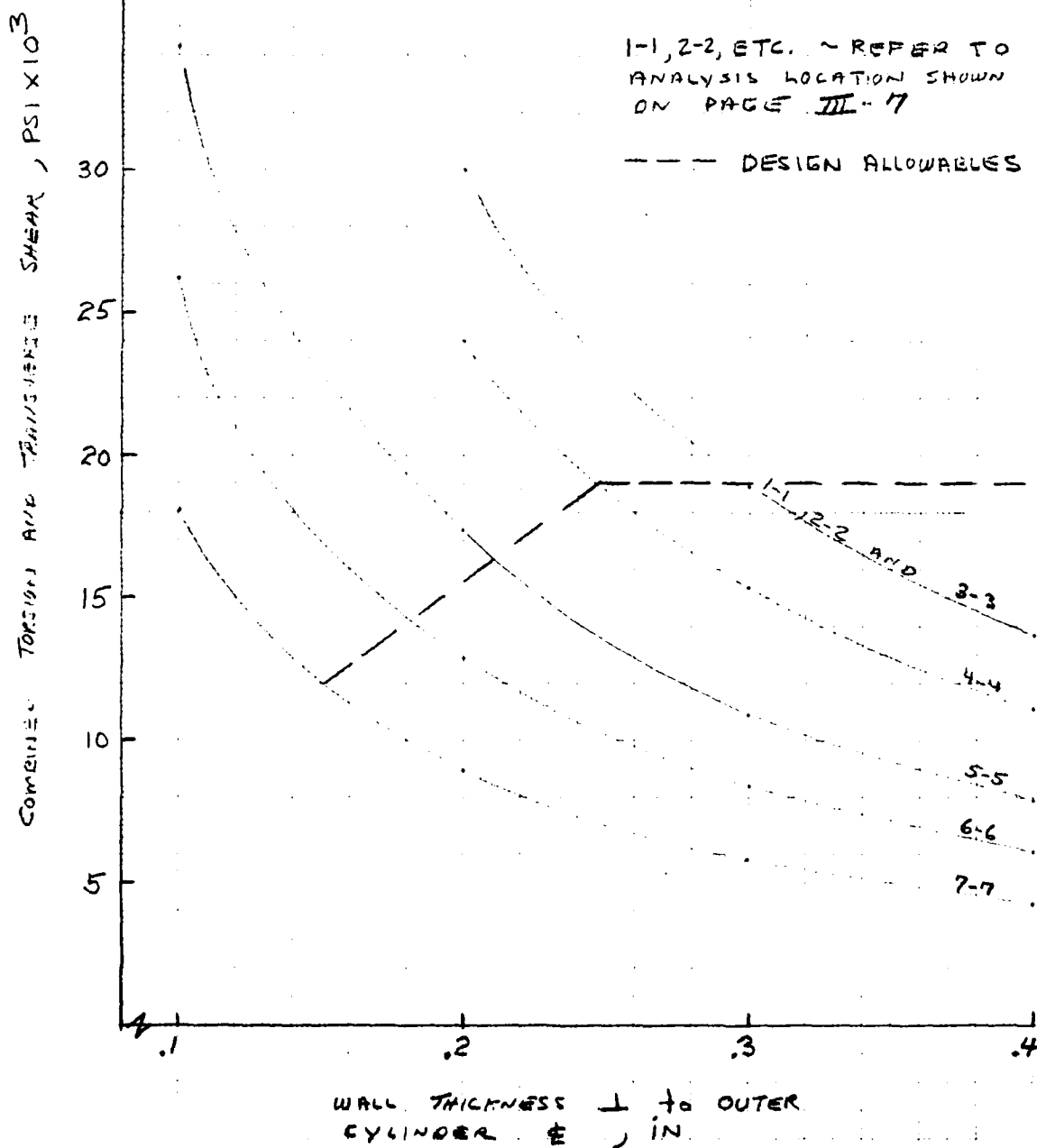
SECTION	FOR $t = .1$			$t = .2$		
	TORSION	V	τ_T	TORSION	V	τ_T
3-3	22,152	39,429	61,581	16,450	19,600	36,052
4-4	19,032	30,702	49,734	8,970	15,000	23,970
5-5	10,920	23,459	34,379	5,226	11,580	16,806
6-6	7,800	18,466	26,266	3,744	9,120	12,864
7-7	7,020	11,147	18,167	3,432	5,520	8,952

SECTION	FOR $t = .3$		
	TORSION	V	τ_T
3-3	6,552	12,350	18,902
4-4	5,694	9,700	15,394
5-5	3,354	7,550	10,904
6-6	2,418	5,990	8,408
7-7	2,184	3,620	5,804

SECTION	FOR $t = .4$		
	TORSION	V	τ_T
3-3	4,680	9,040	13,720
4-4	4,056	7,100	11,156
5-5	2,418	5,530	7,948
6-6	1,716	4,410	6,126
7-7	1,560	2,690	4,250

① see p. III-7

FIG OUTER CYLINDER IN-PLANE SHEAR STRESSES DUE TO TORSIONAL AND TRANSVERSE SHEAR LOADS



HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-25

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR SNB
BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER BENDING STRESSES

$$\sigma_z = \frac{M_y c}{I}$$

SECTION ^①	M_y	c	I	σ_z for $t = .1$
7-8	16,000	1.73	1.48	1,8700
2-2	~~62,000~~ 15,000	~~2.173~~ 1.73	~~1.48~~ 1.48	72,500
3-3	135,000	~~3.173~~ 1.73	.	157,000
4-4	176,000	~~2.0~~ 2.04	2.04	168,000
5-5	223,000	3.45	7.65	101,000
6-6	264,000	4.8	17.32	73,200
7-7	281,000	5.3	22.25	67,000

$t = .2$		$t = .3$		$t = .4$	
I	σ_z	I	σ_z	I	σ_z
3.24	8,550	5.31	5212	7.73	3581
3.24	33,200	~~5.31~~ 7.73	20,200	7.73	13,876
3.24	72,000	~~5.31~~ 7.73	43,983	7.73	30,213
4.52	77,876	~~7.35~~ 10.6	47,891	10.6	33,208
16.14	47,657	25.54	30,123	35.99	21,436
36.13	35,073	56.48	22,426	78.47	16,149
46.25	32,201	72.09	20,659	99.84	14,917

① SEE PAGE III-7

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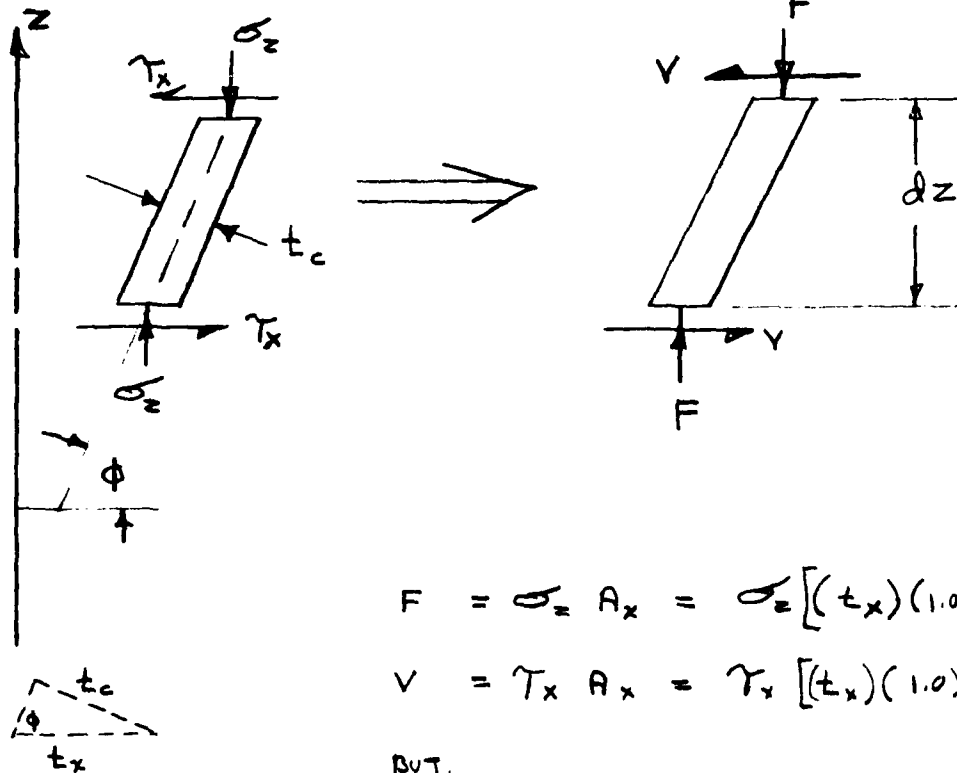
III-26

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____

BLDG. _____ TITLE _____

OUTER CYLINDER
FORCES IN CONE
SECTION



$$F = \sigma_z A_x = \sigma_z [(t_x)(1.0)] = \sigma_z t_x$$

$$V = \tau_x A_x = \tau_x [(t_x)(1.0)] = \tau_x t_x$$

BUT,

$$\sin \phi = t_c / t_x$$

$$t_x = t_c / \sin \phi, t_c = t_x \sin \phi$$

$$F = \frac{\sigma_z t_c}{\sin \phi} \quad \text{or} \quad \sigma_z t_x \quad \text{lb/in}$$

$$V = \frac{\tau_x t_c}{\sin \phi} \quad \text{or} \quad \tau_x t_x \quad \text{lb/in}$$

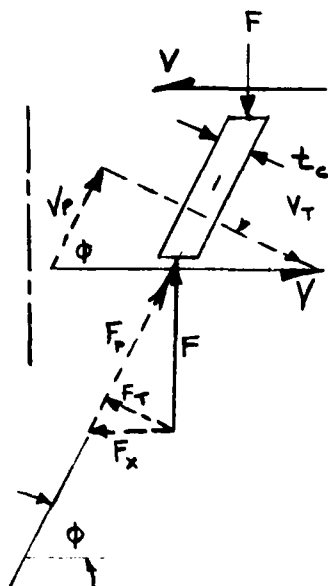
HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-27

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR gnB
BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER STRESSES IN CONE SECTION



$$\sin \phi = F/F_p, F_p = F/\sin \phi$$

$$\tan \phi = F/F_x, F_x = F/\tan \phi$$

$$\sin \phi = F_T/F_x, F_T = F_x \sin \phi$$

$$F_T = \frac{F}{\tan \phi} \sin \phi = F \cos \phi$$

$$\sin \phi = \frac{V_T}{V}, V_T = V \sin \phi$$

$$\cos \phi = \frac{V_p}{V}, V_p = V \cos \phi$$

FORCE PARALLEL TO PILES

$$F_{pT} = F_p + V_p = \frac{F}{\sin \phi} + V \cos \phi$$

FORCE TRANSVERSE TO FIBERS

$$F_{TT} = V_T - F_T = V \sin \phi - F \cos \phi$$

STRESSES

$$\sigma_p = \frac{F_{pT}}{A} = \frac{F_{pT}}{t_c \times 1} = F_{pT} / t_c$$

$$\tau_T = \frac{F_{TT}}{A} = \frac{F_{TT}}{t_c \times 1} = F_{TT} / t_c$$

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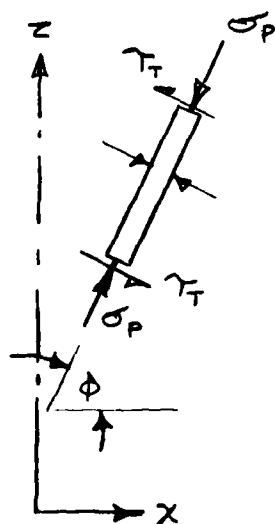
III-28

SKETCH NO.

PLANT PROJECT NO. DATE AUTHOR

BLDG. TITLE

OUTER CYLINDER STRESSES IN CONE SECTION



$$\begin{aligned}\sigma_p &= \frac{F_{PT}}{t_c} = \frac{F_{PT}}{t_x \sin \phi} \\ &= \frac{1}{t_x \sin \phi} \left[\frac{F}{\sin \phi} + V \cos \phi \right] \\ &= \frac{1}{t_x \sin \phi} \left[\frac{\sigma_z t_x}{\sin \phi} + \tau_x t_x \cos \phi \right]\end{aligned}$$

$$\boxed{\sigma_p = \frac{\sigma_z}{\sin^2 \phi} + \frac{\tau_x}{\tan \phi}}$$

$$\begin{aligned}\tau_T &= \frac{F_{TT}}{t_c} = \frac{F_{TT}}{t_x \sin \phi} \\ &= \frac{-F \cos \phi + V \sin \phi}{t_x \sin \phi} = \frac{1}{t_x \sin \phi} \left[-\sigma_z t_x \cos \phi + \tau_x t_x \sin \phi \right]\end{aligned}$$

$$\boxed{\tau_T = \tau_x - \frac{\sigma_z}{\tan \phi}}$$

HERCULES INCORPORATED

ENGINEERING DEPARTMENT

III - 29

SKETCH NO.

PLANT PROJECT NO. DATE 2-73 AUTHOR JNB
BLDG. TITLE A-37 B LANDING GEAR

OUTER CYLINDER
STRESSES $\parallel$ AND $\perp$
WALL STRUCTURE

$$\phi = 70^\circ$$

$$\sigma_p = \frac{\sigma_z}{\sin^2 \phi} + \frac{.3 \tau_x}{\tan \phi} \quad \tau_T = .3 \tau_x - \frac{\sigma_z}{\tan \phi}$$

FOR $t_x = .1$, $t_c = .094$

SECTION ①	σ_z	τ_x	σ_p	τ_T
4-4	168,000	30,702	193,613	-51,446
5-5	101,000	23,459	116,945	-29,729
6-6	73,200	18,400	82,901	-21,107
7-7	67,000	11,147	77,095	-21,046

FOR $t_x = .2$, $t_c = .188$

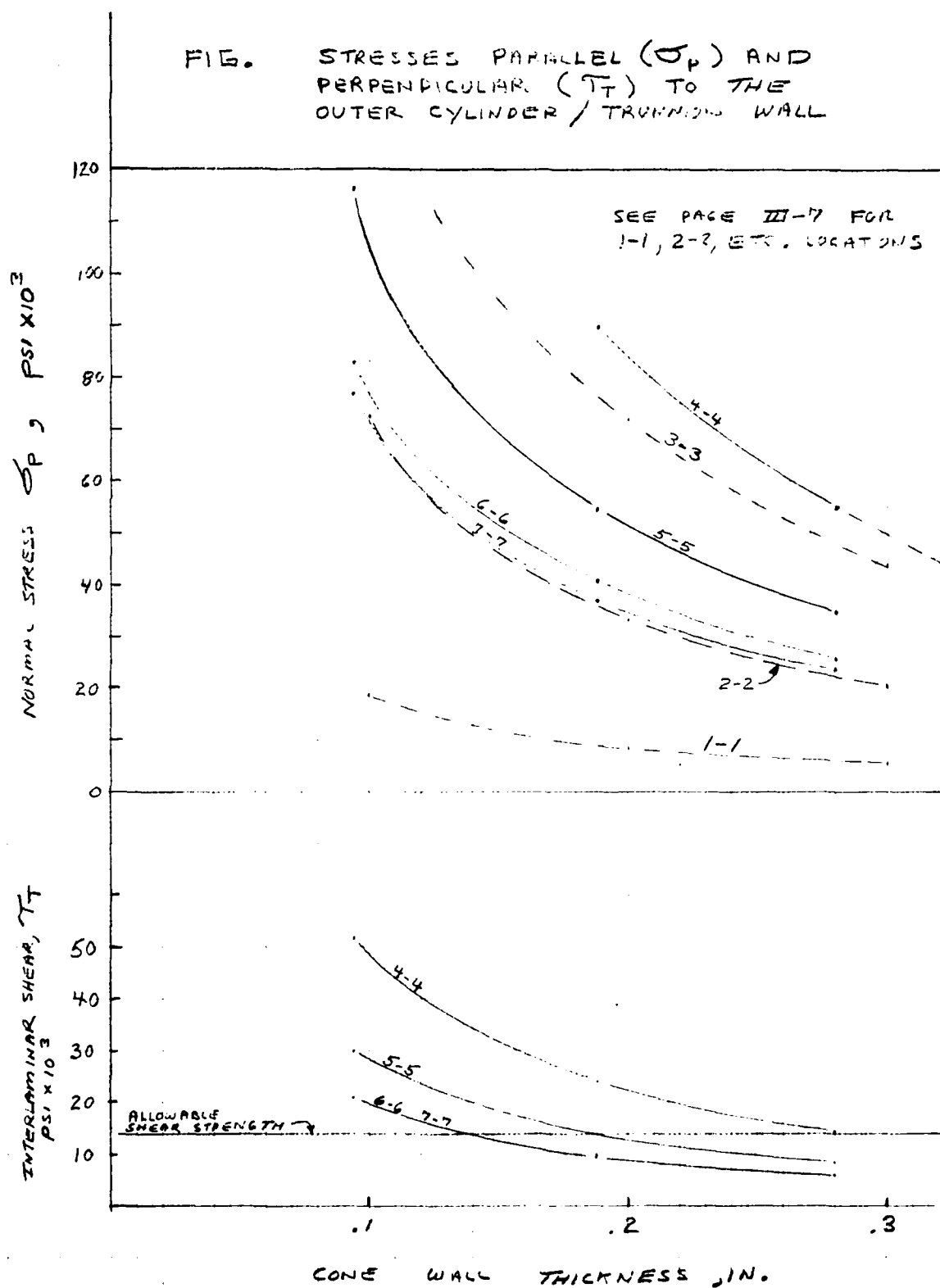
4-4	77,876	15,000	89,833	-23,849
5-5	47,667	11,500	55,239	-13,902
6-6	35,073	9,120	40,716	-10,031
7-7	32,202	5,520	37,072	-10,066

FOR $t_x = .3$, $t_c = .282$

47,891	9700	55,296	-14,523
30,123	7550	34,939	-8,701
23,436	5990	26,063	-6,370
20,559	3020	23,791	-6,434

① see p. III-7

FIG. STRESSES PARALLEL (σ_p) AND PERPENDICULAR (τ_t) TO THE OUTER CYLINDER / TURNING WALL



HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-31

SKETCH NO.

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JNB
BLDG. _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER / TRUNNION REQUIRED DESIGN THICKNESSES

SECTION	DESIGN ALLOWABLES			REQUIRED THICKNESSES						
	(4) σ	INTER-LAMINAR SHEAR	τ	INTER-LAMINAR SHEAR	τ_{xy}	(1) σ_A	(2) σ_b	(3) σ_T	t_{major}	t_{minor}
1-1	50,000	14,000	19,000	<.05	.3	-	<.03	<.03	.3	.3
2-2	50,000	14,000	19,000	<.05	.3	-	.140	.140	.3	"
3-3	50,000	14,000	19,000	<.05	.3	.020	.270	.290	.3	"
4-4	50,000	14,000	19,000	.285	.25	.020	.300	.320	.320	.32
5-5	50,000	14,000	16,500	.190	.21	.014	.205	.219	.219	.21
6-6	50,000	14,000	14,000	.140	.18	.011	.155	.166	.166	.18
7-7	50,000	14,000	12,000	.140	.12	.010	.140	.150	.150	.12

- (1) σ_A = AXIAL STRESS
(2) σ_b = BENDING STRESS
(3) $\sigma_T = \sigma_A + \sigma_b$
(4) SEE PAGE III-7

AD-A129 206

GRAPHITE COMPOSITE LANDING GEAR COMPONENTS VOLUME II
TECHNICAL APPENDICES(U) HERCULES INC MAGNA UT BACCHUS
WORKS L C JENSEN ET AL. JUN 77 AFFDL-TR-77-20-VOL-2

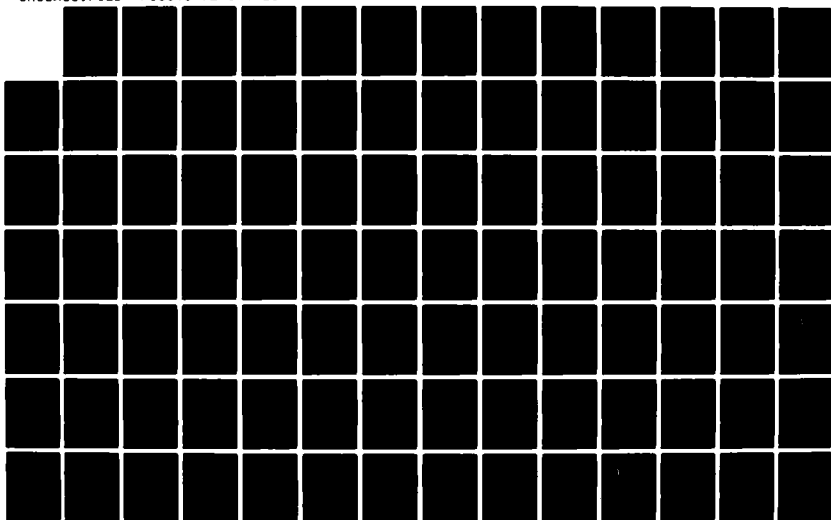
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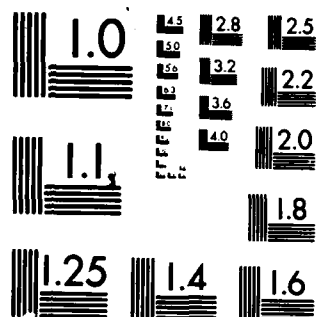
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-32

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JNB
BLDG _____ TITLE A-37 B LANDING GEAR

OUTER CYLINDER / TRUNNION

SECTION	INNER TUBES		(4) WINDINGS	°	OUTER STRUCTURE		TOTAL LOAD (1) CARRING THICKNESSES	
	t_{45}	0°			t_{MINOR} ANGLE PLIES	t_{MAJOR} ANGLE PLIES	t_{MINOR}	t_{MAJOR}
1-1	.025	.025	.125	.125	—	—	.3	.3
2-2			.125		—	—	.3	.3
3-3			.125		—	—	.3	.3
4-4			.098		.152	.076	.250	.3
5-5			.050		.160	.080	.210	.255
6-6			.036		.144	.072	.180	.233
7-7			.034		.086	.043	.120	.202

(1) INCLUDES INNER TUBE THICKNESSES IN SECTIONS 1-1, 2-2 AND 3-3 ONLY.

(2) $t_{\text{MINOR}} = t_{\text{WINDING}} + t_{\text{MINOR}}(\text{ANGLE})$

(3) $t_{\text{MAJOR}} = t_{\text{WINDINGS}} + t_0 + t_{\text{MAJOR}}(\text{ANGLES})$

(4) FOR $\alpha_1 = 60^\circ$ SEE P. III-18

(5) SEE PAGE III-7

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-33

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____

BLDG. _____ TITLE _____

OUTER CYLINDER
REQ 90° PLIES AT
AIRCRAFT/GEAR ATTACHMENT

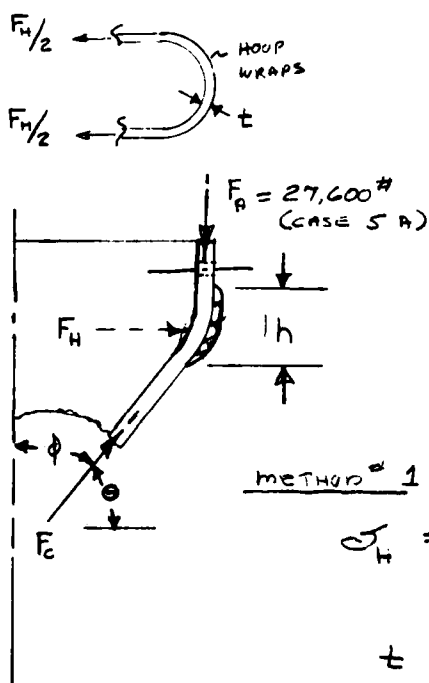
$$\phi = 20^\circ, \theta = 90 - \phi = 70^\circ$$

$$\tan \theta = \frac{F_R}{F_H}$$

$$F_H = F_R / \tan 70^\circ = \frac{27,600^*}{2.748} = 10,000^*$$

$$h = 2.0$$

σ_{ALL} = ALLOWABLE VLT. HOOP STRESS = 138,000 psi



METHOD = 1

$$\sigma_H = k \frac{F_H/2}{h t} = 2.0 \left[\frac{5,000}{2 t} \right]$$

$$t = \frac{5,000}{\sigma_{ALL}} = \frac{5,000}{138,000}$$

$$t = 0.036 \text{ IN}$$

USE t = 0.040

① BASED UPON COL f
DISTRIBUTION

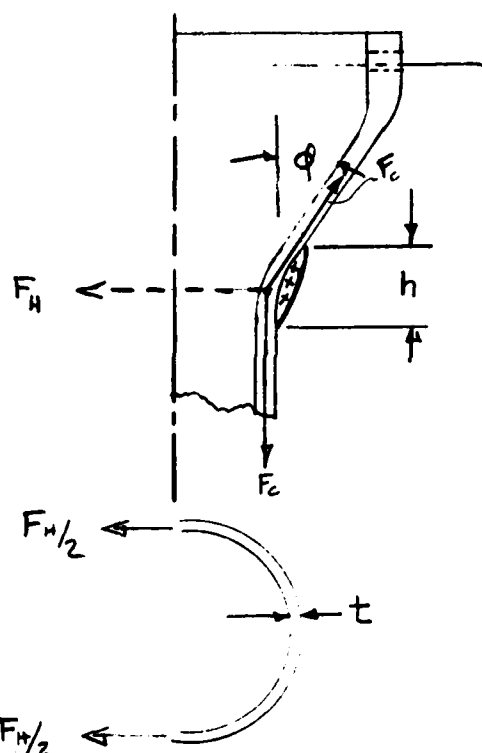
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III-34

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____
BLDG. _____ TITLE _____

OUTER CYLINDER
REQ. 90° PLIES
AT CYLINDER/CONE
JUNCTURE



$$\phi = 20^\circ$$

$$h = 2.0$$

$$\sigma_N \text{ at SECTION 4-4} = 84,000 \text{ PSI}$$

FOR $t = .20$ (SEE FIG —)

$$\therefore F_{C_{\max}} = A \sigma_N = (.2)(84,000)$$

$$= 16,800 \text{ \#}$$

$$\cos(90 - \phi) = F_H / F_C$$

$$F_H = 16,800 (.342) = 5,746 \text{ \#}$$

$$\sigma_H = k \frac{F_H/2}{ht} = \frac{2(2,873)}{2t}$$

$$t = \frac{2,873}{\sigma_{ALL}} = \frac{2,873}{138,000}$$

$$t = \underline{\underline{0.021 \text{ in}}}$$

$$\text{USE } \underline{\underline{t = .025 \text{ IN}}}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-35

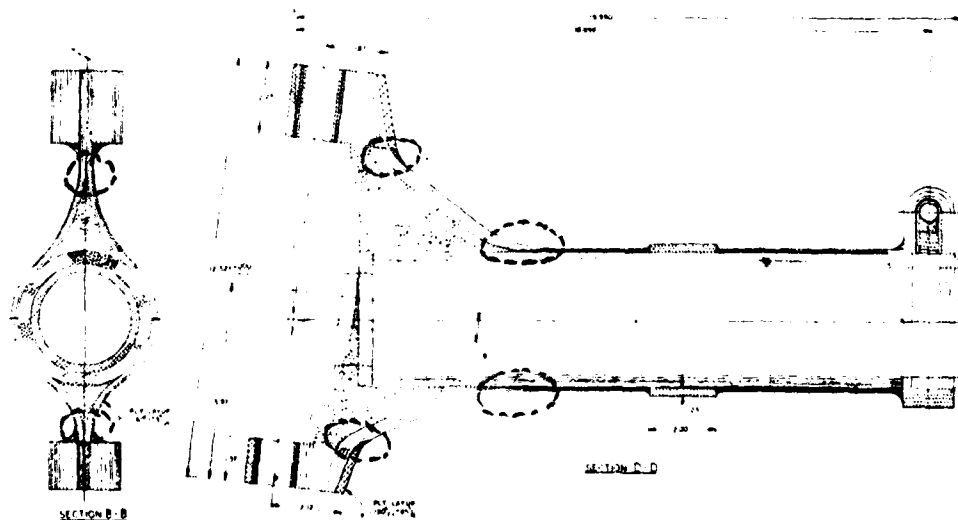
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 10-30-72 AUTHOR J. N. BURNS
BLDG. _____ TITLE A-37B LANDING GEAR

PROPOSAL DESIGN

THE DESIGN OF A COMPOSITE TRUNNION IS A DIFFICULT TASK BECAUSE IT'S A 3D LOADED STRUCTURE. COMPOSITES HAVE EXCELLANT 1-D PROPERTIES, FAIR 2D PROPERTIES BUT POOR PROPERTIES IN THE 3RD DIRECTION (TRANSVERSE PROPERTIES). CONSEQUENTLY, THE DESIGNER ATTEMPTS TO MAXIMIZE THE USE OF THE 1-D AND 2-D PROPERTIES BY SELECTING THE PROPER STRUCTURAL GEOMETRIES. HOWEVER, IT IS VERY DIFFICULT TO ELEMINATE THE CONDITION WHERE INTERLIMBIC SHEAR LIMITS THE DESIGN.

THE PROPOSAL DESIGN IS ESSENTIALLY A BONDED ASSEMBLAGE OF 2-D COMPOSITE SUBCOMPONENTS. (SEE FIGURE 1) THE MAJOR PROBLEM WITH THE DESIGN IS GEOMETRY WHICH PLACES THE BOND BETWEEN VARIOUS SUBCOMPONENTS INTO AN UNDESIRABLE CLEAVAGE TYPE OF STRESS STATE.



HERCULES INCORPORATED ENGINEERING DEPARTMENT

III-36
SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 10-30-72 AUTHOR J.N. BURNS
BLDG. _____ TITLE _____

THERE ARE FOUR BASIC TYPES OF STRESS ENCOUNTERED IN STRUCTURAL BONDING: TENSILE, SHEAR, CLEAVAGE AND PEEL.



The basic types of structural stress.

Tensile stress results when forces perpendicular to the plane of the joint are distributed uniformly over the entire bonded area. If the joint is properly designed, all of the adhesive will contribute to the strength of the bond. Unfortunately, loads rarely are axial and often develop into cleavage stresses. This can be prevented, however, by physical restraints.

Shear stress occurs when force is applied parallel to the plane of the joint and distributed uniformly over the bonded area. Most joints are designed for this type of stress. Here, too, all of the adhesive contributes to the strength of the bond. Since shear bonds are relatively simple to make, joints which depend upon an adhesive's shear strength are more common than tensile joints.

Shear loads concentrate at the ends of a lap joint and only slightly affect the joint's middle portion. Loads resulting from bending of the material can be reduced either by beveling the ends to allow bending, removing material to reduce stiffness, increasing flexibility by inserting a less rigid material between stiff adherends, or bonding flexible doublers on the outer surfaces at points where bending occurs.

Cleavage, an undesirable type of stress, is similar to tensile stress because force is applied perpendicular to the plane of the joint. Cleavage stress, however, is concentrated along one side of the bond, while other areas remain almost unstressed. Cleavage conditions should be avoided in the design of a joint.

Peel is another undesirable type of stress. It is unlike shear stress in that force is applied approximately perpendicular to the plane of the joint. Peel stress, however, is confined to a very thin line at the edge of the bond. When peel occurs the remaining bond area makes no contribution to the strength of the joint.

Added width in a joint can increase the resistance to peel stress, or you can lap the more flexible end over the stiffer adherend. You can also inhibit peel by stiffening the end of the flexible member: that is, by adding either bonded doublers or a mechanical stop such as a rivet, or by recessing the end of the flexible member.



Methods of reducing peel stresses at the point where peel starts.

A joint is rarely subjected to just one type of stress. Commonly, several types act together to weaken the joint. This fact should be borne in mind when designing a joint.

Structural adhesives have the highest resistance to tensile or shear stresses, and designs which subject the bond to cleavage or peel forces should be avoided. The working area of the bond should be as large as possible. Strength is directly proportional to the bond width; increasing the width will always increase the strength of a joint. Increasing the depth, or amount of overlap, does not always increase the bond strength, however. Peel stress is distributed only by increasing the width of a joint; thus depth has no effect.

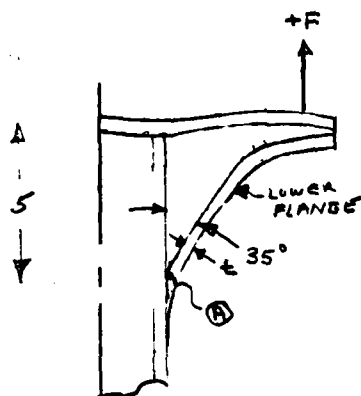
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III-37

SKETCH NO. _____

PLANT _____ PROJECT NO. _____ DATE 10-30-72 AUTHOR T.N. BURNS

BLDG. _____ TITLE _____



FWD

CRITICAL CLEAVAGE LOAD CONDITION: LOAD
CONDITION 4A WHERE $F = 20,908 \#$

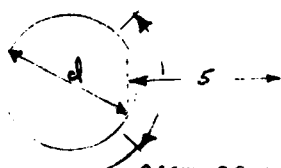


$$F_x = \frac{5F}{5} = 20,908 \#$$

$$F_z = F_x \tan 35^\circ = 14,640 \#$$

$$F_A = F_x / \cos 35^\circ = 25,524 \#$$

$$F_T = \sin 35^\circ (F_x) = 11,992$$



ASSUMED LOAD
CARRYING AREA,
 $A = (.25)\pi d^2 t$
 $= (.25)\pi (4.2)^2$
 $= 1.257 \text{ in}^2$

TENSILE STRESS @ A

$$\sigma_T = F_x / A = \frac{20,908}{1.257} = 16,633 \text{ psi}$$

ALLOWABLE $\sim 10,000 \text{ psi}$

$$\text{m.s.} = -.66$$

CRITICAL INTERLAMINAR SHEAR @ A: LOAD CONDITION 5A, $F_z = 26,827 \#$

SHEAR FOR
CONDITION 4A

$$\tau = \frac{F_x}{A} = \frac{20,908}{.25\pi d^2 t} = \frac{20,908}{.25\pi (4)^2} = 33,270 \text{ psi}$$

ALLOWABLE $= 10,000$

$$\text{m.s.} = -2.33$$

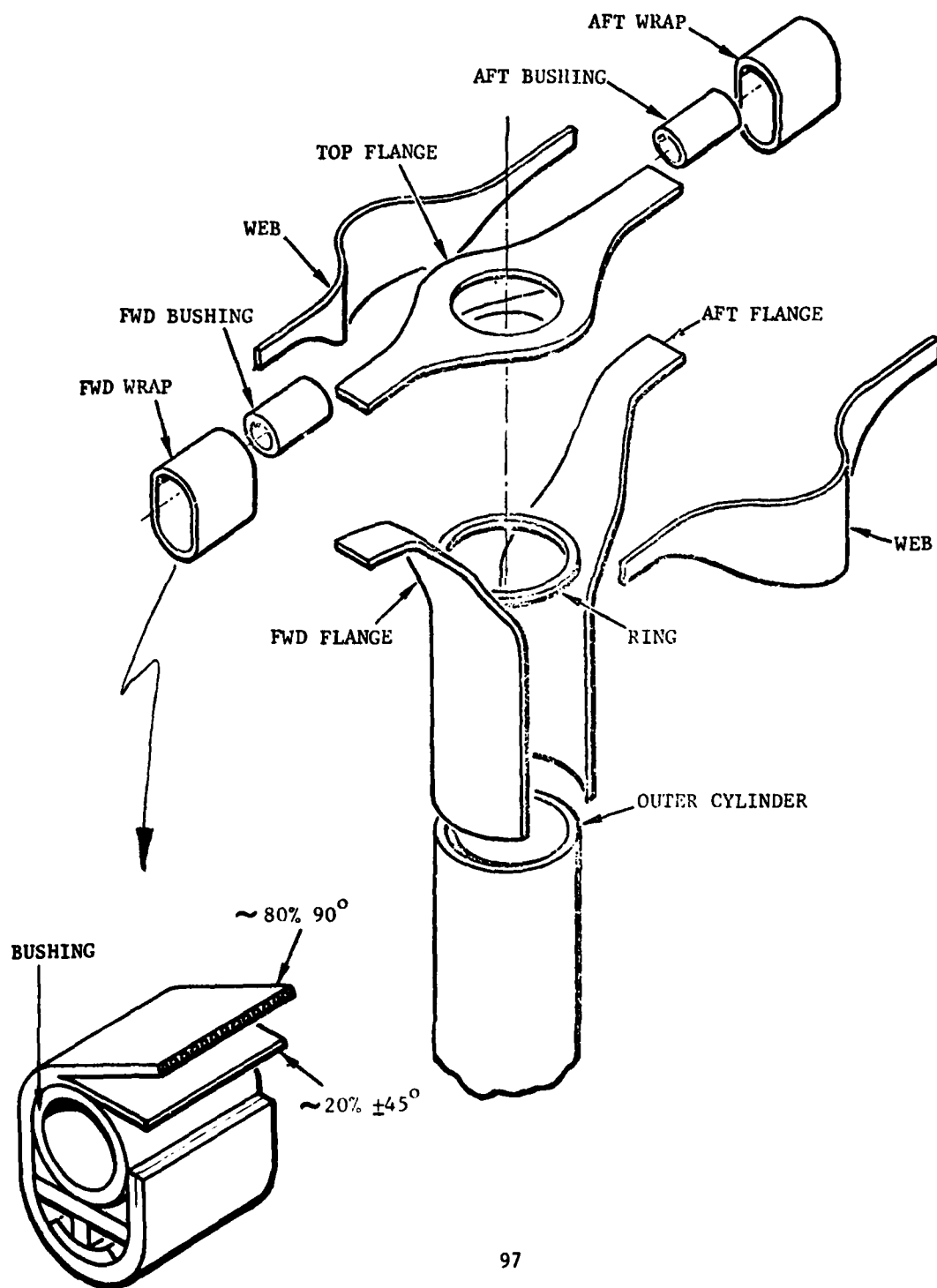
SHEAR FOR
CONDITION 5A

$$\tau = \frac{26,827}{20,908} \times 33,270 = 42,685 \text{ psi}$$

$$\text{m.s.} = -3.27$$

CONCLUSION: THE ABOVE (-) MARGINS OF SAFETY SHOW THE
PROPOSAL DESIGN TO BE STRUCTURAL INADEQUATE.
POSITIVE M.S. COULD BE PREDICTED BY INCREASING
THE LOWER FLANGE THICKNESS. THIS, HOWEVER, DOES
NOT SOLVE THE CLEAVAGE PROBLEM THAT EXISTS AT
POINT A. STRESS CONCENTRATIONS AT THIS POINT CANNOT
BE PREDICTED BY THIS HAND ANALYSIS. IT IS RECOMMENDED
THE DESIGN BE CHANGED TO ELIMINATE THE CLEAVAGE CONDITION.

TRUNNION DESIGN



APPENDIX A
PART IV
DESIGN ANALYSIS
OF
THE PISTON

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. II.1

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JAMES N. BURD
BLDG. _____ TITLE A-37 B LANDING BEAR

PISTON DESIGN

CONFIGURATION

SEE FIGURE 1

WT. = 3.89 #

LOADS

APPLIED LOADS PER FIGURE 2

SHEAR DIAGRAM PER FIGURE 3

MOMENT DIAGRAM PER FIGURE 4

AXIAL LOAD PER FIGURE 5

INTERNAL PRESSURE OF 1500 PSI LIMIT = 2250 PSI ULT.

PISTON LAY-UP AND MATERIAL

$[0_4/\pm 45/90]_5$ OF 2002/AS GRAPHITE EPOXY

0° IS || TO PISTON &

DESIGN ALLOWABLES

ULTIMATE DESIGN ALLOWABLES

1. BASED UPON LIMIT INTERACTION CURVE (SEE FIGURE 6)
2. ULT. ALLOWABLE = LIMIT ALLOWABLE FROM INTERACTION CURVE $\times 1.50$
3. HOOP STRESS = $\frac{PR}{t} = 2250 \frac{(1.09)}{.49} = 5004$ PSI
4. FROM FIGURE 6, USING $\sigma_{yc} = 5004 \times \frac{1}{1.5} = 3336$ PSI
ALLOWABLES ARE:

$$\begin{aligned}\sigma_{xe} &= 72,000 \times 1.5 = 108,000 && \text{PSI} \\ \sigma_{xc} &= 72,000 \times 1.5 = 108,000 && \text{PSI} \\ \sigma_{ye} &= 3336 \times 1.5 = 5004 && \text{PSI} \\ \sigma_{yc} &= 3336 \times 1.5 = 5004 && \text{PSI} \\ \tau_{xy} &= 13,860 \times 1.5 = 20,790 && \text{PSI} \\ \text{INTERLAMINAR SHEAR} &= 12,000 && \text{PSI}\end{aligned}$$

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SKETCH NO. IV.2

PLANT BACCHUS PROJECT NO. _____ DATE 12-18-72 AUTHOR J.N. BURNS
BLDG. _____ TITLE _____

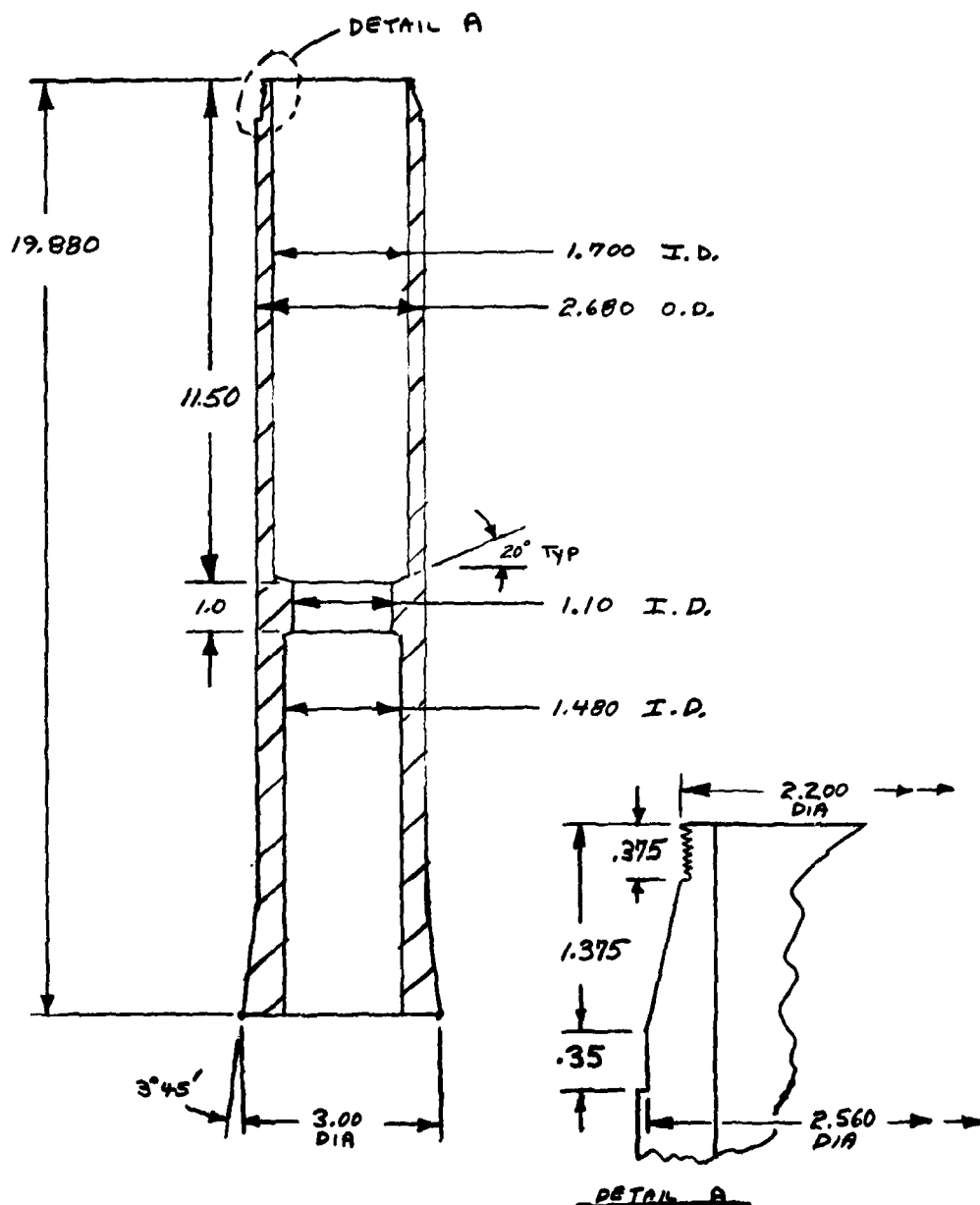
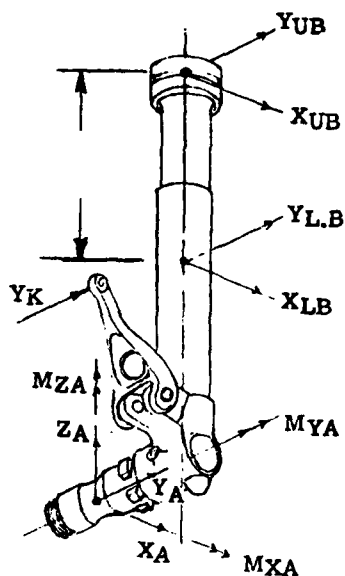


FIGURE 1
PISTON
A-37B LANDING GEAR
MAT. ~ 2002/AS

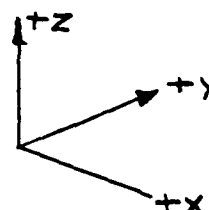
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FIGURE 2
SKETCH NO. IV, 3

PLANT _____ PROJECT NO. _____ DATE 1-18-73 AUTHOR gng
BLDG. _____ TITLE A-37 B GRAPHITE LANDING GEAR
ULTIMATE PISTON DESIGN LOADS



Forces →
Moments → (Left hand rule)
X Positive Aft
Y Positive Outboard
Z Positive Up



Piston

PISTON													
Load Condition			Z _A	X _A	Y _A	M _{ZA}	M _{XA}	M _{YA}	X _{LB}	Y _{LB}	Y _K	X _{UB}	Y _{UB}
2 Pt. Level Landing	Max. Vert.	1A	15000	-5600	0	0	0	0	9500	15300	-5200	-3500	-10100
	Spin-up	1B	7700	7300	0	0	0	0	-12100	-3900	6800	4800	-2900
	Spring Back	1C	11700	-9700	0	0	0	0	16200	18200	-9100	-6400	-9100
Tail Down Landing	Max. Vert.	2A	13900	-9600	0	0	0	0	16000	19400	-9000	-6400	-10400
	Spring Back	2C	8300	-10400	0	0	0	0	14900	17000	-9700	-4500	-7200
Drift Landing	Right	3A	7700	-900	4700	4400	38800	0	1400	-6100	-300	-500	1800
	Left	3B	7700	-900	-6200	-5900	-51700	0	1400	21000	-1600	-500	-13300
Braked Roll		4A	11400	7200	0	0	0	-70600	-14700	-1300	6100	7500	-4800
Reverse Brake		5A	9500	-9500	0	0	0	70600	17900	14000	-8200	-8300	-5800
Right Turn		6A	11500	-1300	-5600	-5500	-48000	0	1800	19100	-1700	-500	-11600
3G Taxi		7	19200										

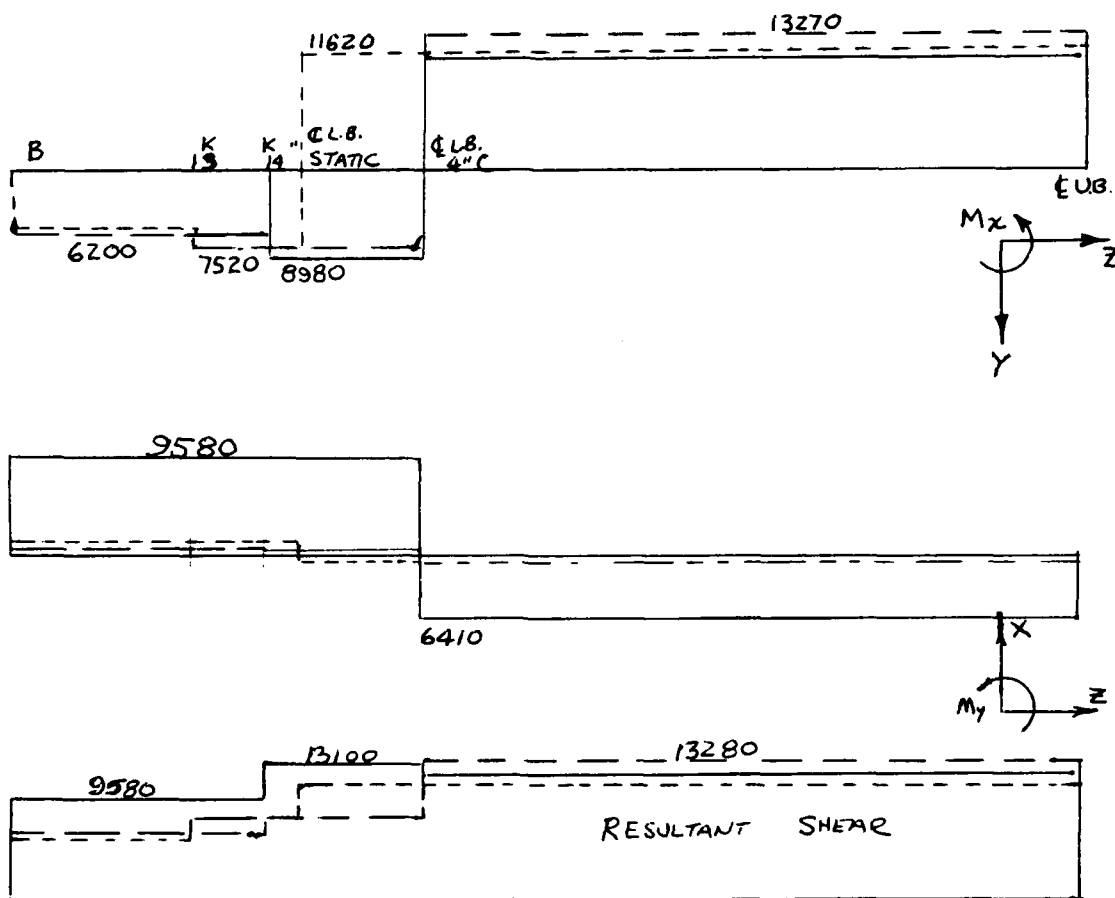
REFERENCE : BENDIX THIRD INTERIM REPORT - PHASE I COMPLETION
APRIL 1, 1970 TO DEC. 14, 1970 ON THE F117H
COMPOSITE MATERIAL LANDING GEAR PROGRAM

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV. 4

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____
BLDG. _____ TITLE _____

FIGURE 3
PISTON
SHEAR DIAGRAM (ULTIMATE)



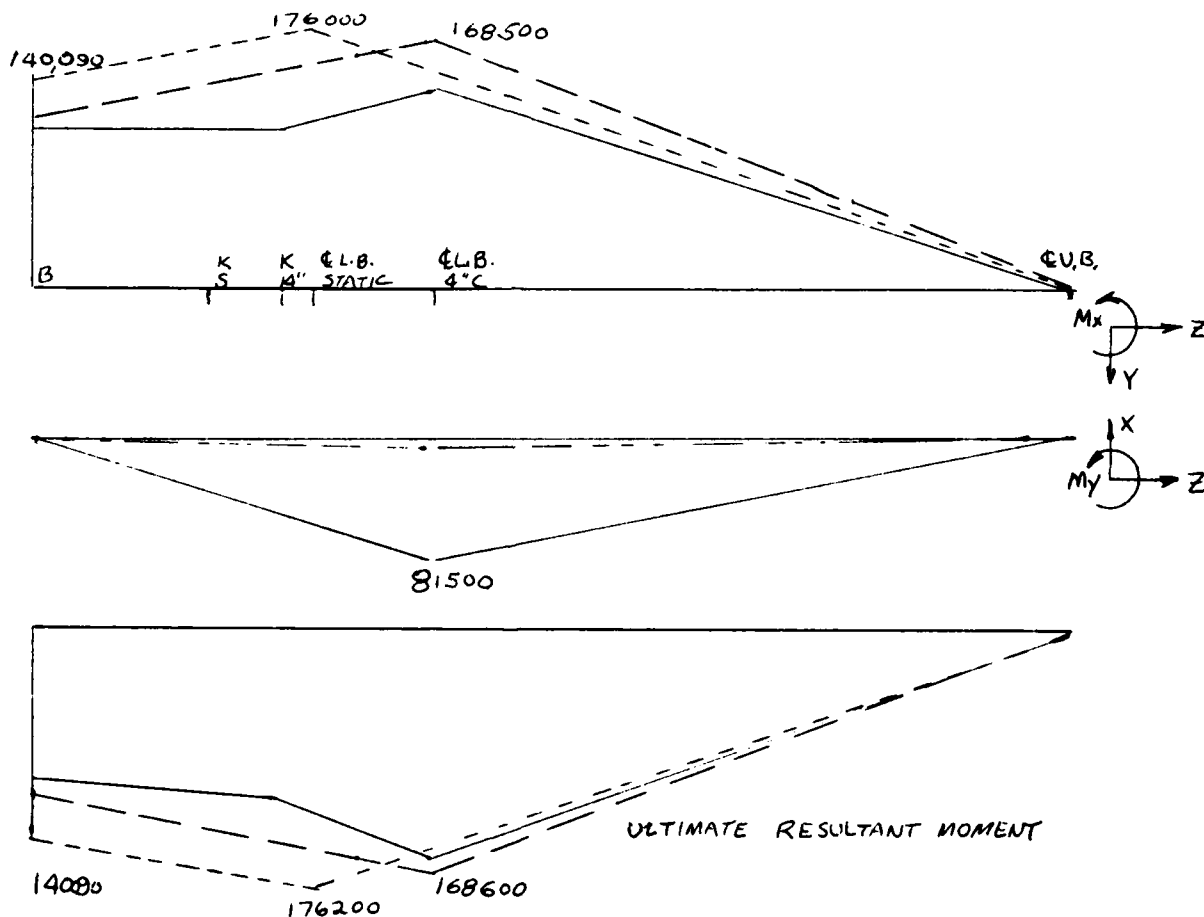
SCALE 1 IN = 3 IN
SCALE 1 IN = 15000 LB
—— COND 2A
---- COND 6A
- - - COND 3B

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SKETCH NO. IV.5

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____
BLDG. _____ TITLE _____

FIGURE 4
PISTON ULTIMATE MOMENT DIAGRAM



SCALE 1 IN = 3 IN
SCALE 1 IN = 100,000 IN LB
——— COND 2A
----- COND 3A
- - - - COND 3B

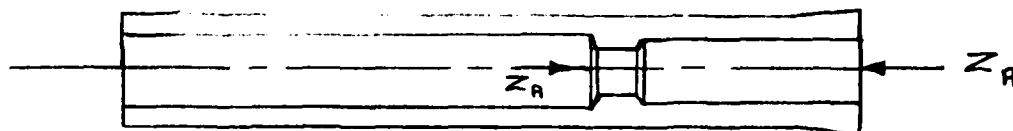
HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.6

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR _____

BLDG. _____ TITLE _____

FIGURE 5
UNIFORM AXIAL
LOADING



Z_A LOADS ARE SHOWN IN FIGURE 2

FIG. 6
DESIGN PROPERTIES (77°F)
FOR
2002 AS GRAPHITE EPOXY LAMINATES $[0^\circ/\pm 45^\circ/90^\circ]$
55% FIBER VOL.
QUASI-ORTHOTROPIC

ELASTIC CONSTANTS

$$E_x = 10.83 \times 10^6 \text{ PSI}$$

$$E_y = 4.31 \times 10^6 \text{ PSI}$$

$$\mu_{xy} = 0.30$$

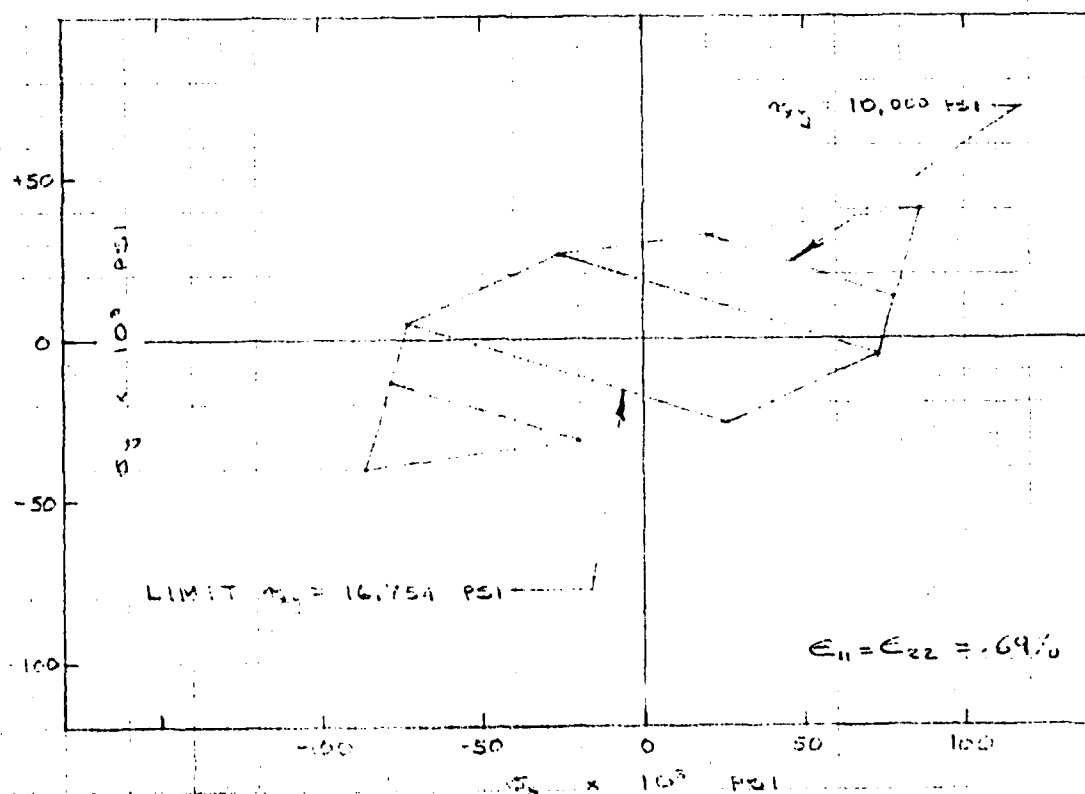
$$G_{xy} = 1.69 \times 10^6 \text{ PSI}$$

THERMAL COEFFICIENTS

$$\alpha_x = 0.118 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

$$\alpha_y = \pm 2.078 \text{ IN/IN/}^\circ\text{F} \times 10^{-6}$$

"LIMIT" INTERACTION CURVE



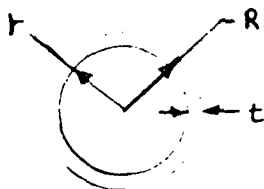
HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.8

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gnc
BLDG. _____ TITLE A-37 B LANDING GEAR

PISTON DESIGN

REQUIRED WALL THICKNESS FOR SHEAR



$$O.D. = 2.68 \text{ in} , R = 1.34$$

$$F_s = \frac{2V}{A} = \frac{2V}{\pi[R^2 - r^2]}$$

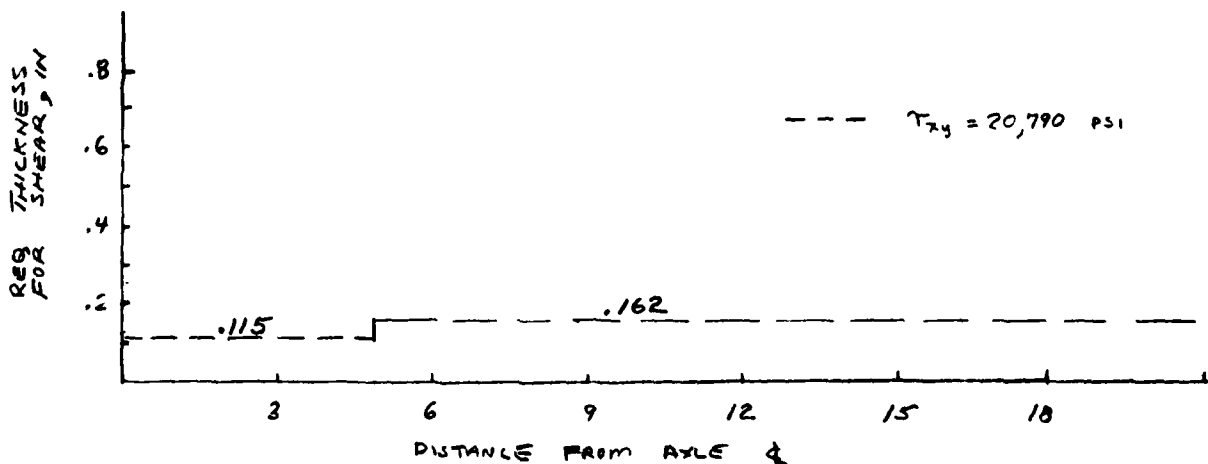
$$r^2 = R^2 - \frac{2V}{\pi F_s}$$

$$F_s = F_{allowable} = \tau_{xy} = 20,790 \text{ PSI}$$

$$V = 13,280^*, 13,100^*, 9,580^* \text{ (SEE FIG. 3)}$$

$$r^2 = (1.34)^2 - \frac{2V}{\pi(20,790)} = 1.795 - 3.06 \times 10^{-5} V$$

<u>V</u>	<u>r</u>	<u>t</u>
13,280	1.178	.162
13,100	1.181	.159
9,580	1.225	.115



HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.9

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37 B LANDING TIE BAR

PISTON DESIGN

REQUIRED WALL THICKNESS FOR MOMENT

LOADS

SEE FIGURE 4

DESIGN ALLOWABLES

$$\sigma_{x_t} = 108,000 \text{ PSI} \quad , \quad \sigma_{x_c} = 108,000 \text{ PSI}$$

SECTION PROPERTIES

$$O.D. = 2.68 \text{ IN} \quad , \quad R = C = 1.34$$

REQ t_w

$$F_b = \frac{Mc}{I} = \frac{Mc}{\frac{\pi}{4}[R^4 - r^4]}$$

$$r^4 = R^4 - \frac{Mc}{F_b \frac{\pi}{4}} = (1.34)^4 - \frac{m(1.34)}{108,000(1.785)} = 3.23 - 1.58 \times 10^{-5} m$$

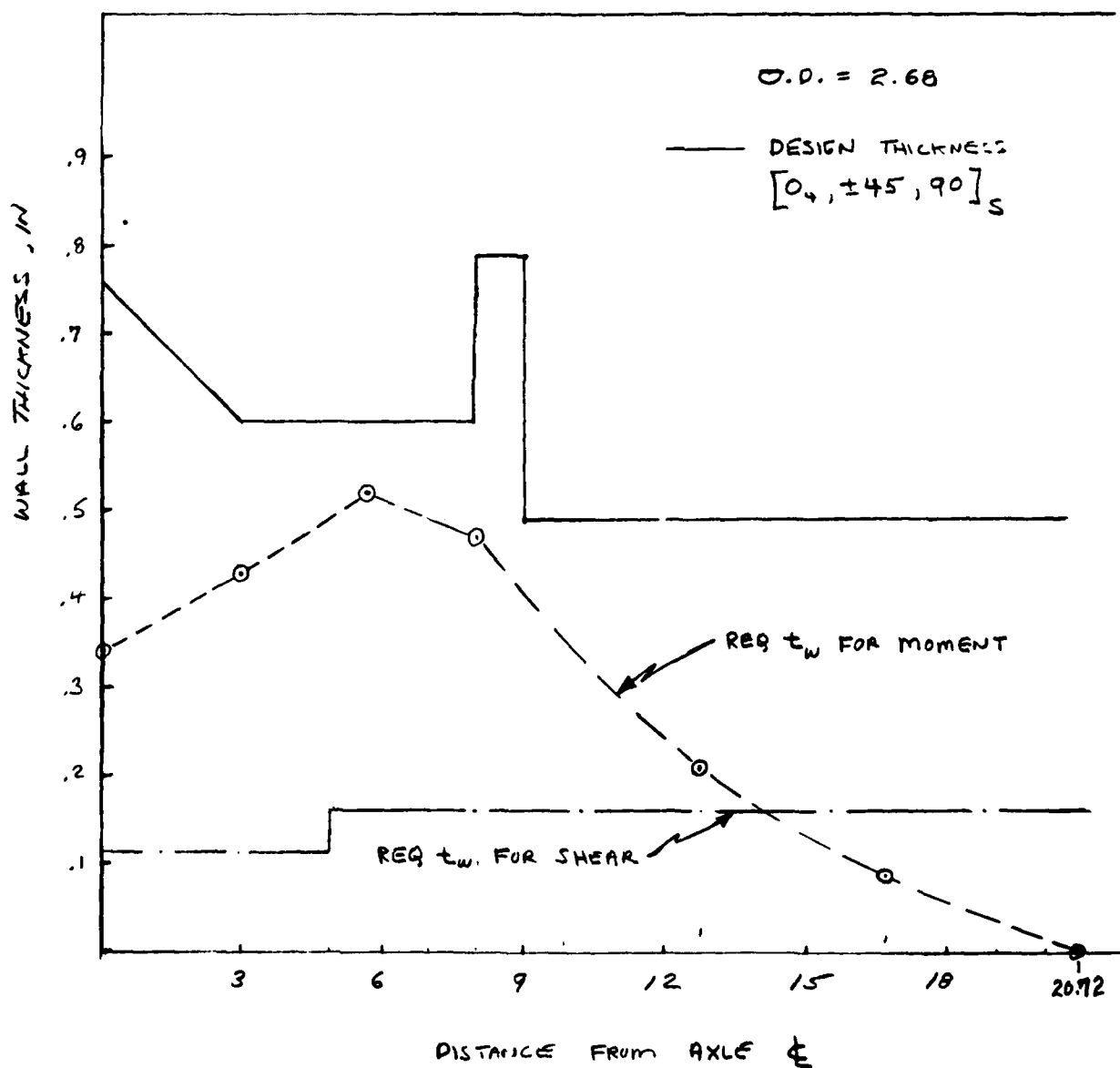
<u>m</u>	<u>r^4</u>	<u>r</u>	<u>t</u>
140,090	1.02	1.00	.34
176,200	.45	.82	.52
168,600	.57	.87	.47
100,000	1.65	1.13	.21
50,000	2.44	1.25	.09
160,500	.69	.91	.43

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV. 1D

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gmb
BLDG. _____ TITLE A-37 B LANDING GEAR

PISTON DESIGN
ACTUAL VS. REQ. WALL
THICKNESSES

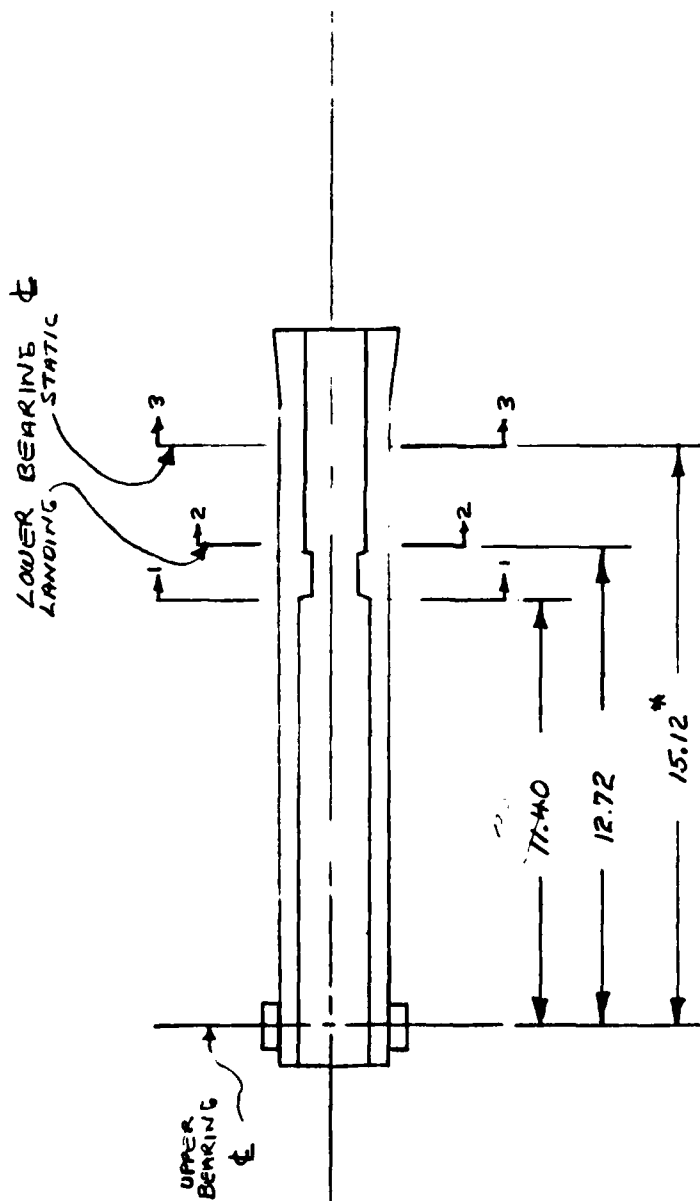


HERCULES INCORPORATED
ENGINEERING DEPARTMENT

FIG 7

SKETCH NO. IV.11

PLANT _____ PROJECT NO. _____ DATE _____ AUTHOR J. N. BURKE
BLDG. _____ TITLE A-37 B GRAPHITE PISTON



* VALUE FOR WHICH LOADS WERE DEVELOPED BY BENDIX. HI COMPOSITE DESIGN CLOSE FOR INITIAL DESIGN BUT THIS VALUE IS SMALL, BUT THIS VALUE IS CLOSE FOR INITIAL DESIGN

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.12

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR gnb
BLDG. _____ TITLE A-37 B LANDING GEAR

STRESSES AT SECTION 1-1 (SEE FIG. 7)

SECTION PROPERTIES

$$I.D. = 1.7 \quad O.D. = 2.68 \quad A = .785 [(2.68)^2 - (1.7)^2] = 3.37 \text{ in}^2$$

$$I = \frac{\pi}{4} [R_o^4 - R_i^4] = .785 [(1.34)^4 - (.85)^4] = 2.123 \text{ in}^4$$

LOADS

$$\text{SHEAR} = 13,280$$

$$\text{AXIAL LOADING} = 0.0$$

$$\text{MOMENT} = 13,280 \times 11.4 = 151,392 \text{ IN-IB}$$

SHEAR STRESS

$$F_s = \frac{4}{3} \frac{V}{A} \left[1 + \frac{Dd}{D^2 + d^2} \right] = \frac{4}{3} \frac{V}{A} \left[1 + \frac{(2.68)(1.7)}{(2.68)^2 + (1.7)^2} \right] = 1.94 \frac{V}{A}$$

$$F_s = 1.94 \frac{(13,280)}{(3.37)} = \underline{7,650 \text{ PSI}} \quad \text{m.s.} = \frac{20,790}{7,650} - 1 = \underline{+1.72}$$

NORMAL STRESS

$$F_z = F_b + F_c = \frac{mc}{I} + \frac{P}{A}$$

$$= \frac{151,392 (1.34)}{2.123} + 0 = \underline{96,300 \text{ PSI}}$$

$$\text{m.s.} = \frac{108,000}{96,300} - 1 = \underline{+0.12}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.13

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JMB
BLDG. _____ TITLE A-37 B LANDING GEAR

STRESSES AT SECTION 3-3 (SEE FIG 7)

SECTION PROPERTIES

$$I.D. = 1.480 \quad O.D. = 2.680 \quad A = .785[(2.68)^2 - (1.48)^2] = 3.9 \text{ in}^2$$

$$I = \frac{\pi}{4}[R_o^4 - R_i^4] = .785[(1.34)^4 - (.74)^4] = 2.25 \text{ in}^4$$

LOADS (CONDITION 6A IS CRITICAL)

$$\text{MOMENT} = 176,200 \text{ IN-LB}$$

$$\text{SHEAR} = 11,600 \text{ LB}$$

$$\text{AXIAL LOAD} = 11,500 \text{ LB COMPRESSION}$$

STRESSES

$$f_s \approx 2 \frac{V}{A} = \frac{2(11,600)}{3.9} = \underline{5,960} \quad \text{m.s.} = \frac{20,790}{5,960} = \underline{+2.49}$$

$$f_b = \frac{Mc}{I} = \frac{176,200(1.34)}{(2.25)} = \pm 105,000$$

$$f_a = \frac{P}{A} = \frac{-11,500}{3.90} = -2,950$$

$$f_t = f_a \pm f_b = -2,950 \pm 105,000 \\ = \underline{-107,950} \quad , \quad \underline{+102,050}$$

$$(-) \text{ m.s.} = \frac{108,000}{107,950} - 1 = \underline{+0.00} \quad (+) \text{ m.s.} = \frac{108,000}{102,050} - 1 = \underline{+0.06}$$

HERCULES INCORPORATED ENGINEERING DEPARTMENT

SKETCH NO. IV.14

PLANT _____ PROJECT NO. _____ DATE 2-73 AUTHOR JNB
BLDG. _____ TITLE A-37 B HANDING GEAR

PISTON

RETAINING LEDGE FOR METERING PIN

LOAD

MAX CONDITION ~ 7 (36 TAXI)

$F = 19,200 \text{ lbs}$

PROPERTIES

$F_{su} = 10,000 \text{ PSI}$

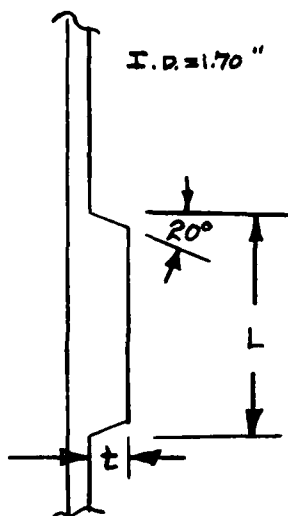
$F_{bu} = 40,000 \text{ PSI}$

REQ. t

$$R_i = \left[R_o^2 - \frac{F}{F_{bu} \pi} \right] = \left[(.85)^2 - \frac{19,200}{\pi 40,000} \right]$$

$$R_i = .723 - .153 = .570$$

$$t = R_o - R_i = .85 - .57 = .28$$



REQ L

$$F_s = \frac{3}{2} \frac{F}{A} = \frac{3}{2} \frac{F}{\pi d l}$$

$$l = \frac{\frac{3}{2} F}{\pi d F_{su}} = \frac{1.5 (19,200)}{\pi (1.7) (10,000)}$$

$$l = .539 \text{ INCHES USE, } 1.0 \text{ INCHES}$$

APPENDIX A
PART V

LOADS USED IN THE
DESIGN AND ANALYSIS
OF THE LEFT MAIN LANDING GEAR

Sketch V.1

V.A. Applied Loads

The following loads were calculated from the Cessna test results for the right main landing gear of the A-37B aircraft. The coordinate system used for the right gear is inverted for the left, automatically, and needs no further sign changes.

The loads calculated for the end of the axle agree with the Bendix loads table in Reference 1, except that Reference 1 has two minor errors. They have accidentally switched the F_y loads for cases 3A and 3B, thereby effecting the corresponding bending moments M_z and M_x .

Limit loads tested for by Cessna are found in Reference 2. A total of eleven loading conditions are defined by Cessna and are identified and coded in Table V.1.

TABLE V.1
LOADING CONDITION CHART

Code			
1A	Landing	2 Points	Maximum vertical
1B		Level	Spin-up
1C		Landing	Spring back
2A		Tail Down	Maximum vertical
2C		Landing	Spring back
3A		Drift	Right
3B	Static	Landing	Left
4A		Braked roll	
5A		Reverse brake	
6A		Right turn	
7		2G taxi	

Limit loads for a 14,000 pound A-37B aircraft, as found by Cessna, are shown in Figure V.2 and listed in Table V.3.

Sketch V-2

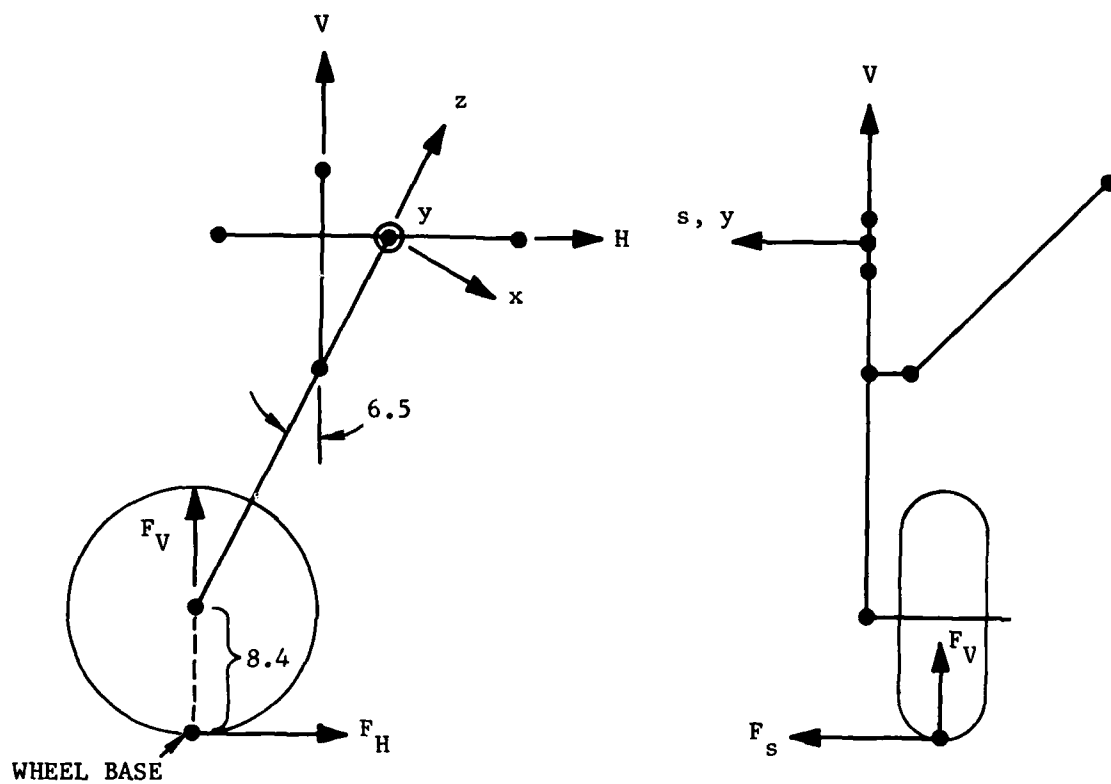


Figure V.2. Wheel Load Vectors Whose Values are Listed in Table V.3

TABLE V.3
LIMIT LOADS ON 14,000 #A-37B AT WHEEL⁺

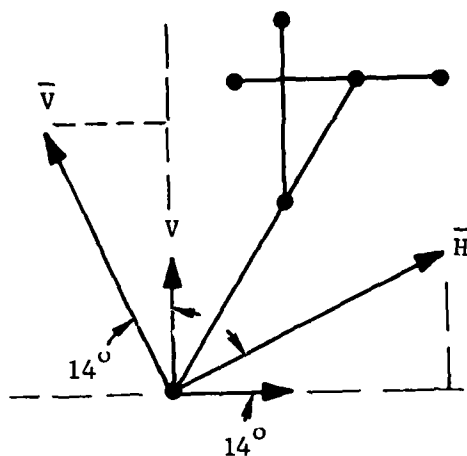
Sketch V-3

Condition	F_H (pounds)	F_s (pounds)	F_v (pounds)
1A	-2,582	0	10,326
1B	5,401	0	4,541
1C	-5,550	0	8,489
2A*	-5,296	0	9,946
2C*	-6,247	0	6,290
3A	0	-4,130	5,163
3B	0	3,098	5,163
4A	5,600	0	7,000
5A	-5,600	0	7,000
6A	0	-3,844	7,688
7	0	0	12,790

* See Figure V.4

+ Reference 6

Sketch 2-9



$$H = -\bar{V} \sin 14^\circ + \bar{H} \cos 14^\circ$$

$$V = \bar{V} \cos 14^\circ + \bar{H} \sin 14^\circ$$

CONDITION	$\bar{H}$	$\bar{V}$
2A	-2733	10,932
2C	-4540	7,615

CONDITION	H	V
2A	-5296	9946
2C	-6247	6290

Figure V.4. Calculations for Tail-Down Condition

Sketch E-5

The objective of the applied loads analysis is to transfer the loads in the H,S,V system at the wheel base to the near end of the axle in the x,y,z system. This point on the axle is the centroid of the tire. The reason for doing this transformation and rotation allows for a simpler loads analysis on the rest of the gear.

The transformation and rotation is achieved as shown in Figures V.5 and V.6 below.

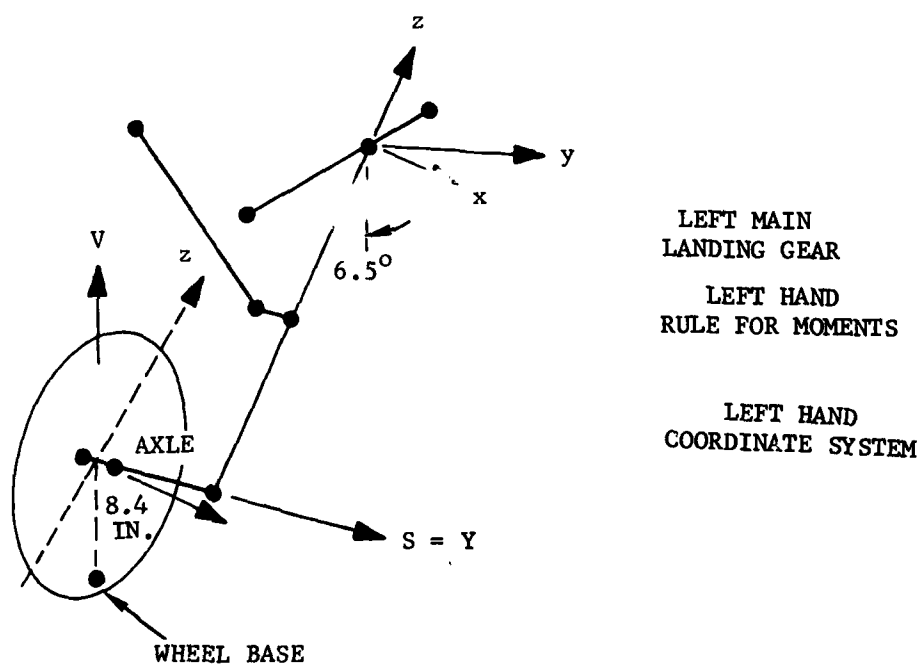


Figure V.5. Over-all View

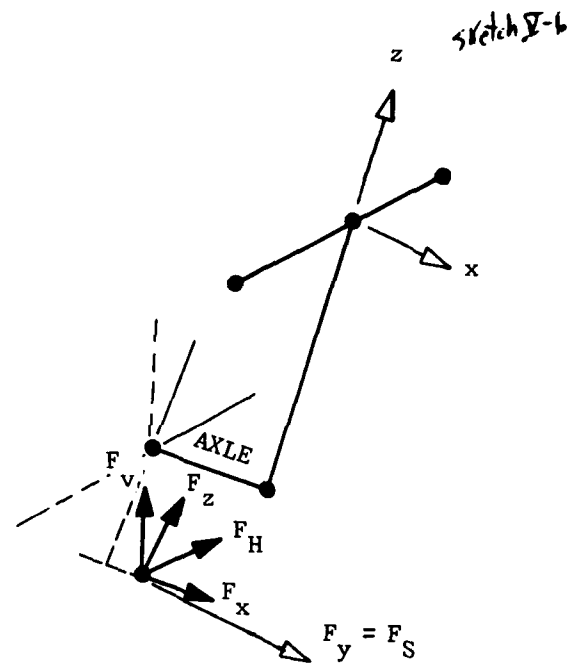
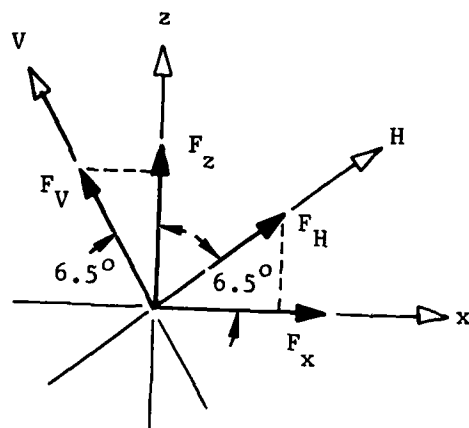


Figure V.6. Rotating Forces at Wheel Base

$$F_x = F_H \cos 6.5^\circ - F_V \sin 6.5^\circ$$

$$F_y = F_s$$

$$F_z = F_H \sin 6.5^\circ + F_V \cos 6.5^\circ$$

F_x , F_y , F_z will also be the same forces at the axle.

Next, moments about the x, y, and z axes can be easily found from the F_x , F_y , and F_z loads and are calculated at the axle (see Figure V.7).

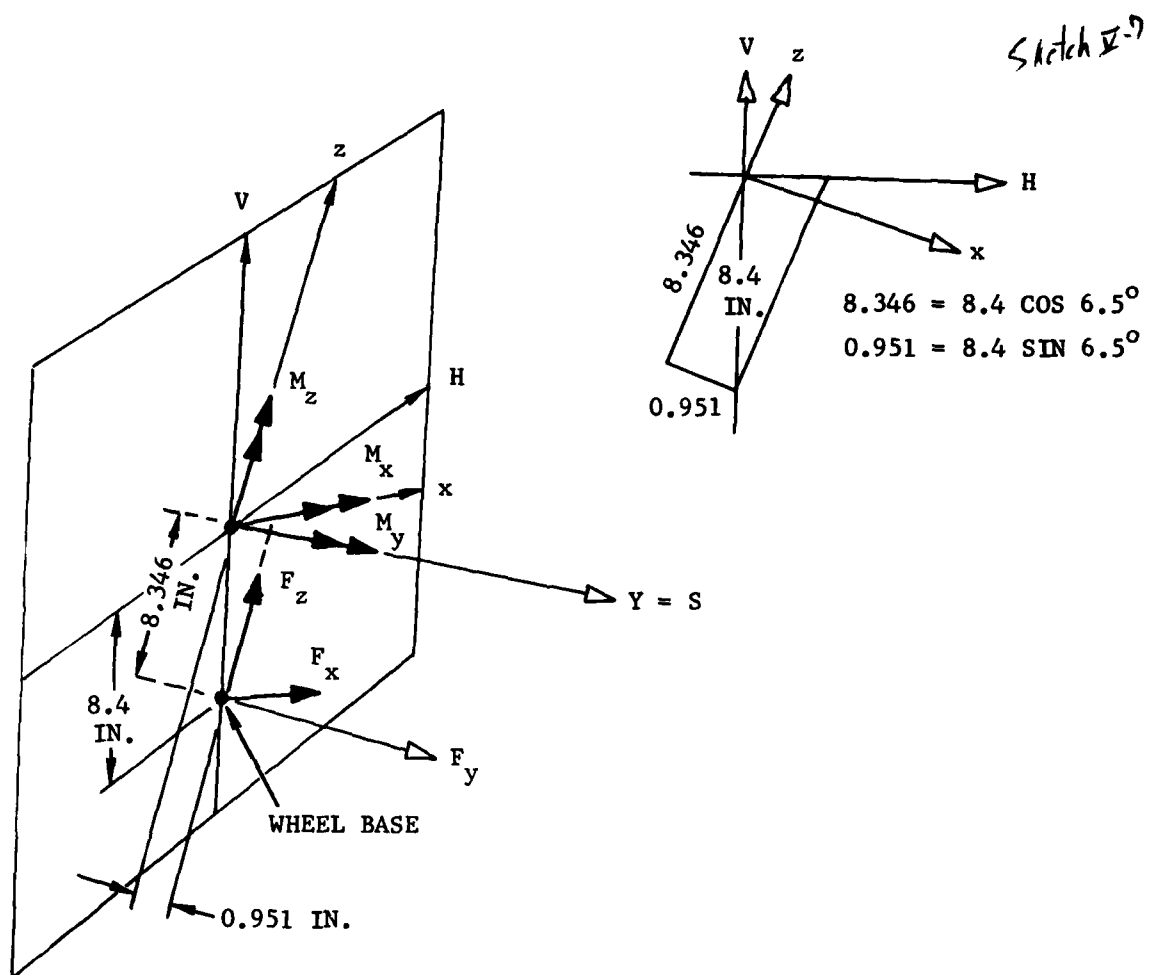


Figure V.7

Solutions of moments about the x, y, z axes translated to the end of the axle, due to loads F_x , F_y , F_z at the wheel base, are given below.

$$M_x = 8.346 F_y$$

$$M_y = -8.346 F_x - .951 F_z^*$$

$$M_z = .951 F_y$$

* $M_y = 0$ for nonbraking conditions. That is, $M_y \neq 0$ for cases 4A and 5A only.

Sketch V-8

Tables V.8 and V.9 list the limit and ultimate applied loads at the axle. The ultimate loads are 1.5 x the limit loads.

TABLE V.8
LIMIT LOADS AT THE AXLE END

	No.	F _x	F _y	F _z	M _x	M _y	M _z
1A	1	-3735	0	9967	0	0	0
1B	2	4853	0	5124	0	0	0
1C	3	-6476	0	7806	0	0	0
2A	4	-6388	0	9283	0	0	0
2C	5	-6919	0	5542	0	0	0
3A	6	-585	-4130	5130	-34469	0	-3928
3B	7	-585	3098	5130	25856	0	2947
4A	8	4771	0	7590	0	-47037	0
5A	9	-6357	0	6322	0	47043	0
6A	10	-871	-3844	7639	-32083	0	-3656
7	11	* 0	0	12708	0	0	0

* Upon calculation = -1448. However, for taxi conditions the inertia of the tire is neglected.

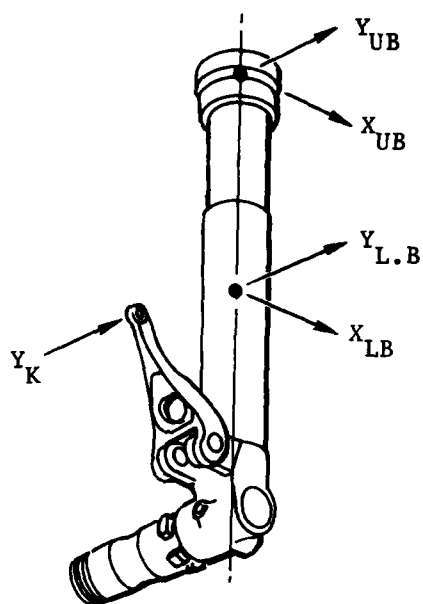
TABLE V.9
ULTIMATE LOADS AT THE AXLE END
(= 1.5 x LIMIT)

Sketch V-9

	No.	F _x	F _y	F _z	M _x	M _y	M _z
1A	1	-5603	0	14951	0	0	0
1B	2	7280	0	7686	0	0	0
1C	3	-9714	0	11709	0	0	0
2A	4	-9582	0	13925	0	0	0
2C	5	-10379	0	8313	0	0	0
3A	6	-878	-6195	7695	-51704	0	-5892
3B	7	-878	4647	7695	38784	0	4421
4A	8	7157	0	11385	0	-70556	0
5A	9	-9536	0	9483	0	70565	0
6A	10	-1307	-5766	11459	-48125	0	-5484
7	11	0	0	19062	0	0	0

V.B. Free Body Loads

The free body loads for the outer and inner assemblies have been adopted from Reference 4 and are summarized in Figures V.10 and V.12 and Tables V.11 and V.13. Corrections for conditions 3A and 3B have been made, and the slight shift in side brace position with respect to the outer cylinder has been neglected. The loads given do account for a 7.5-inch axle length.



X_{UB} AND Y_{UB} RELATE TO
THE UPPER BEARING
REACTION WITH THE I.D.
OF THE OUTER CYLINDER.

X_{LB} AND Y_{LB} RELATE TO
THE LOWER BEARING
REACTION WITH THE I.D.
OF THE OUTER CYLINDER.

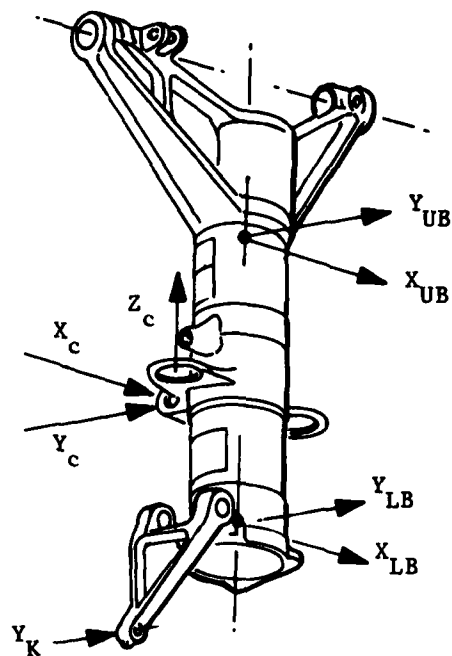
Figure V.10. Inner Assembly Load Definition

TABLE V.11
INNER ASSEMBLY APPLIED LOADS*

Cond.	X_{UB}	Y_{UB}	X_{LB}	Y_{LB}	Y_K
1A	-3900	-10100	9500	15300	-5200
1B	4800	-2900	-12100	-3900	6800
1C	-6400	-9100	16200	18200	-9100
2A	-6400	-10400	16000	19400	-9000
2C	-4500	-7200	14900	17000	-9700
3A	-500	-13300	1400	21000	-1600
3B	-500	1800	1400	-6100	-300
4A	7500	-4800	-14700	-1300	6100
5A	-8300	-5800	17900	14000	-8200
6A	-500	-11600	1800	19100	-1700
7+	0	0	0	0	0

* Loads acting ON, not BY, the assembly.

⁺ 2G taxi load acts through fluid pressure.



UB AND LB REFER TO THE
UPPER AND LOWER BEARING
LOCATIONS ON THE O.D.
OF THE PISTON.

X_c , Y_c , AND Z_c ARE
SIDE BRACE REACTIONS.

Figure V.12. Outer Assembly Load Definition

TABLE V.13
OUTER ASSEMBLY LOADS*

Cond	X_{UB}	Y_{UB}	X_c	Y_c	Z_c	X_{LB}	Y_{LB}	Y_K
1A	3900	10000	1100	7500	-9300	-9500	-15300	5200
1B	-4800	2900	500	3300	-4100	12100	3900	-6800
1C	6400	9100	900	6200	-7600	-16200	-18200	9100
2A	6400	10400	1000	-7230	-8900	-1600	-19400	9000
2C	4500	7200	600	4600	-5600	-14900	-17000	9700
3A	500	13300	2600	18300	-22600	-1400	-21000	1600
3B	500	-1800	-1000	-7300	9000	-1400	6100	300
4A	-7500	4800	700	5100	-6300	14700	1300	-6100
5A	8300	5800	700	5100	-6300	-17900	-14000	8200
6A	500	11600	2600	18400	-22700	-1800	-19100	1700
7+	0	0	0	0	0	0	0	0

* Loads acting ON, not BY, the assembly.

⁺ 2G Taxi load acts through fluid pressure to trunnion.

V.C. Reaction Loads

Sketch I-12

Free body loads not shown in Figure 12 of the previous section are the reaction loads between the aircraft frame and the trunnion of the landing gear. Because these loads are critical to the trunnion design, an indeterminate analysis using the finite-element method was performed. Rigid beams were used to model portions of the gear as shown in Figure V.14 below.

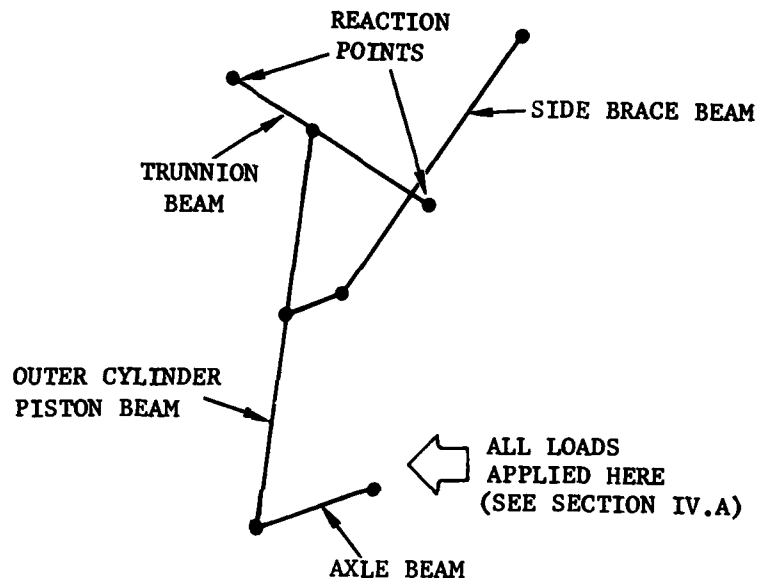
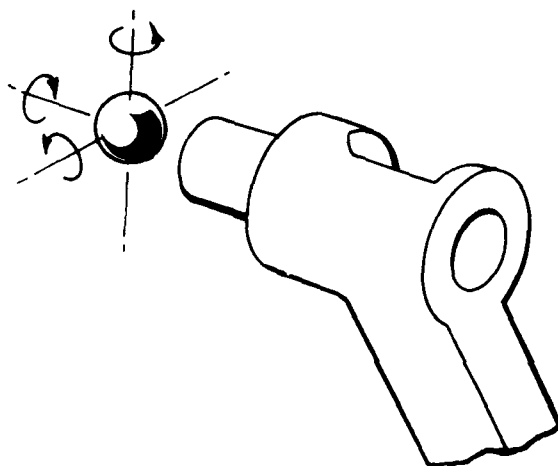
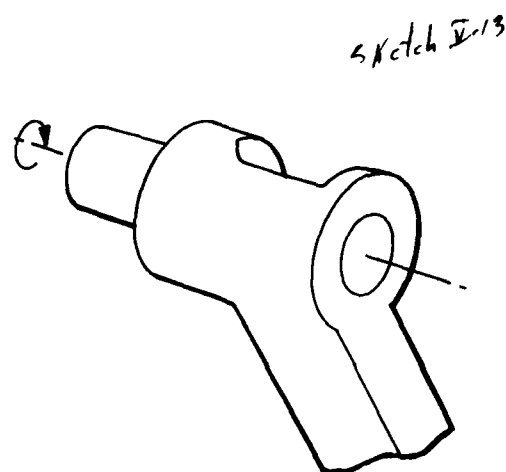


Figure V.14. Finite-Element Beam Model of Landing Gear.

In Figure V.14, the reaction points are the forward and aft lug locations on the trunnion. This model allows for easy and quick calculations of all lug loads for all loading (landing and static) conditions. Also, two boundary conditions were looked at, at the reaction points. One is a ball joint and the other a single pin joint (see Figure V.15 below).



BALL JOINT (NO MOMENTS AT
REACTION POINTS)



SINGLE PIN JOINT (2 MOMENTS
AT EACH REACTION POINT)

Figure V.15. Boundary Conditions at Reaction Points

The two boundary conditions at the reaction points were analyzed to two extreme load conditions on the trunnion. The ball joint creates a conservative load state at the base of the trunnion arms (at the junction near the outer cylinder), and a single pin joint creates a conservative load state at the lugs. In reality, the load state is somewhere between these two boundary conditions because of the "slop" or looseness between the lugs and the frame of the aircraft. Both conditions are investigated in the chapter on trunnion design and analysis.

Figures V.16 and V.18 and Tables V.17 and V.19 show and list the loads, respectively, for the ball joint boundary condition in both the H,S,V and x,y,z systems. Figures V.20 and V.22 and Tables V.21 and V.23 show and list, respectively, the single pin joint boundary conditions in both the H,S,V and x,y,z systems.

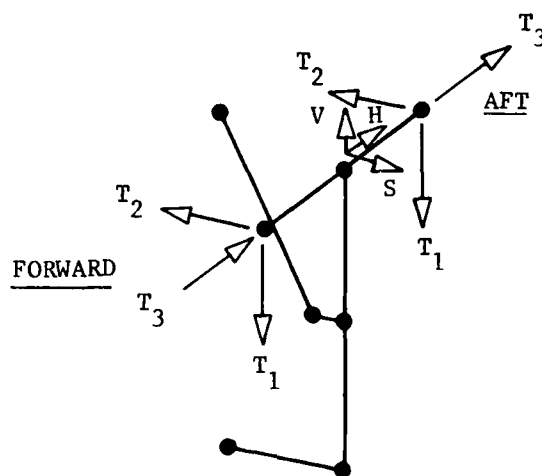


Figure V.16. Trunnion Reaction Loads in H,S,V System

TABLE V.17

TRUNNION REACTION LOADS IN H,S,V SYSTEM FOR BALL JOINTS

Case	Forward			Aft		
	T_1 Lbs	T_2 Lbs	T_3 Lbs	T_1 Lbs	T_2 Lbs	T_3 Lbs
1A	13,066	5970	3866	-6,958	1547	0
1B	-14,404	-2965	0	17,088	6267	-8124
1C	21,255	7816	8313	-16,254	-1661	0
2A	21,259	8146	7965	-15,403	-938	0
2C	22,379	7630	9393	-18,675	-3071	0
3A	-6,308	5066	17	-8,418	6657	0
3B	9,354	-495	26	7,135	-1771	0
4A	-17,884	-2251	0	22,017	7338	-8444
5A	24,253	7309	8363	-20,120	-2222	0
6A	-4,196	5432	-14	-6,732	6709	0
7	1,851	3394	-2173	5,648	5836	0

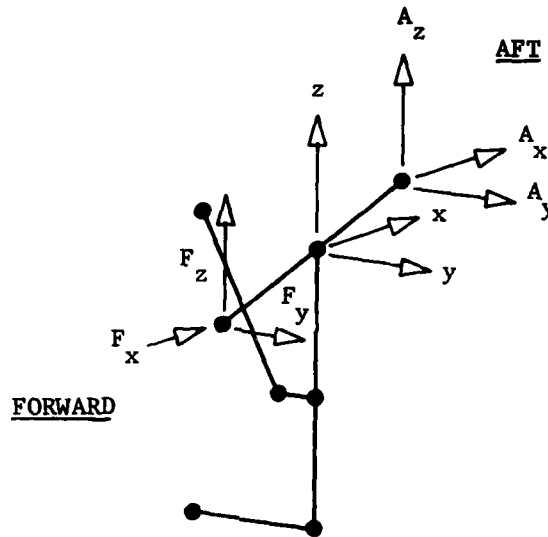


Figure V.18. Trunnion Reaction Loads

TABLE V.19

TRUNNION REACTION LOADS IN THE x,y,z SYSTEM FOR BALL JOINTS

Cond	F_x Lbs	F_y Lbs	F_z Lbs	A_x Lbs	A_y Lbs	A_z Lbs
1A	5,320	-5,970	-12,544	-787	-1,547	6,913
1B	-1,630	2,965	14,311	-6,137	-6,267	-17,897
1C	10,665	-7,816	-20,177	-1,840	16,612	16,149
2A	10,320	-8,146	-20,217	-1,743	938	15,303
2C	11,865	-7,630	-21,171	-2,114	3,071	18,553
3A	-697	-5,066	6,269	-953	-6,657	8,363
3B	1,084	495	-9,290	807	1,771	-7,089
4A	-2,024	2,251	17,769	-5,897	-7,338	-22,831
5A	11,054	-7,309	-23,150	-2,277	2,222	19,990
6A	-488	-5,432	4,167	-762	-6,709	6,688
-	-1,949	-3,394	-2,085	639	-5,836	-5,611

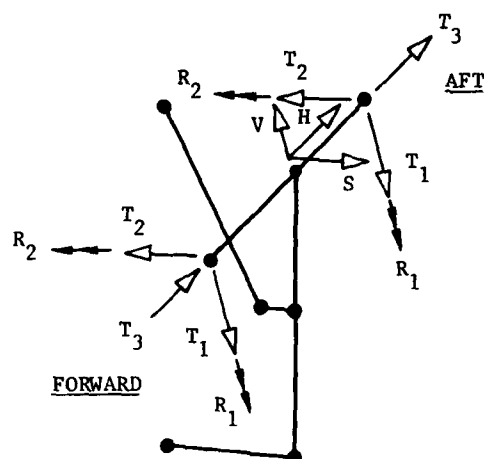
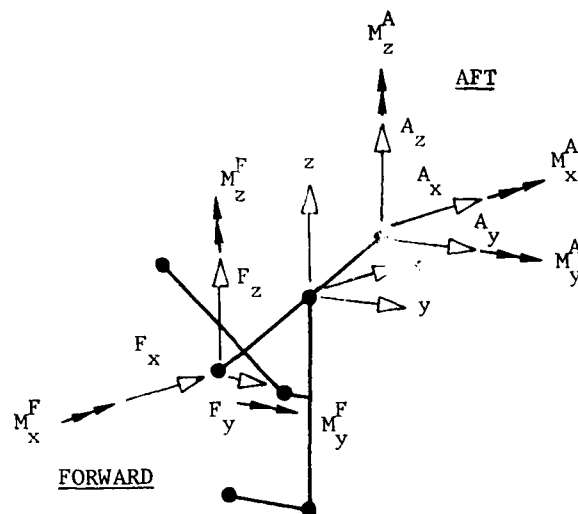


Figure V.20. Trunnion Reaction Loads

TABLE V.21
TRUNNION REACTION LOADS IN THE H,S,C SYSTEM FOR
SINGLE PIN CONDITION

Cond	T ₁ Lbs	T ₂ Lbs	T ₃ Lbs	R ₁ In./Lbs	R ₂ In./Lbs
1A	17,466	6,918	3,866	-21,992	52,458
1B	-21,371	-5,017	0	13,867	-61,777
F 1C	29,522	9,887	8,313	-30,337	87,401
O 2A	29,336	10,125	7,965	-31,285	87,063
R 2C	31,435	9,977	9,393	-30,222	92,678
W 3A	-5,785	4,670	17	-16,426	-20,397
A 3B	9,781	-204	26	1,135	32,486
R 4A	-26,714	-4,389	0	11,610	-77,037
D 5A	34,040	9,395	8,363	-28,648	100,390
6A	-3,504	5,103	-14	-17,791	-13,096
7	983	2,819	-2,173	-10,427	4,658
1A	-11,358	599	0	9,488	5,555
1B	24,055	8,320	-8,124	13,190	-30,077
1C	-24,521	-3,731	0	3,041	21,594
2A	-23,480	-2,918	0	5,186	19,426
A 2C	-27,731	-5,418	0	-719	26,710
F 3A	-8,941	7,053	0	21,649	27,286
T 3B	6,708	-2,062	0	-4,968	-26,854
4A	30,848	9,476	-8,443	16,579	-39,384
5A	-29,907	-4,308	0	1,141	28,644
6A	-7,334	7,038	0	22,123	21,033
7	6,515	6,411	0	18,006	-16,093



54.7c 6-17

Figure V.22. Trunnion Reaction Loads

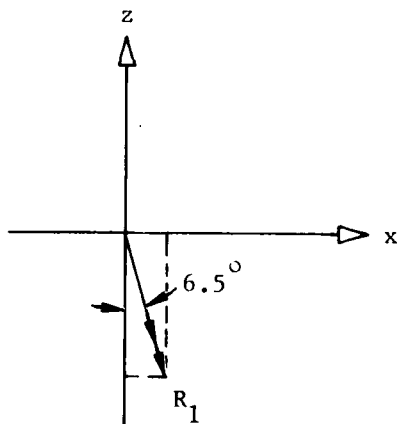
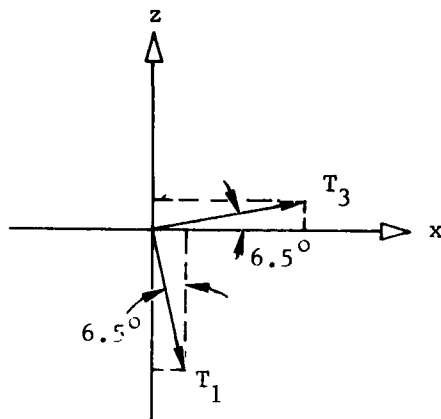
TABLE V.23

TRUNNION REACTION LOADS IN THE x,y,z SYSTEM 1
SINGLE PIN CONDITION

Cond	F_x Lbs	F_y Lbs	F_z Lbs	M_x^F In./Lbs	M_y^F In./Lbs	M_z^F In./Lbs
1A	5,818	-6,918	-16, 16	2,489	52,458	-21,850
1B	-2,419	5,017	21,233	-1,569	-61,777	13,777
F 1C	11,601	-9,887	-28,391	3,434	87,401	-30,141
O 2A	11,234	-10,125	-28,245	3,541	87,063	-31,083
R 2C	12,891	9,977	-30,187	3,421	92,678	-30,027
W 3A	-637	4,670	5,749	1,859	-20,397	-16,320
A 3B	1,133	204	-9,715	-128	32,486	1,127
R 4A	-3,024	4,389	26,542	-1,314	-77,037	11,535
D 5A	12,162	-9,395	-32,874	3,243	100,390	-28,463
6A	-420	-5,103	3,569	2,013	-13,096	-17,676
7	-2,047	-2,819	-1,222	1,180	4,658	-10,359
Cond	A_y Lbs	A_z Lbs	A_x Lbs	M_x^A In./Lbs	M_y^A In./Lbs	M_z^A In./Lbs
1A	-1,285	-599	11,284	-1,074	5,555	9,427
1B	-5,348	-8,320	-24,820	-1,493	-30,077	13,105
1C	-2,775	3,731	24,363	-344	21,594	3,021
2A	-2,658	3,918	23,327	-587	19,426	5,152
A 2C	-3,139	5,418	27,552	81	26,710	-714
F 3A	-1,012	-7,053	-8,883	-2,450	27,286	21,509
T 3B	759	2,062	-6,664	562	-26,854	-4,936
4A	-4,896	-9,476	-31,605	-1,876	-39,384	16,472
5A	-3,385	4,308	29,714	-129	28,644	1,133
6A	-830	-7,038	7,286	-2,504	21,033	21,980
7	737	-6,411	-6,473	-2,038	-16,093	17,890

Sketch 2-18

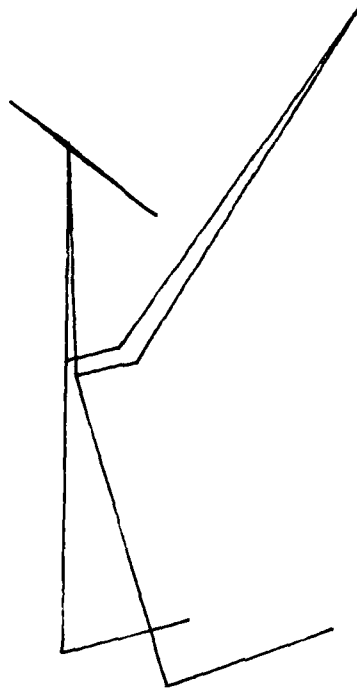
The loads given from the computer output were the T_j , R_j loads. Transformations to get A_j , F_j , M_j^F , M_j^A were made by calculations using the following equations shown below.



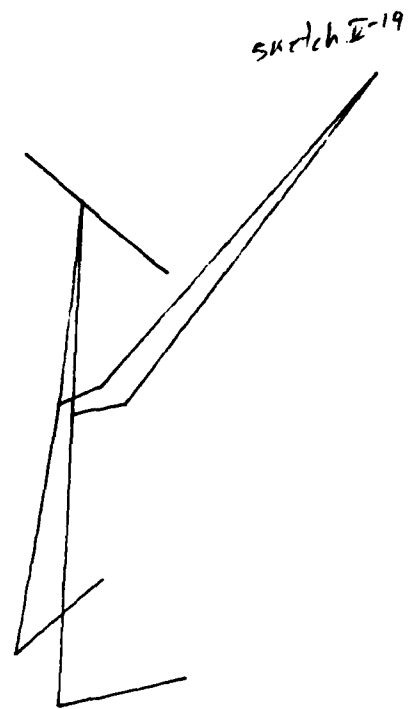
$$\begin{aligned}
 F_y &= -T_2^{\text{fwd}} \\
 A_y &= -T_2^{\text{aft}} \\
 F_x &= T_3^{\text{fwd}} \cos 6.5 + T_1^{\text{fwd}} \sin 6.5 \\
 A_x &= T_3^{\text{aft}} \cos 6.5 + T_1^{\text{aft}} \sin 6.5 \\
 F_z &= T_3^{\text{fwd}} \sin 6.5 - T_1^{\text{fwd}} \cos 6.5 \\
 A_z &= T_3^{\text{aft}} \sin 6.5 - T_1^{\text{aft}} \cos 6.5 \\
 M_x^F &= -R_1^{\text{fwd}} \sin 6.5 \\
 M_y^F &= R_2^{\text{fwd}} \\
 M_z^F &= R_1^{\text{fwd}} \cos 6.5 \\
 M_x^A &= -R_1^{\text{aft}} \sin 6.5 \\
 M_y^A &= R_2^{\text{aft}} \\
 M_z^A &= R_1^{\text{aft}} \cos 6.5
 \end{aligned}$$

Figure V.26 shows the general computer-plotted, deflected shapes of the landing gear under the given load conditions.

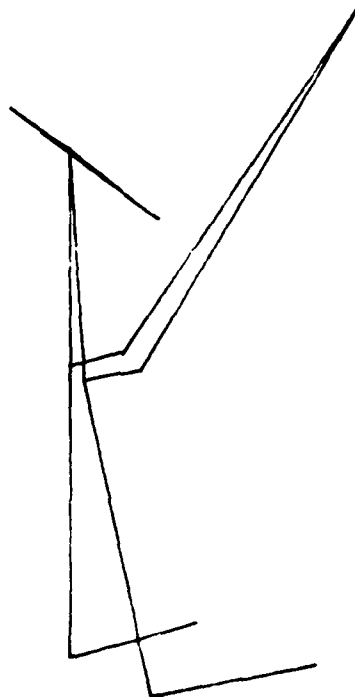
Figure V.26



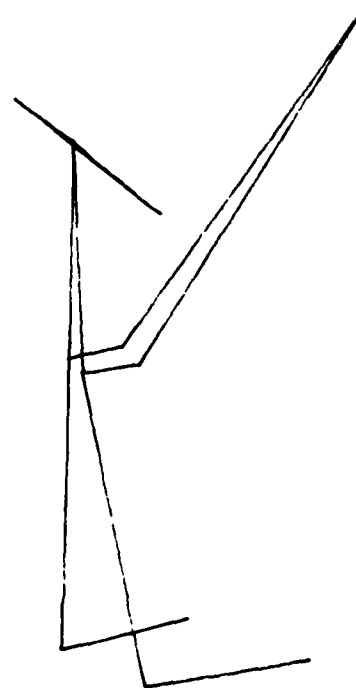
(a) LOAD CONDITION 1A



(b) LOAD CONDITION 1B



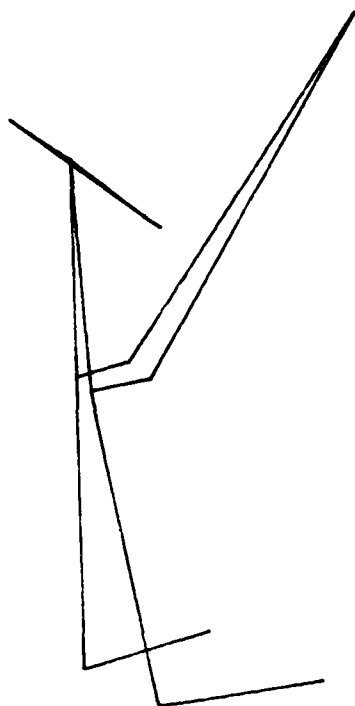
(c) LOAD CONDITION 1C



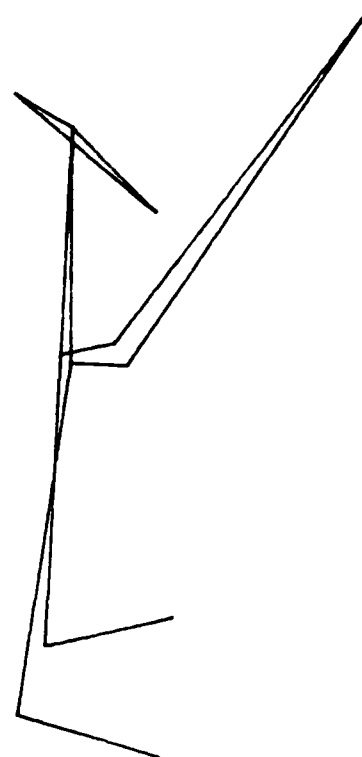
(d) LOAD CONDITION 2A

Figure V.26

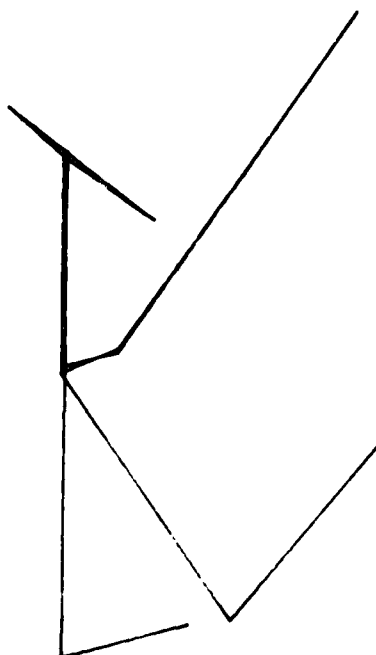
Sketch 3-20



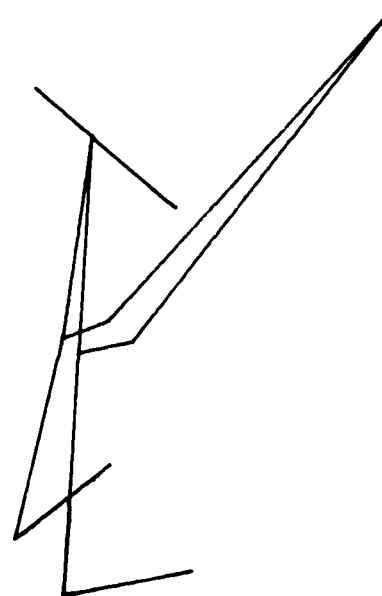
(e) LOAD CONDITION 2C



(f) LOAD CONDITION 3A

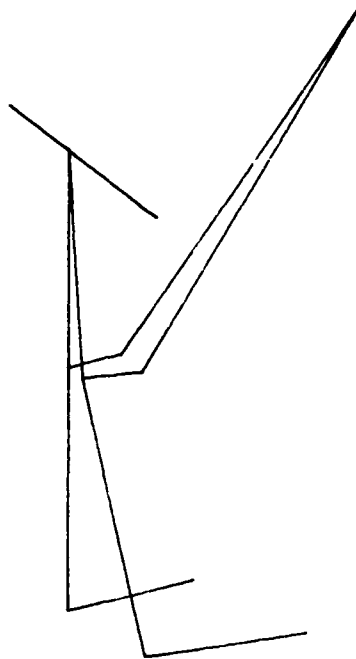


(g) LOAD CONDITION 3B

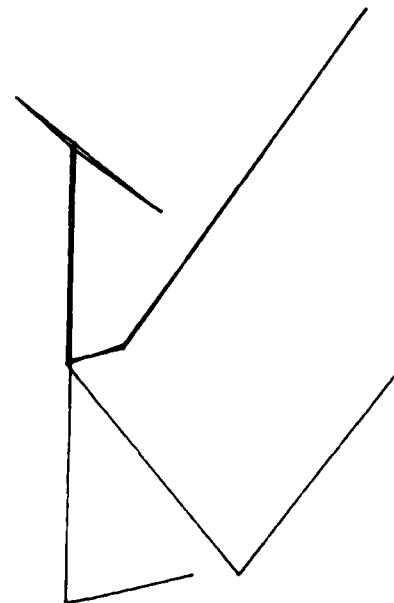


(h) LOAD CONDITION 4A

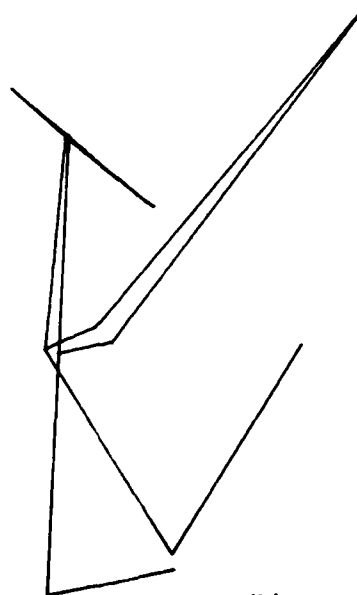
Sketch 8-2'



(i) LOAD CONDITION 5A



(j) LOAD CONDITION 6A



(k) LOAD CONDITION 7

Sketch I-22

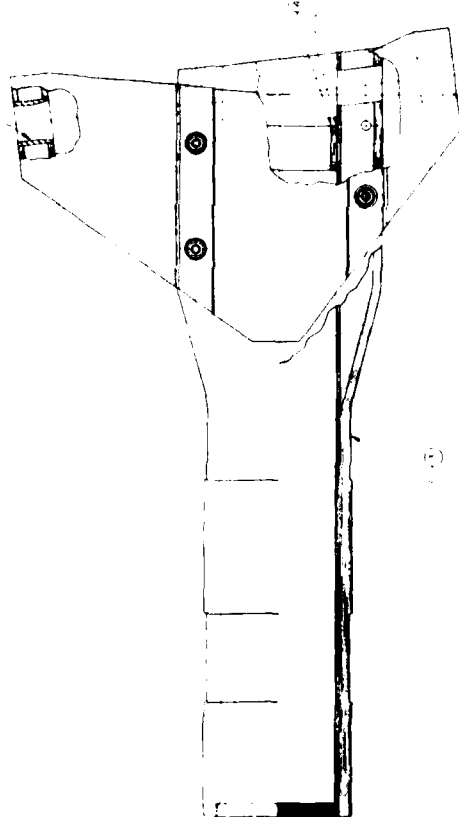
REFERENCES

1. "Third Interim Report, Filament Composite Material Landing Gear Program," The Bending Corporation, Indiana, 14 December 1970.
2. "Landing Gear and Support Structure, Static Test," Cessna Aircraft Company, Wichita, Kansas, Report Number 318E-6704-081, Revision H, 16 September 1971.

APPENDIX A
PART VI

GRAPHITE COMPOSITE LANDING GEAR COMPONENT DRAWINGS

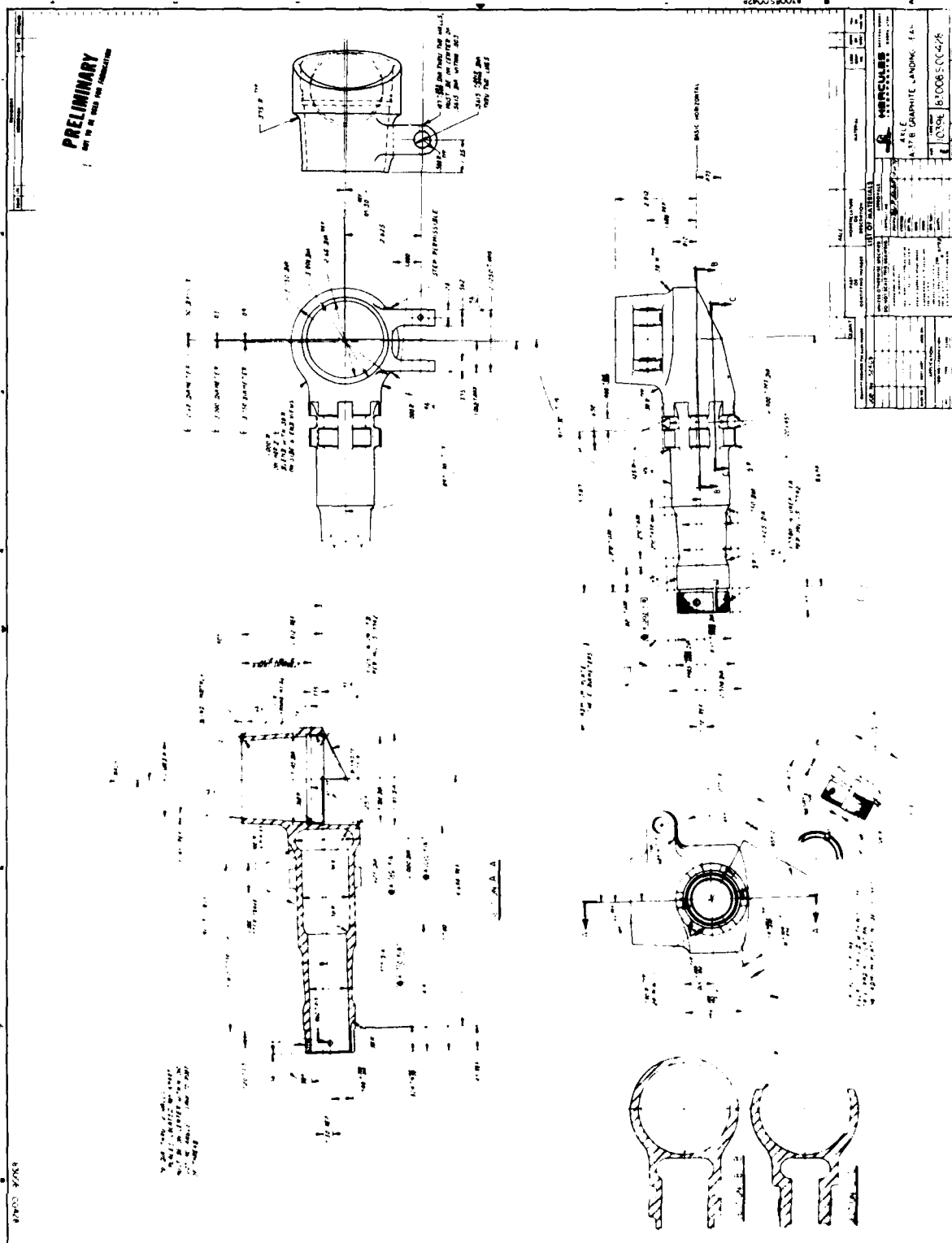
This diagram shows the top view of the aircraft fuselage. The main cabin door is located on the left side of the fuselage, forward of the wing. There are four emergency exits: two on the upper fuselage (one on each side) and two on the lower fuselage (one on each side). The diagram is labeled with circled numbers 1 through 6, corresponding to the labels in the adjacent table.

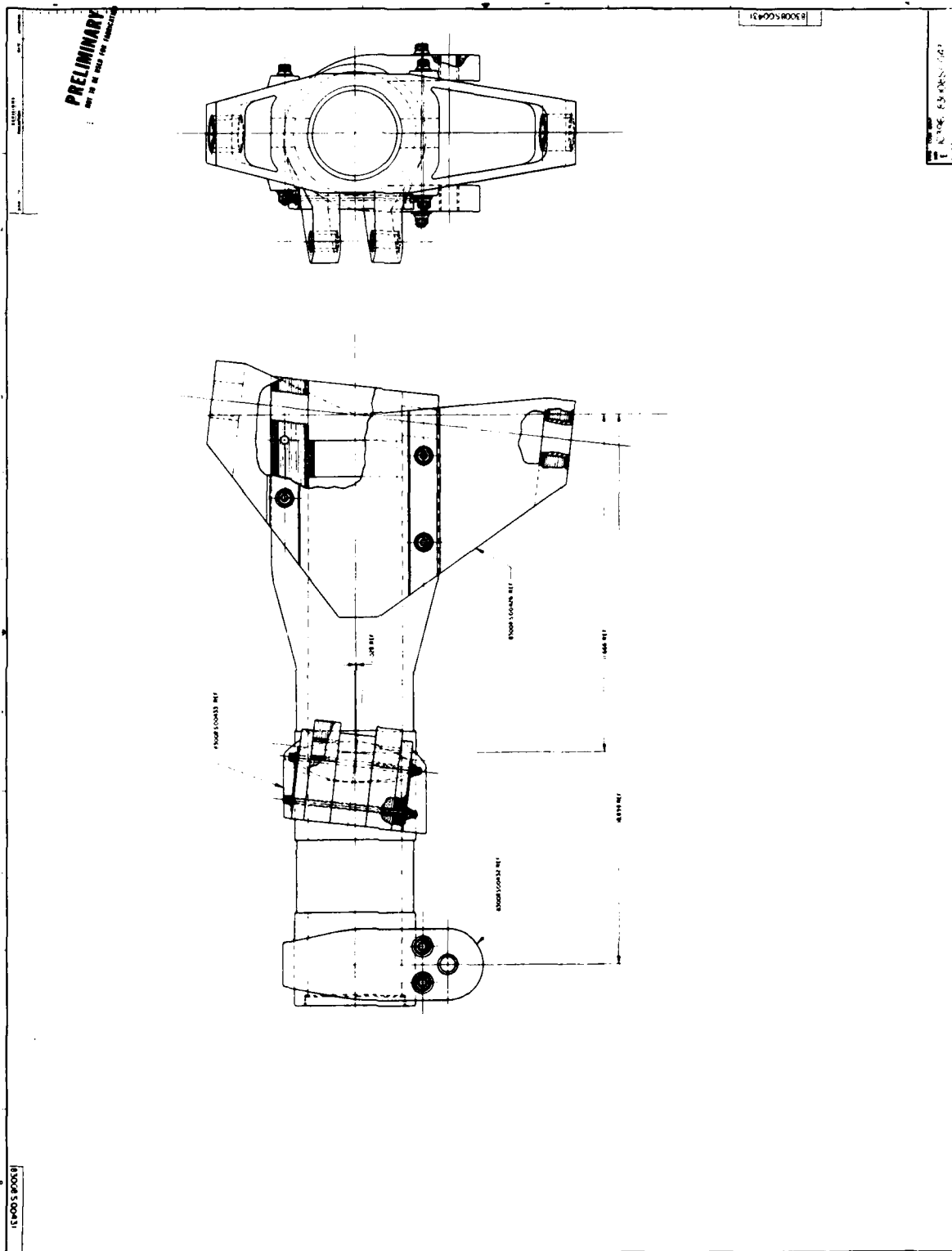


The image shows a document, possibly a passport or a form, with various sections and stamps. The document is oriented vertically. At the top, there is a header section with the word "HARCOURT" printed in large, bold, capital letters. Below this, there are several smaller sections containing text and stamps. On the left side, there is a vertical column of text that appears to be a list of names or identifiers. In the center, there is a large rectangular area with a grid pattern, possibly a table or a form for recording data. On the right side, there is a vertical column of text that appears to be a list of names or identifiers. The document is heavily marked with lines, borders, and stamps, suggesting it is an official form.

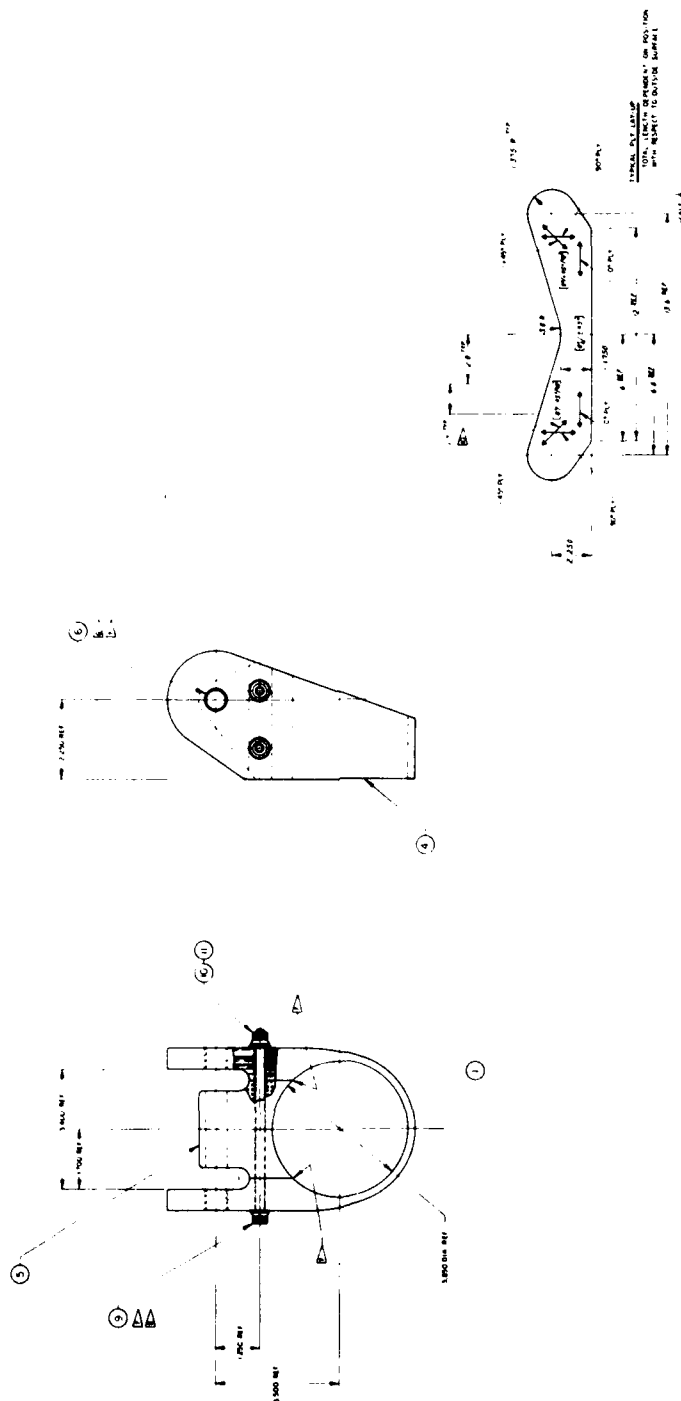
[illegible]

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[illegible]

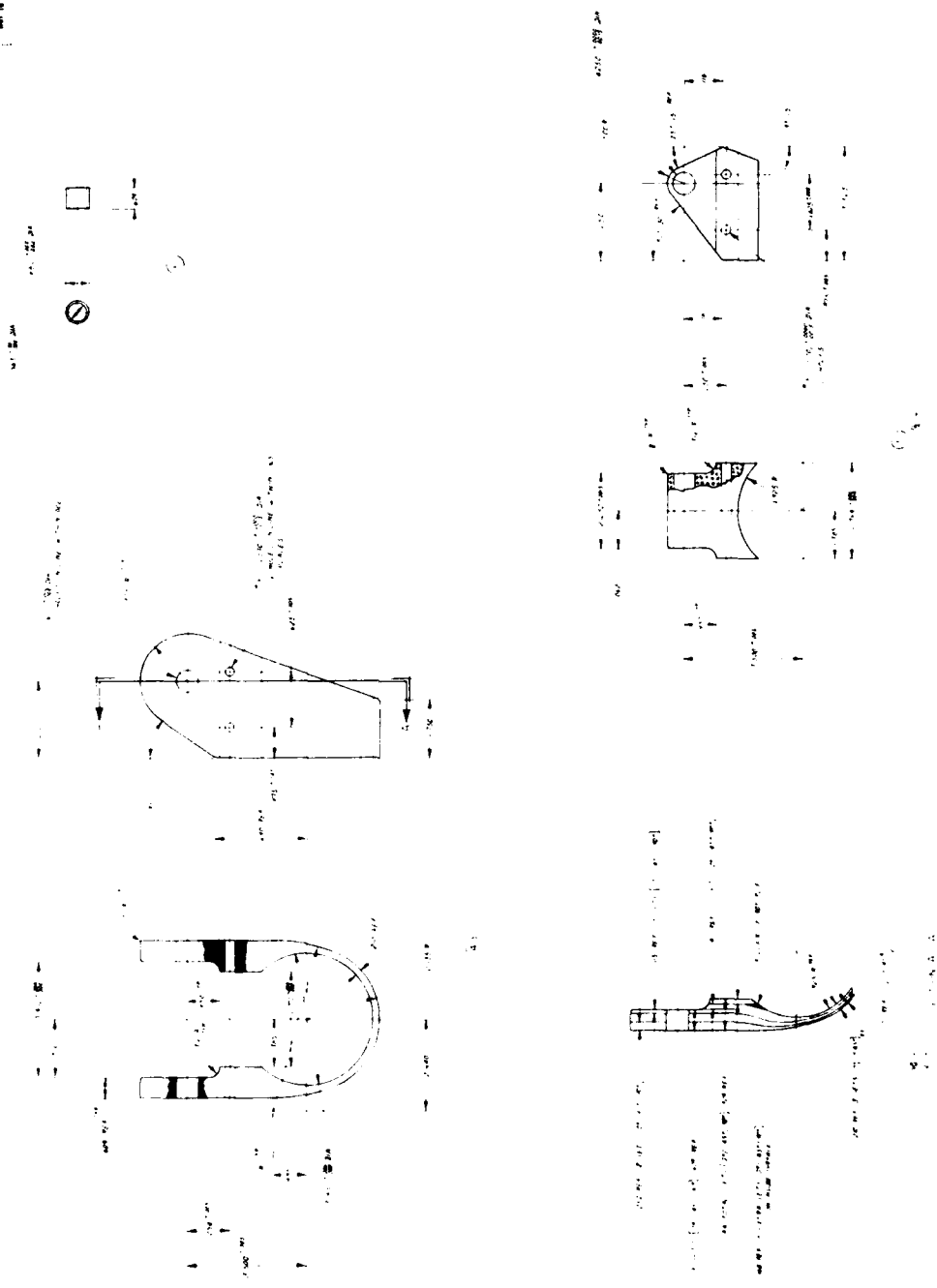
1. 1942-1943 - 1943 - 1944 - 1945 - 1946 - 1947 - 1948 - 1949 - 1950 - 1951 - 1952 - 1953 - 1954 - 1955 - 1956 - 1957 - 1958 - 1959 - 1960 - 1961 - 1962 - 1963 - 1964 - 1965 - 1966 - 1967 - 1968 - 1969 - 1970 - 1971 - 1972 - 1973 - 1974 - 1975 - 1976 - 1977 - 1978 - 1979 - 1980 - 1981 - 1982 - 1983 - 1984 - 1985 - 1986 - 1987 - 1988 - 1989 - 1990 - 1991 - 1992 - 1993 - 1994 - 1995 - 1996 - 1997 - 1998 - 1999 - 2000 - 2001 - 2002 - 2003 - 2004 - 2005 - 2006 - 2007 - 2008 - 2009 - 2010 - 2011 - 2012 - 2013 - 2014 - 2015 - 2016 - 2017 - 2018 - 2019 - 2020 - 2021 - 2022 - 2023 - 2024 - 2025 - 2026 - 2027 - 2028 - 2029 - 2030 - 2031 - 2032 - 2033 - 2034 - 2035 - 2036 - 2037 - 2038 - 2039 - 2040 - 2041 - 2042 - 2043 - 2044 - 2045 - 2046 - 2047 - 2048 - 2049 - 2050 - 2051 - 2052 - 2053 - 2054 - 2055 - 2056 - 2057 - 2058 - 2059 - 2060 - 2061 - 2062 - 2063 - 2064 - 2065 - 2066 - 2067 - 2068 - 2069 - 2070 - 2071 - 2072 - 2073 - 2074 - 2075 - 2076 - 2077 - 2078 - 2079 - 2080 - 2081 - 2082 - 2083 - 2084 - 2085 - 2086 - 2087 - 2088 - 2089 - 2090 - 2091 - 2092 - 2093 - 2094 - 2095 - 2096 - 2097 - 2098 - 2099 - 2100 - 2101 - 2102 - 2103 - 2104 - 2105 - 2106 - 2107 - 2108 - 2109 - 2110 - 2111 - 2112 - 2113 - 2114 - 2115 - 2116 - 2117 - 2118 - 2119 - 2120 - 2121 - 2122 - 2123 - 2124 - 2125 - 2126 - 2127 - 2128 - 2129 - 2130 - 2131 - 2132 - 2133 - 2134 - 2135 - 2136 - 2137 - 2138 - 2139 - 2140 - 2141 - 2142 - 2143 - 2144 - 2145 - 2146 - 2147 - 2148 - 2149 - 2150 - 2151 - 2152 - 2153 - 2154 - 2155 - 2156 - 2157 - 2158 - 2159 - 2160 - 2161 - 2162 - 2163 - 2164 - 2165 - 2166 - 2167 - 2168 - 2169 - 2170 - 2171 - 2172 - 2173 - 2174 - 2175 - 2176 - 2177 - 2178 - 2179 - 2180 - 2181 - 2182 - 2183 - 2184 - 2185 - 2186 - 2187 - 2188 - 2189 - 2190 - 2191 - 2192 - 2193 - 2194 - 2195 - 2196 - 2197 - 2198 - 2199 - 2200 - 2201 - 2202 - 2203 - 2204 - 2205 - 2206 - 2207 - 2208 - 2209 - 2210 - 2211 - 2212 - 2213 - 2214 - 2215 - 2216 - 2217 - 2218 - 2219 - 2220 - 2221 - 2222 - 2223 - 2224 - 2225 - 2226 - 2227 - 2228 - 2229 - 2230 - 2231 - 2232 - 2233 - 2234 - 2235 - 2236 - 2237 - 2238 - 2239 - 2240 - 2241 - 2242 - 2243 - 2244 - 2245 - 2246 - 2247 - 2248 - 2249 - 2250 - 2251 - 2252 - 2253 - 2254 - 2255 - 2256 - 2257 - 2258 - 2259 - 2260 - 2261 - 2262 - 2263 - 2264 - 2265 - 2266 - 2267 - 2268 - 2269 - 2270 - 2271 - 2272 - 2273 - 2274 - 2275 - 2276 - 2277 - 2278 - 2279 - 2280 - 2281 - 2282 - 2283 - 2284 - 2285 - 2286 - 2287 - 2288 - 2289 - 2290 - 2291 - 2292 - 2293 - 2294 - 2295 - 2296 - 2297 - 2298 - 2299 - 2300 - 2301 - 2302 - 2303 - 2304 - 2305 - 2306 - 2307 - 2308 - 2309 - 2310 - 2311 - 2312 -

NOTES

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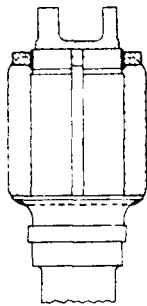
VIEW A



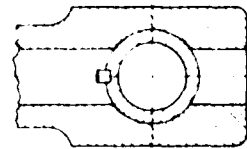
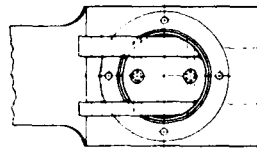
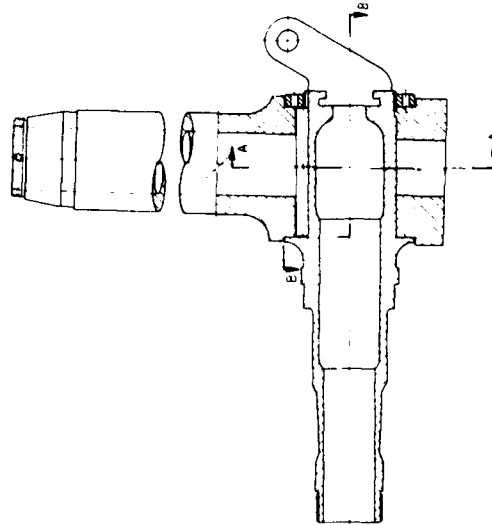
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| 3 | STEEL PLATE | 1 | PC | 1/2" THICK |
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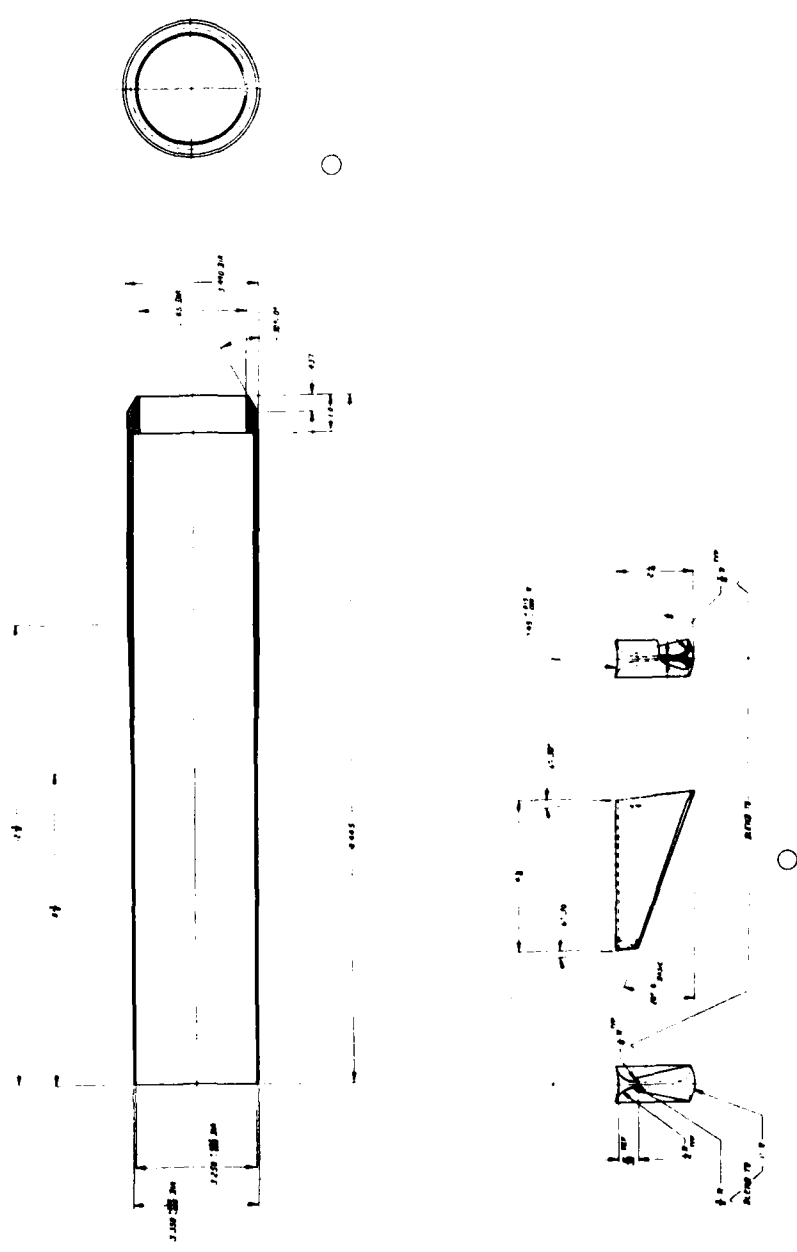


SECTION B-B

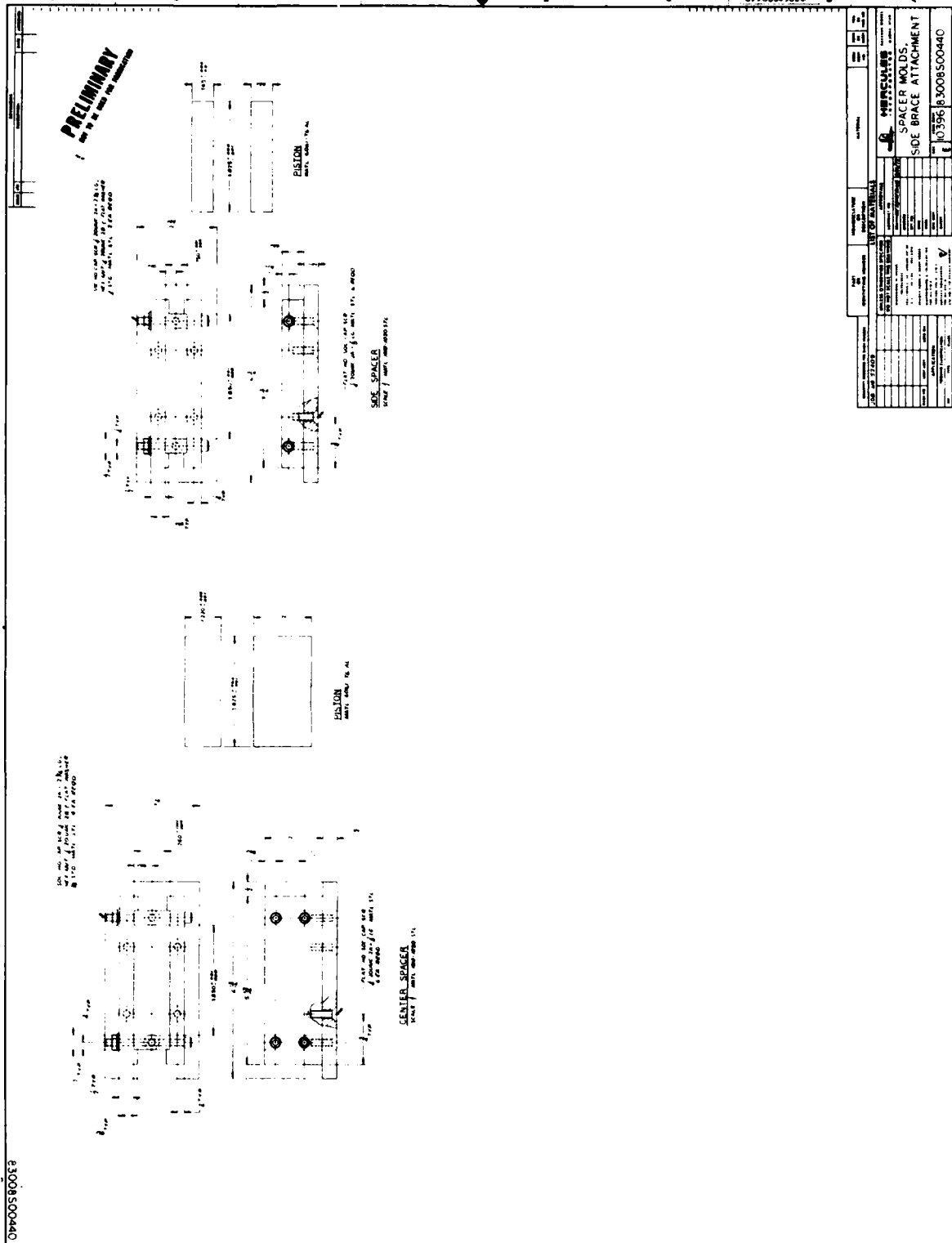


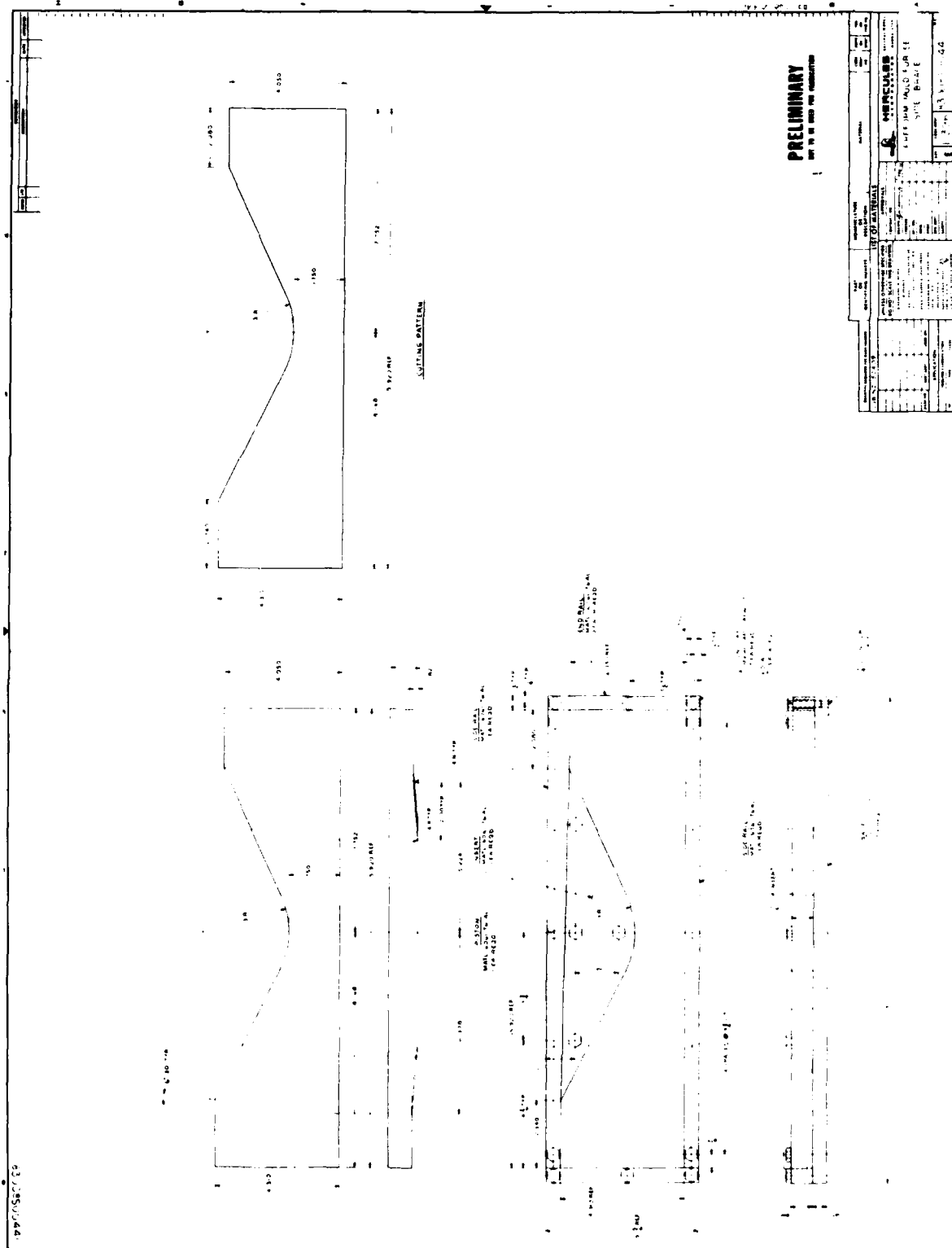
SECTION A-A

| | |
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| DATE
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10/29/83 0008500047E |
| APPROVED
10/29/83 0008500047E | REVIEWED
10/29/83 0008500047E |
| DESIGNED
10/29/83 0008500047E | CHECKED
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| MANUFACTURED
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| ASSEMBLED
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| SHIPPED
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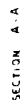


APPENDIX A
PART VII
TOOLING DRAWINGS





Self-Administered Test for Marijuana



$\frac{d}{dt} \left(\frac{1}{\rho} \right) = -\frac{1}{\rho^2} \frac{d\rho}{dt}$

1997-1998 1999-2000

On the way to the station, I saw a car with a sign that said "GO TO THE STATION". I saw a car with a sign that said "GO TO THE STATION". I saw a car with a sign that said "GO TO THE STATION".

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APPENDIX B

FABRICATION OF COMPOSITE
LANDING GEAR COMPONENTS

APPENDIX B

FABRICATION OF COMPOSITE LANDING GEAR COMPONENTS

Fabrication of the graphite composite components for the landing gear was performed using a combination of hand layups and tape winding of the plies with frequent compaction steps. Written procedures and M&IR's were used for all composite part fabrication.

The outer cylinder/trunnion was constructed and cured as a unit. The side brace, torque arm attachments, inner cylinder, and gussets were cured separately and bonded in position as the final operation.

The fabrication processes and fabrication tooling are presented in the following paragraphs.

1.0 Torque Arm Attachment

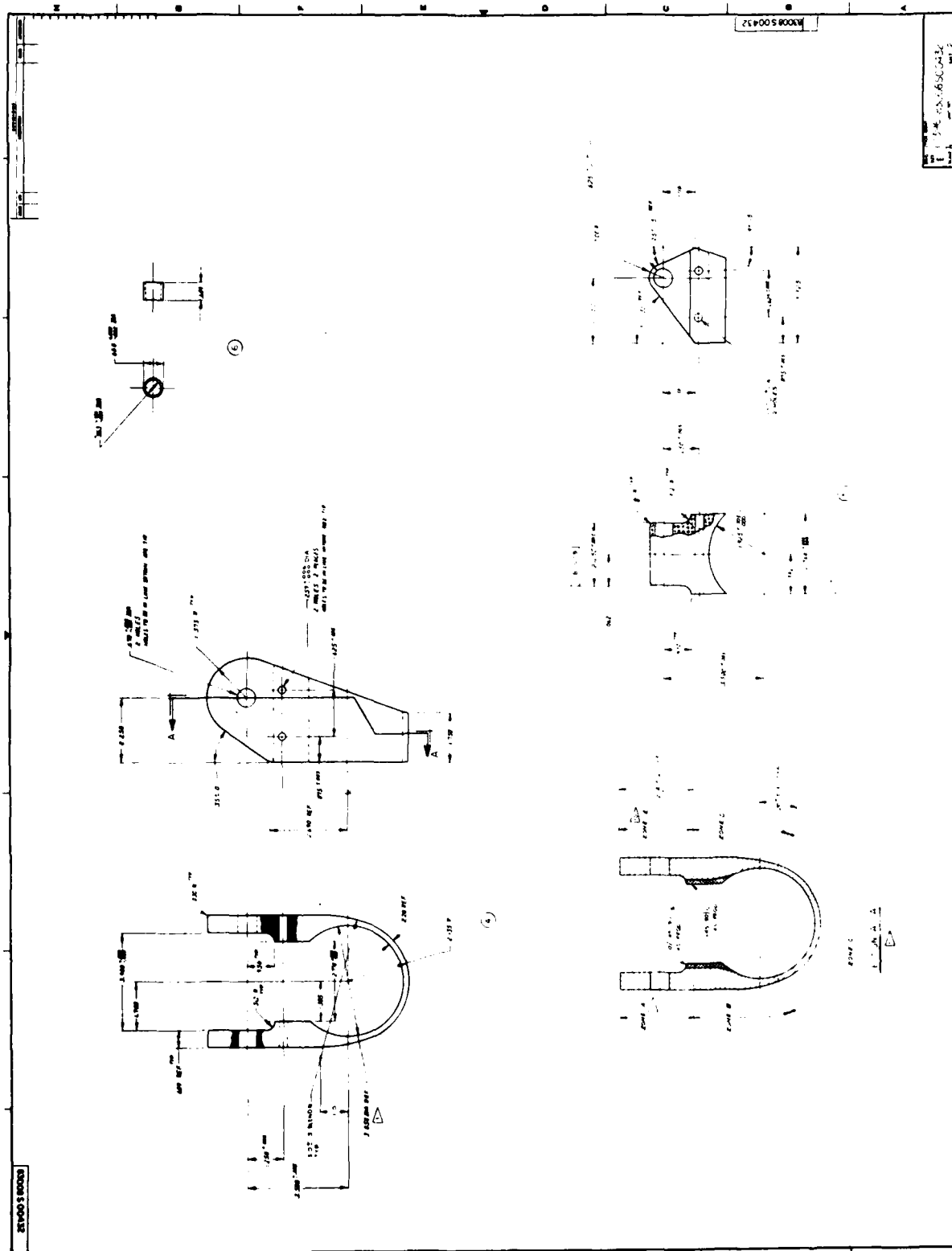
The torque arm attachment is shown on Drawing 83008S00432 (Figures II-1 and II-2). The tools used in the fabrication of the part are the inner ply insert mold (Figure II-3, Drawing 83008S00437), the exterior band set mold (Figure II-4, Drawing 83008S00438) and the layup tool (Figures II-5 and II-6, Drawing 83008S00439). The spacer block (Item 5 of Drawing 83008S00432) was machined from a chopped graphite composite billet so no tooling was required for fabrication.

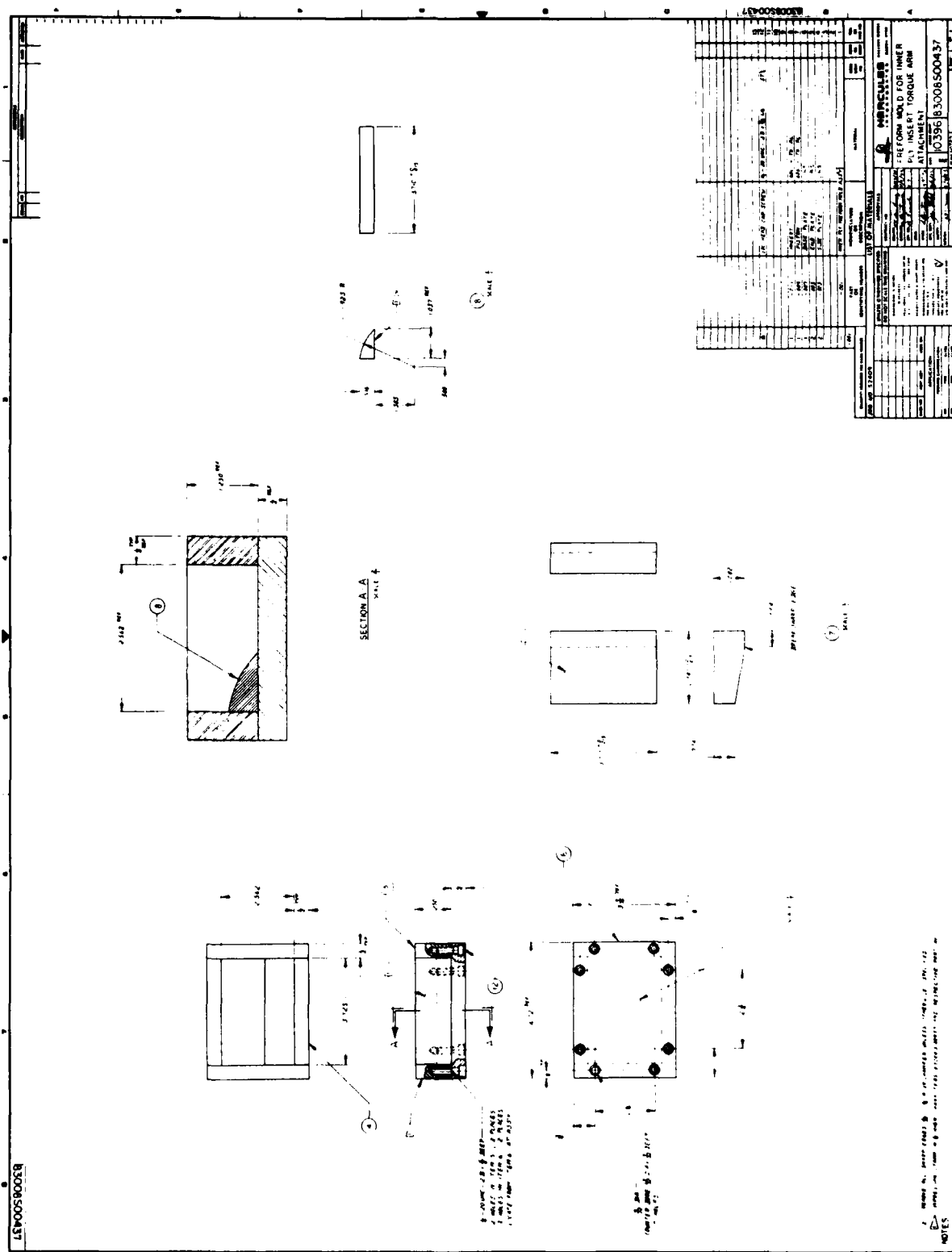
Using 3501-5/AS prepreg tape, the following fabrication procedures were used:

1.1 Torque Arm Attachment Fabrication Process

A. Inner ply insert preform layup (Mold Drawing 83008S00437)

1. Clean mold with MEK and allow to dry.
2. Apply Frecote #33 mold release to contact surfaces.
3. Cut 36 each 90° plies as shown in Table II-I with the fiber direction in the length direction as shown in Figure II-7.
4. Cut 10 each 0° plies (plies 37 through 46) as shown in Table II-I with the fiber direction in the width direction as shown in Figure II-8.
5. Place all 46 plies sequentially in the mold with ply No. 1 being laid in the mold first. The first ply and all subsequent plies are to be laid in the mold so that the one edge touches the curved portion of the mold as shown in Figure II-9.





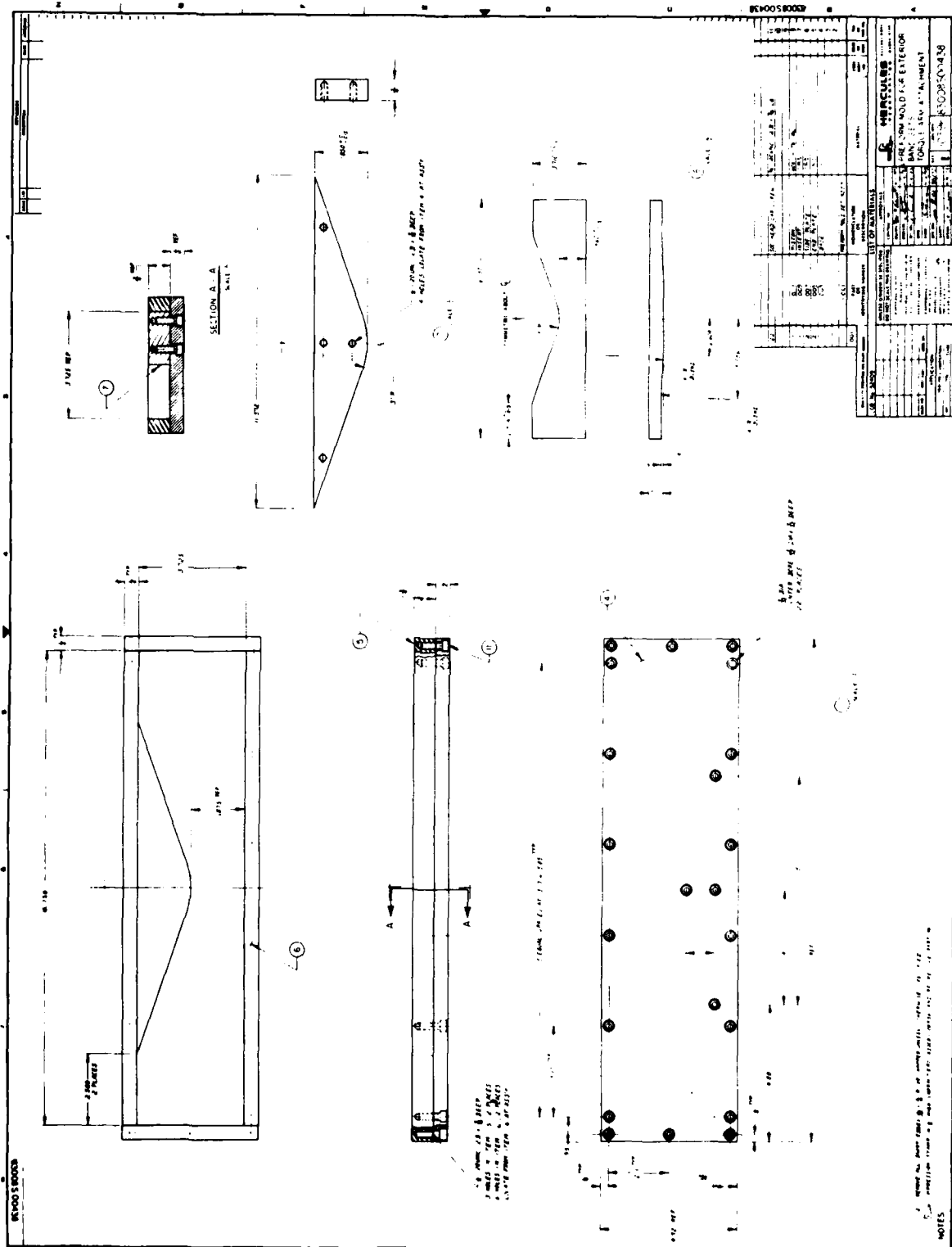
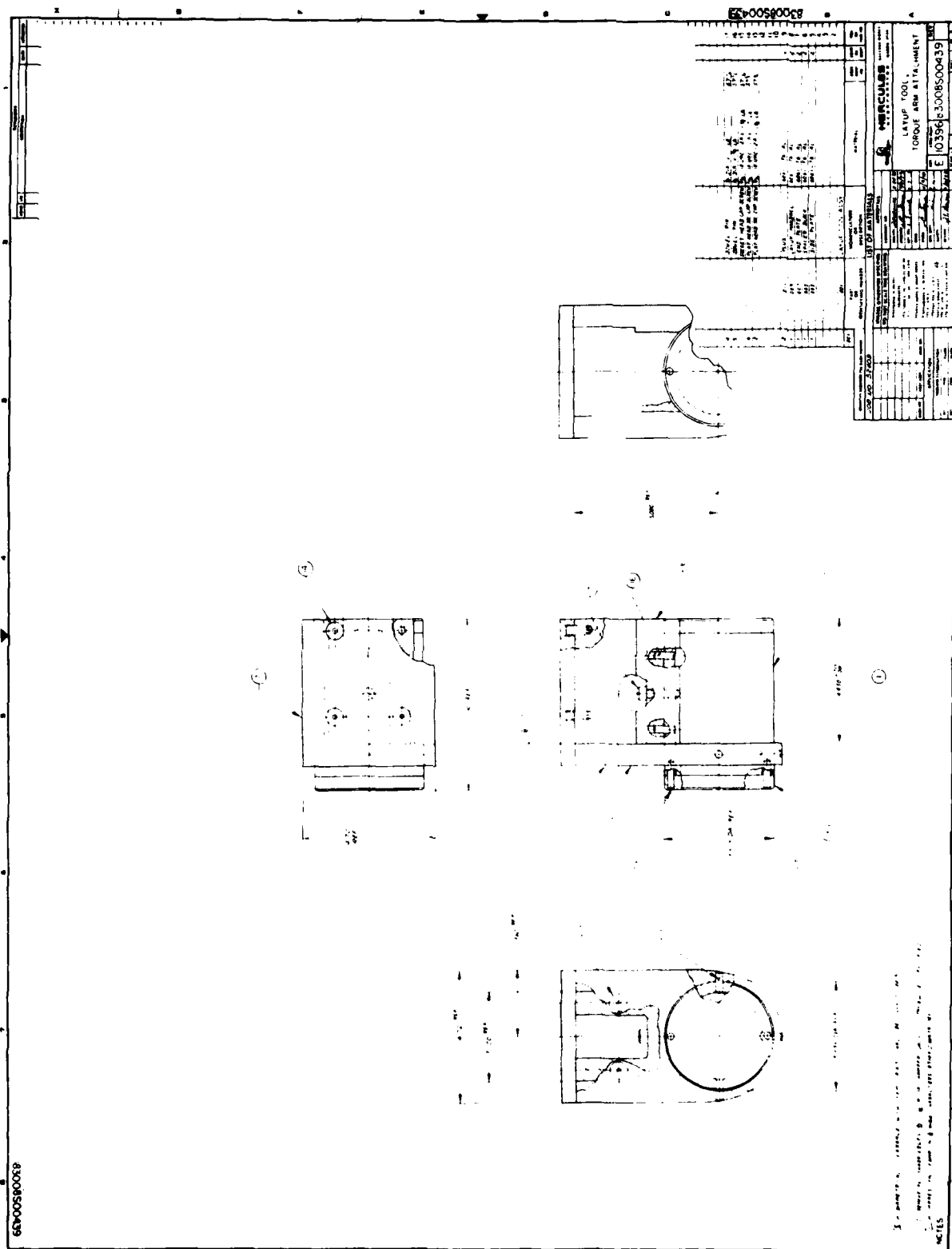
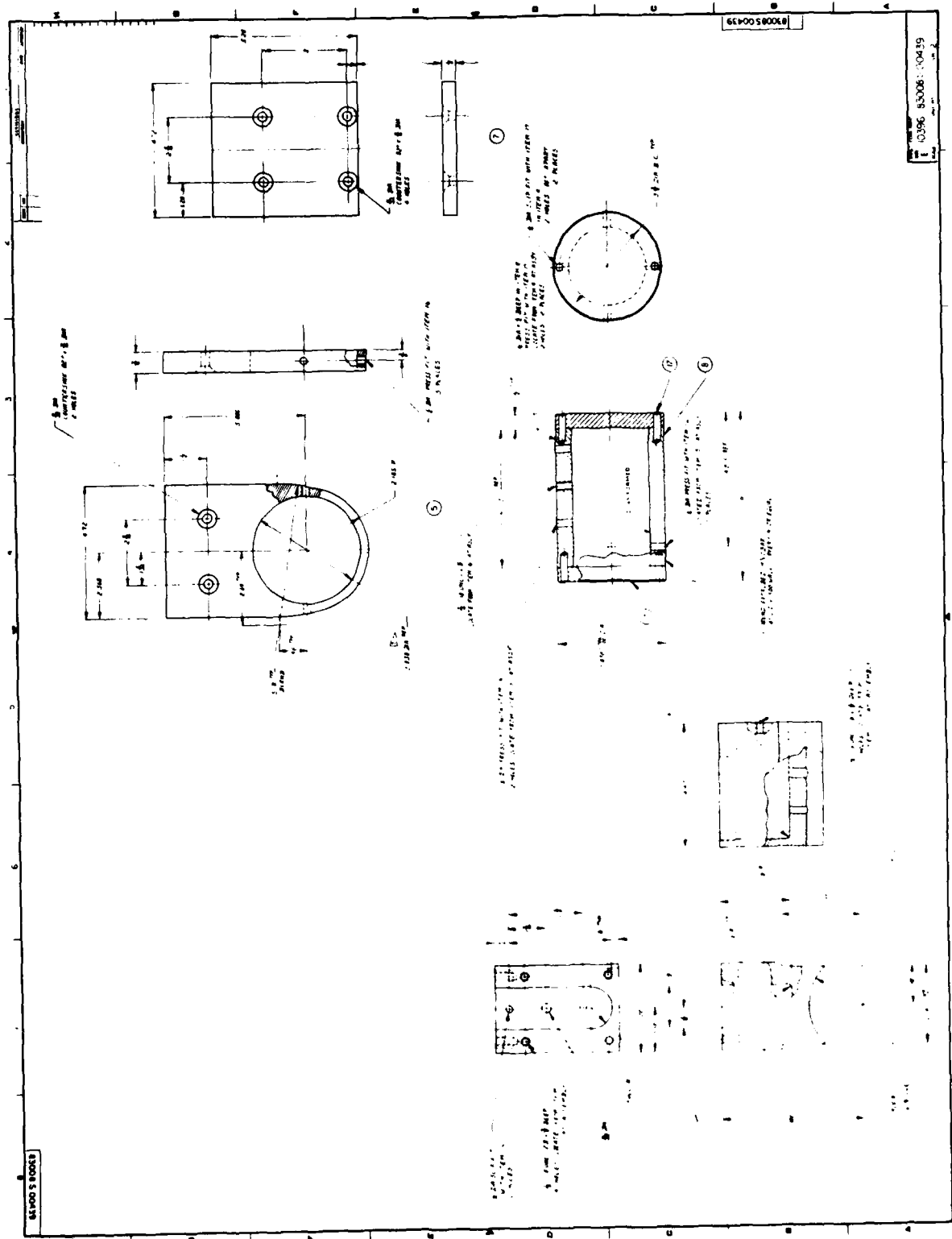


Figure II-4. Exterior Band Set Mold, Torque Arm Attachment
Drawing 83008S00438

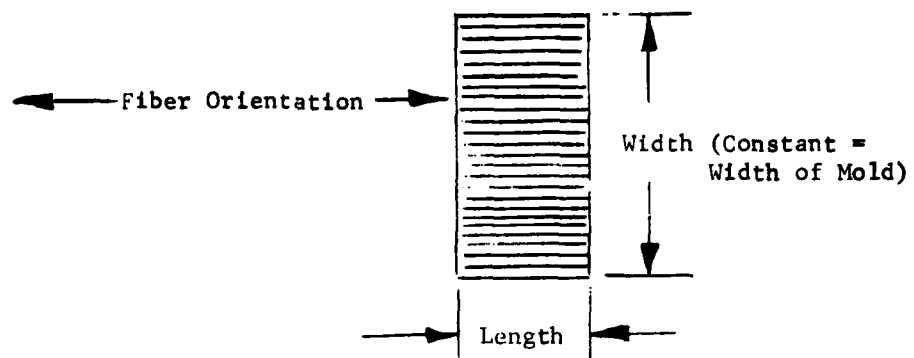




| Ply No. | Length
Figure II-7 | Ply No. | Length
Figure II-7 | Length
Figure II-8 |
|---------|-----------------------|---------|-----------------------|-----------------------|
| 1 | .800 | 24 | .455 | |
| 2 | .785 | 25 | .440 | |
| 3 | .770 | 26 | .425 | |
| 4 | .755 | 27 | .410 | |
| 5 | .740 | 28 | .395 | |
| 6 | .725 | 29 | .380 | |
| 7 | .710 | 30 | .365 | |
| 8 | .695 | 31 | .550 | |
| 9 | .680 | 32 | .335 | |
| 10 | .665 | 33 | .320 | |
| 11 | .650 | 34 | .305 | |
| 12 | .635 | 35 | .290 | |
| 13 | .620 | 36 | .275 | |
| 14 | .605 | 37 | | .260 |
| 15 | .590 | 38 | | .245 |
| 16 | .575 | 39 | | .230 |
| 17 | .560 | 40 | | .215 |
| 18 | .545 | 41 | | .200 |
| 19 | .530 | 42 | | .170 |
| 20 | .515 | 43 | | .155 |
| 21 | .500 | 44 | | .140 |
| 22 | .485 | 45 | | .125 |
| 23 | .470 | 46 | | .110 |

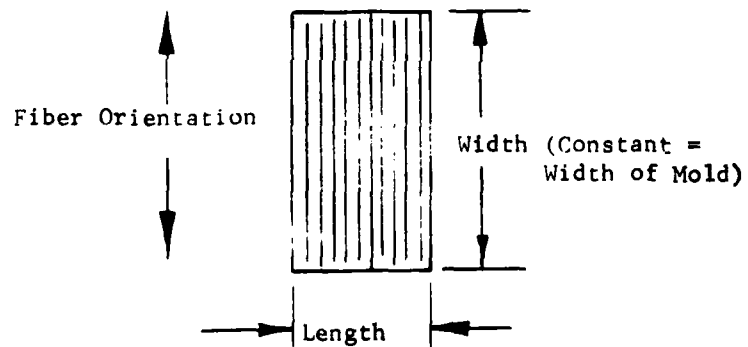
TABLE II-I

INNER PLY INSERT FILLET PLY LENGTH VERSUS PLY NO.



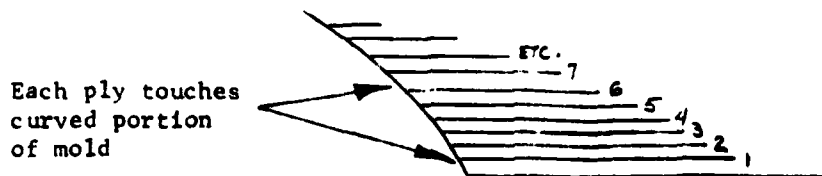
Cutting Pattern for 90° Sets

Figure II-7



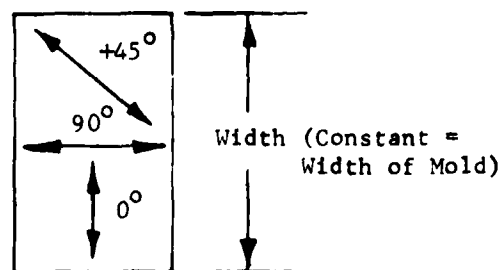
Cutting Pattern for 0° Sets

Figure II-8



Inner Ply Insert Fillet Ply Placement

Figure II-9



Cutting Pattern for +45° Sets

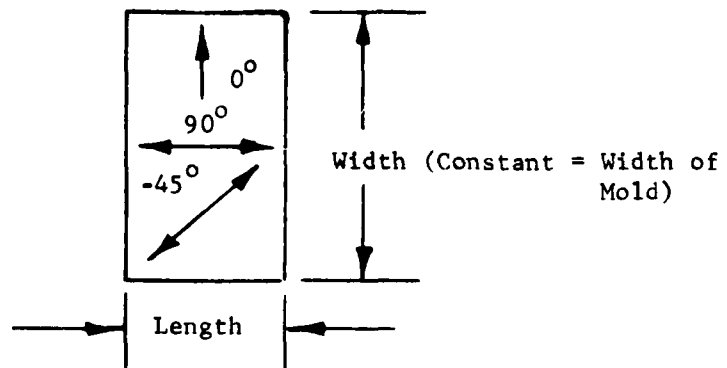
Figure II-10

6. Cut and lay up 11 sets of $\overline{0}^{\circ}$, $+45^{\circ}$, 90° _s. Each set will be cut in the length direction as shown in Table II-II and Figure II-10.
 7. Cut and lay up 11 sets of $\overline{0}^{\circ}$, -45° , 90° _s. Each set will be cut in the length direction as shown in Table II-II and Figure II-11.
 8. Place the 11 sets of $\overline{0}^{\circ}$, $+45^{\circ}$, 90° _s sequentially in the mold with set No. 1 being laid in the mold first. The first set and all subsequent sets are to be laid in the mold as shown in Figure II-12 with the one edge touching the vertical portion of the mold opposite the curved metal insert.
 9. Place piston in mold (Figure II-13) and place assembly in press. Set pressure to 200 psi. Hold temperature and pressure for 10 minutes. Maintain pressure and reduce temperature. Remove pressure when part is at room temperature or below.
 10. Strip inner ply insert from mold.
 11. Repeat Steps A1 through A4.
 12. Place the 11 sets of $\overline{0}^{\circ}$, -45° , 90° _s (made in Step 7) sequentially in the mold as was done in Step 8.
 13. Repeat Steps 9 and 10.
- B. Exterior band sets (Item 4 of Drawing 83008S00432; Mold Drawing 83008S00438)
1. Clean mold with MEK.
 2. Apply Frecote mold release to contact surfaces.
 3. Cut out and lay up preform set No. 1 in the mold. The orientation, length and ply number within the set are given in Table II-III. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-15.
 4. Place the piston in the mold and the assembly in the press. "B" stage at 200°F and 200 psi for 10 minutes. Cool under pressure.

| Set No. | Length |
|---------|--------|
| 1 | 1.75 |
| 2 | 1.84 |
| 3 | 1.92 |
| 4 | 2.00 |
| 5 | 2.09 |
| 6 | 2.18 |
| 7 | 2.26 |
| 8 | 2.34 |
| 9 | 2.43 |
| 10 | 2.52 |
| 11 | 2.60 |

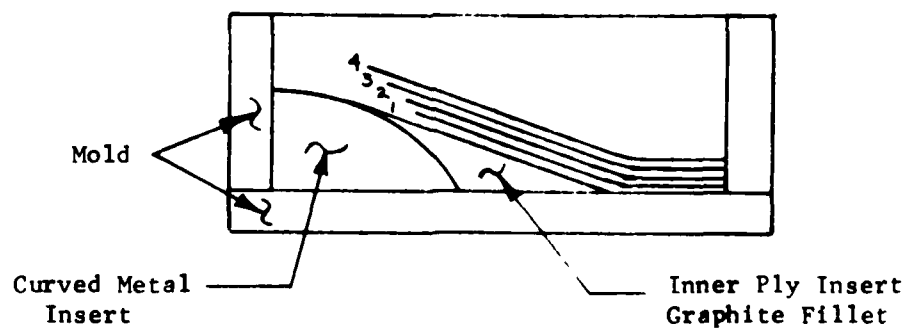
TABLE II-II

INNER PLY INSERT SET LENGTH VERSUS SET NO.
 $\underline{0}^{\circ}$, $+45^{\circ}$, 90° _s or $\underline{0}^{\circ}$, -45° , 90° _s



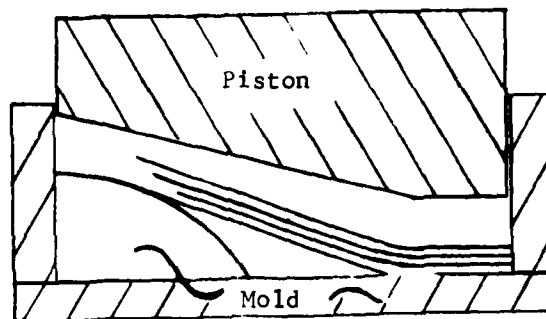
Cutting Pattern for -45° Sets

Figure II-11



Position of Inner Ply Insert in Mold

Figure II-12



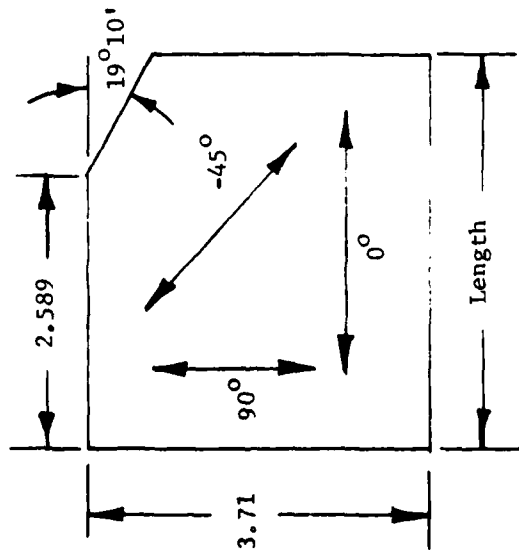
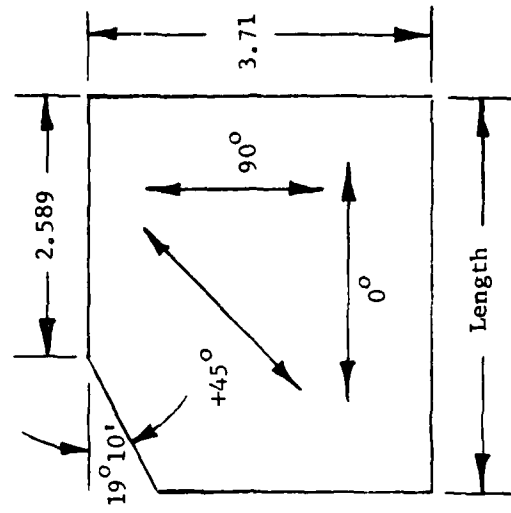
Piston-Mold Assembly

Figure II-13

| Ply No. | Length | Left Side Orientation | Right Side Orientation |
|---------|--------------------|-----------------------|------------------------|
| 1 | Full | 0° | 0° |
| 2L | 5.60 | 90° | -- |
| 2R | 5.60 | -- | 90° |
| 3L | 5.45 | -45° | -- |
| 3R | 5.45 | -- | +45° |
| 4L | 5.30 | 90° | -- |
| 4R | 5.30 | -- | 90° |
| 5L | 5.15 | 0° | -- |
| 5R | 5.15 | -- | 0° |
| 6L | 5.00 | -45° | -- |
| 6R | Butt to
Ply 2L | -- | +45° |
| 7L-11R | Full | 0° | 0° |
| 8L | 4.85 | 90° | -- |
| 8R | 4.85 | -- | 90° |
| 9L | 4.70 | -45° | -- |
| 9R | 4.70 | -- | +45° |
| 10L | 4.55 | 90° | -- |
| 10R | 4.55 | -- | 90° |
| 11L | 4.40 | 0° | -- |
| 12L | Butt to
Ply 12R | -45° | -- |
| 12R | 4.40 | -- | +45° |
| 13L | 4.25 | 0° | -- |
| 13R | 4.25 | -- | 0° |
| 14L | 4.10 | 90° | -- |
| 14R | 4.10 | -- | 90° |
| 15L | 3.95 | -45° | -- |
| 15R | 3.95 | -- | +45° |
| 16L | 3.80 | 90° | -- |
| 16R | 3.80 | -- | 90° |
| 17 | Full | 0° | 0° |
| 18L | 3.65 | -45° | -- |
| 18R | 3.65 | -- | +45° |
| 19L | 3.50 | -45° | -- |
| 19R | 3.50 | -- | +45° |
| 20 | Full | 0° | 0° |
| 21L | 3.35 | 90° | -- |
| 21R | 3.35 | -- | 90° |
| 22L | 3.20 | -45° | -- |
| 22R | 3.20 | -- | +45° |
| 23L | 3.05 | 90° | -- |
| 23R | 3.05 | -- | 90° |
| 24L | 2.90 | 0° | -- |
| 24R | 2.90 | -- | 0° |
| 25L | Butt to
Ply 21R | -45° | -- |
| 25R | 2.75 | -- | +45° |

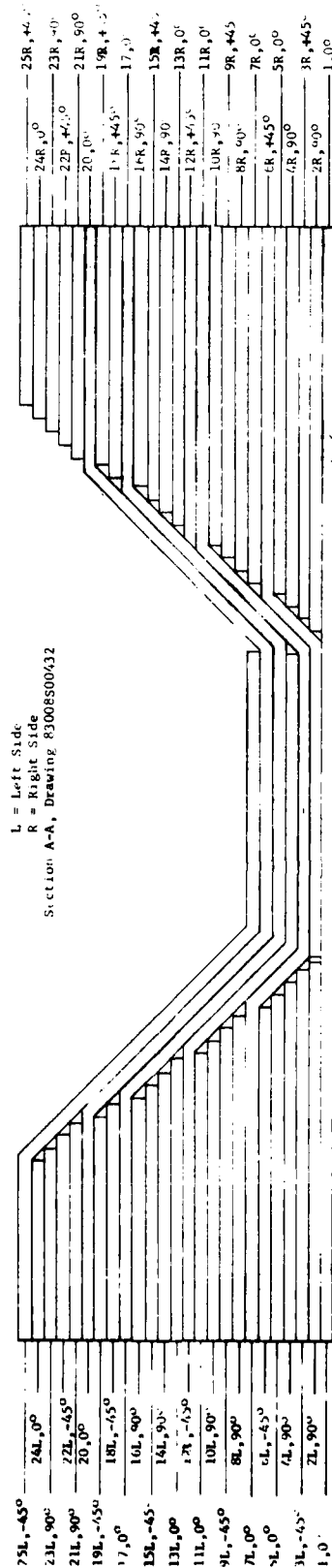
TABLE II-III

EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 1 AND 4, PLY LENGTH VERSUS ORIENTATION



Cutting Pattern
Sets 1, 2, 3, 4, 5 and 6

Figure II-14



Torque Arm Attachment
 Sets 110, 1 and 4
 Layout Sequence

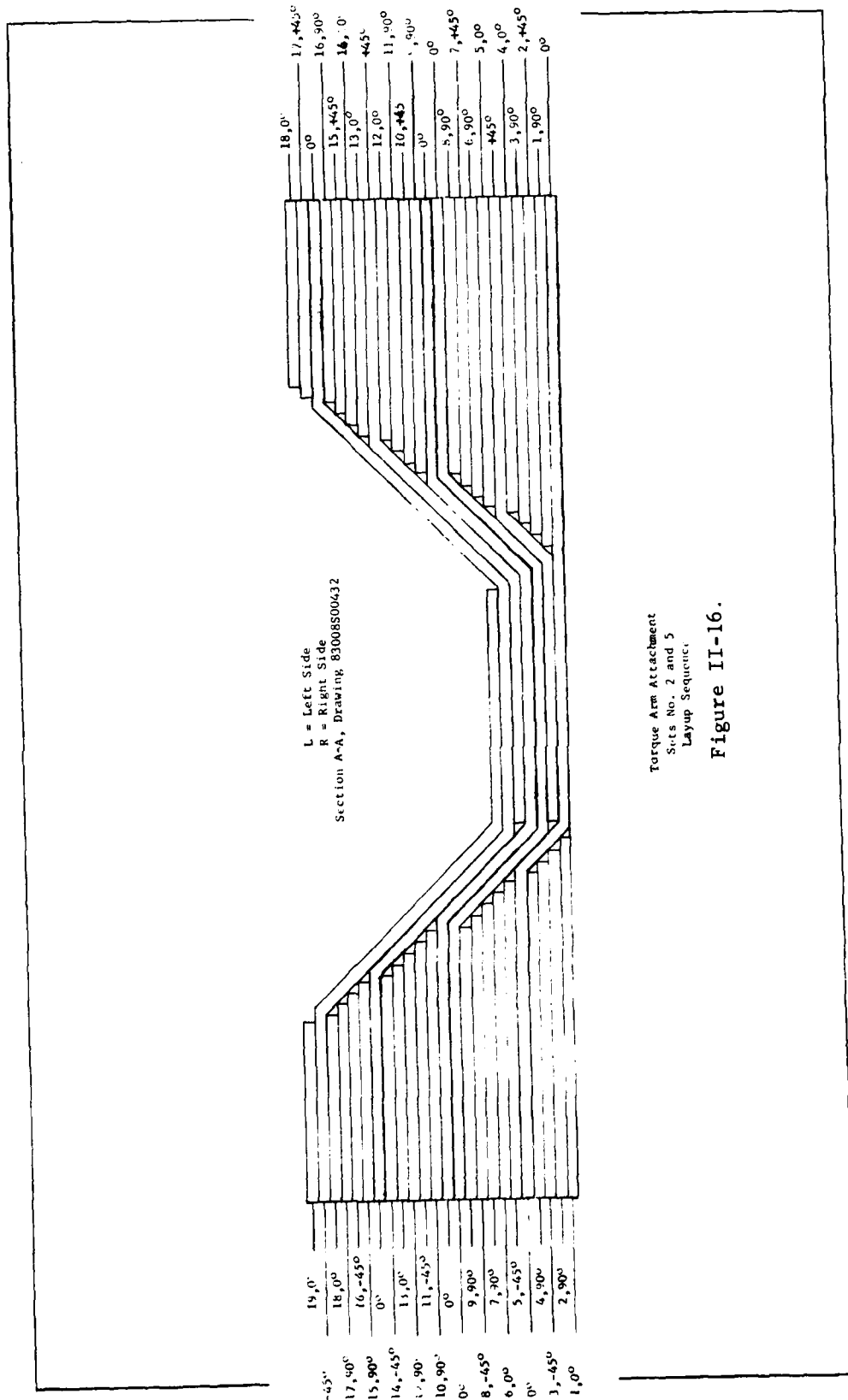
Figure II-15

5. Strip preform set from mold.
 6. Fabricate preform set No. 4 by repeating Steps 1, 2, 3, 4 and 5.
 7. Repeat Steps 1 and 2.
 8. Cut out and lay up preform set No. 2 in the mold. The orientation, length and ply number within the set are given in Table II-IV. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-16.
 9. Repeat Steps 4 and 5.
 10. Fabricate preform set No. 5 by repeating Steps 1, 2, 8, 4 and 5.
 11. Repeat Steps 1 and 2.
 12. Cut out and lay up preform set No. 3 in the mold. The orientation, length and ply number within the set are given in Table II-V. The cutting pattern and layup sequence for the set are shown in Figures II-14 and II-17.
 13. Repeat Steps 4 and 5.
 14. Fabricate preform set No. 6 by repeating Steps 1, 2, 12, 4 and 5.
- C. Forming exterior band sets on layup mandrel (Mandrel Drawing 83008S00439)
1. Place layup mandrel in oven and heat to 200°F.
 2. Using hot mandrel, drape each exterior band set (fabricated in Section B) over the mandrel so that they conform approximately to the shape of the mandrel. This is a rough forming operation so each set will be about the same shape.
- D. Final assembly (Mandrel Drawing 83008S00439)
1. Fabricate an exterior aluminum sheet metal (.050 in.) caul plate that will conform to the outside dimensions of the cured band sets. Refer to Drawing 83008S00432 for dimensions.
 2. Heat the layup mandrel to 200°F and place the two inner ply insert preforms in position. (See Figure II-18.)

| Ply No. | Length | Left Side Orientation | Right Side Orientation |
|---------|--------------------|-----------------------|------------------------|
| 1L | 5.60 | 0° | -- |
| 5L-1R | Full | 0° | 0° |
| 2L | 5.45 | 90° | -- |
| 2R | 5.45 | -- | 90° |
| 3L | 5.30 | -45° | -- |
| 3R | 5.30 | -- | +45° |
| 4L | 5.15 | 90° | -- |
| 4R | 5.15 | -- | 90° |
| 5R | 5.00 | -- | 0° |
| 6L | 5.00 | -45° | -- |
| 6R | Butt to
Ply 6L | -- | +45° |
| 7L | 4.85 | 0° | -- |
| 7R | 4.85 | -- | 0° |
| 8L | 4.70 | 90° | -- |
| 8R | 4.70 | -- | 90° |
| 9L | 4.55 | -45° | -- |
| 9R | 4.55 | -- | +45° |
| 10L | 4.40 | 90° | -- |
| 10R | 4.40 | -- | 90° |
| 11 | Full | 0° | 0° |
| 12 | Full | 0° | 0° |
| 13L | 4.25 | 90° | -- |
| 13R | 4.25 | -- | 90° |
| 14L | 4.10 | -45° | -- |
| 14R | 4.10 | -- | +45° |
| 15L | 3.95 | 90° | -- |
| 15R | 3.95 | -- | 90° |
| 16L | 3.80 | 0° | -- |
| 16R | 3.80 | -- | 0° |
| 17L | 3.65 | -45° | -- |
| 17R | Butt to
Ply 12L | -- | +45° |
| 18L-22R | Full | 0° | 0° |
| 18R | 3.65 | -- | 0° |
| 19L | 3.50 | 90° | -- |
| 19R | 3.50 | -- | 90° |
| 20L | 3.35 | -45° | -- |
| 20R | 3.35 | -- | +45° |
| 21L | 3.20 | 90° | -- |
| 21R | 3.20 | -- | 90° |
| 22L | 3.05 | 0° | -- |
| 23L | Butt to
Ply 22R | -45° | -- |
| 23R | 3.05 | -- | +45° |
| 24L | 2.90 | 0° | -- |
| 24R | 2.90 | -- | 0° |

TABLE II-IV

EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 2 AND 5, PLY LENGTH VERSUS ORIENTATION

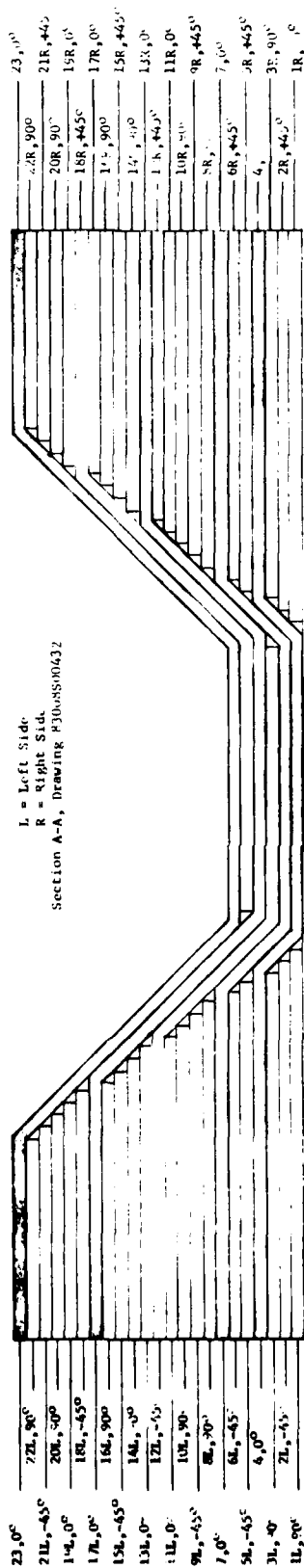


Torque Arm Attachment
 Sets No. 2 and 5
 Layout Sequence

Figure II-16.

| Ply No. | Length | Left Side Orientation | Right Side Orientation |
|---------|--------------------|-----------------------|------------------------|
| 1L | 5.60 | 90° | -- |
| 1R | 5.60 | -- | 90° |
| 2L | 5.45 | -45° | -- |
| 2R | 5.45 | -- | +45° |
| 3L | 5.30 | 90° | -- |
| 3R | 5.30 | -- | 90° |
| 4 | Full | 0° | 0° |
| 5L | 5.15 | -45° | -- |
| 5R | 5.15 | -- | +45° |
| 6L | 5.00 | -45° | -- |
| 6R | 5.00 | -- | +45° |
| 7 | Full | 0° | 0° |
| 8L | 4.85 | 90° | -- |
| 8R | 4.85 | -- | 90° |
| 9L | 4.70 | -45° | -- |
| 9R | 4.70 | -- | +45° |
| 10L | 4.55 | 90° | -- |
| 10R | 4.55 | -- | 90° |
| 11L | 4.40 | 0° | -- |
| 11R | 4.40 | -- | 0° |
| 12L | Butt to
Ply 8R | -45° | -- |
| 12R | 4.25 | -- | +45° |
| 13L | 4.25 | 0° | -- |
| 17L-13R | Full | 0° | 0° |
| 14L | 4.10 | 90° | -- |
| 14R | 4.10 | -- | 90° |
| 15L | 3.95 | -45° | -- |
| 15R | 3.95 | -- | +45° |
| 16L | 3.80 | 90° | -- |
| 16R | 3.80 | -- | 90° |
| 17R | 3.65 | -- | 0° |
| 18L | 3.65 | -45° | -- |
| 18R | Butt to
Ply 18L | -- | +45° |
| 19L | 3.50 | 0° | -- |
| 19R | 3.50 | -- | 0° |
| 20L | 3.35 | 90° | -- |
| 20R | 3.35 | -- | 90° |
| 21L | 3.20 | -45° | -- |
| 21R | 3.20 | -- | +45° |
| 22L | 3.05 | 90° | -- |
| 22R | 3.05 | -- | 90° |
| 23 | Full | 0° | 0° |

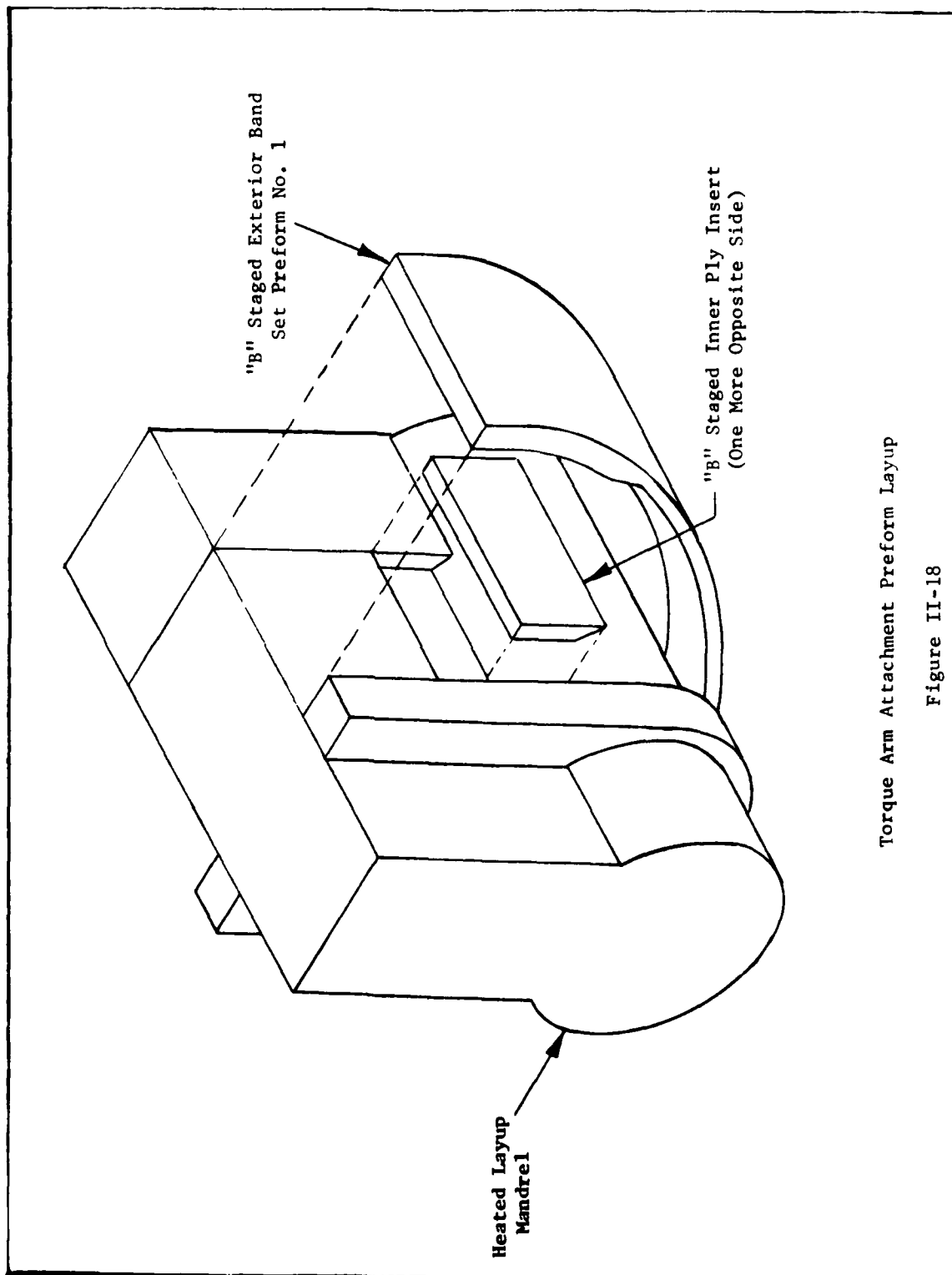
TABLE II-V
EXTERIOR BAND SETS, TORQUE ARM ATTACHMENT
SETS NO. 3 AND 6, PLY LENGTH VERSUS ORIENTATION



L = Left Side
R = Right Side
Section A-A, Drawing FIDUNSH0432

Torque Arm Attachment
Sits No. 3 and :
Layup Sequence

Figure II-17



Torque Arm Attachment Preform Layout

Figure II-18

3. Place exterior band set No. 1 in position (see Figure II-17) and sequentially add band sets Nos. 2, 3, 4, 5 and 6.
4. Place the caul plate over band set No. 6.
5. Wrap the assembly with TX-1040 release fabric.
6. Wrap this assembly with 12 end glass roving using the No. 21 Winding Machine to rotate the mandrel. Set the torque motor at 70 units to apply proper roving tension.
7. Cool the assembly and remove the glass roving, TX-1040 and caul plate.
8. Trim excess prepreg at top of mandrel and place end plate (Item 7 of Drawing 83008S00439) on mandrel.

E. Final cure

1. Replace caul plate and TX-1040 and wrap assembly with 12 end glass roving.
2. Install vacuum bag over this assembly and cure in autoclave.
3. Cure cycle:
 - a. Hold vacuum throughout cure cycle.
 - b. Raise temperature 3°/minute to 250°F.
 - c. Apply 100 psi at 200°F level.
 - d. Hold at 250°F for 4 hours.
 - e. Raise temperature at 3°/minute to 300°F.
 - f. Hold for 1 hours at 300°F and 100 psi.
 - g. Cool down with 100 psi pressure to room temperature (or 150°F maximum).

F. Spacer block fabrication (Item 5 of Drawing 83008S00438)

1. Cut up 5 lbs of 3501/AS prepreg (.005 in. thick) into 1/2 in. x 1/2 in. pieces.
2. Using a standard 4.75 in. diameter slug mold, pack the cavity with 5 lbs of chopped 3501/AS prepreg.

3. Place piston in mold and place assembly in press.
4. Raise temperature to 250°F and apply 2000 psi for 1/2 hour.
5. Raise temperature to 350°F and apply 2000 psi for 2 hours.
6. Cool down and strip billet from mold.
7. Machine billet to configuration of Item 5 of Drawing 83008S00438.

2.0 Side Brace Attachment

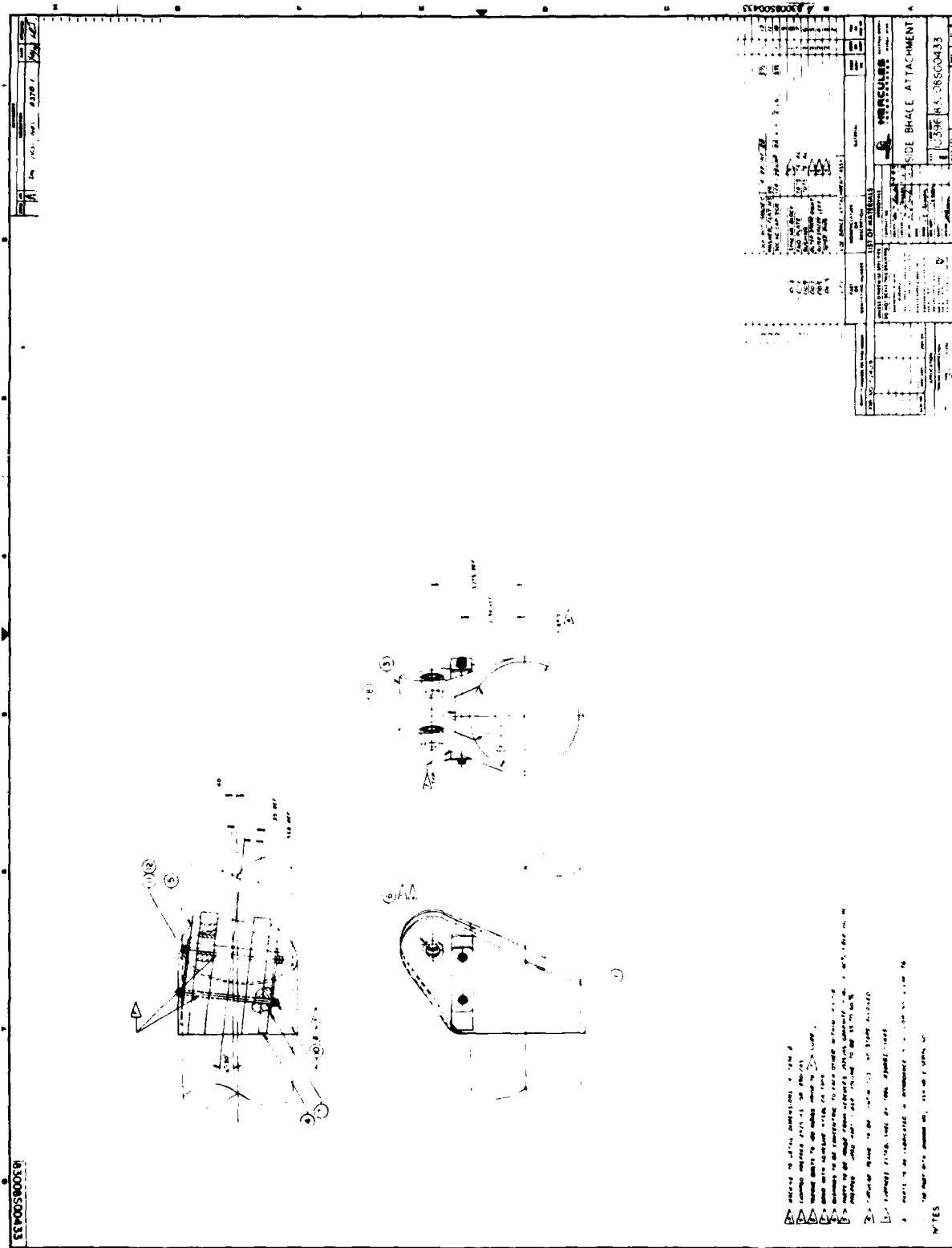
The side brace attachment is shown on Drawing 83008S00433 (Figure II-19 and II-20). The tools used in the fabrication of the part are the exterior band set mold (Figure II-21, Drawing 83008S00441) and the layup tool (Figures II-22 and II-23, Drawing 83008S00445). The spacing block (Item 8 of Drawing 83008S00433) was machined from a chopped graphite composite billet so no tooling was required for fabrication. The outer spacer right and outer spacer left (Items 4 and 5 of Drawing 83008S00433) were machined from a graphite composite flat plate so no tooling was required for fabrication.

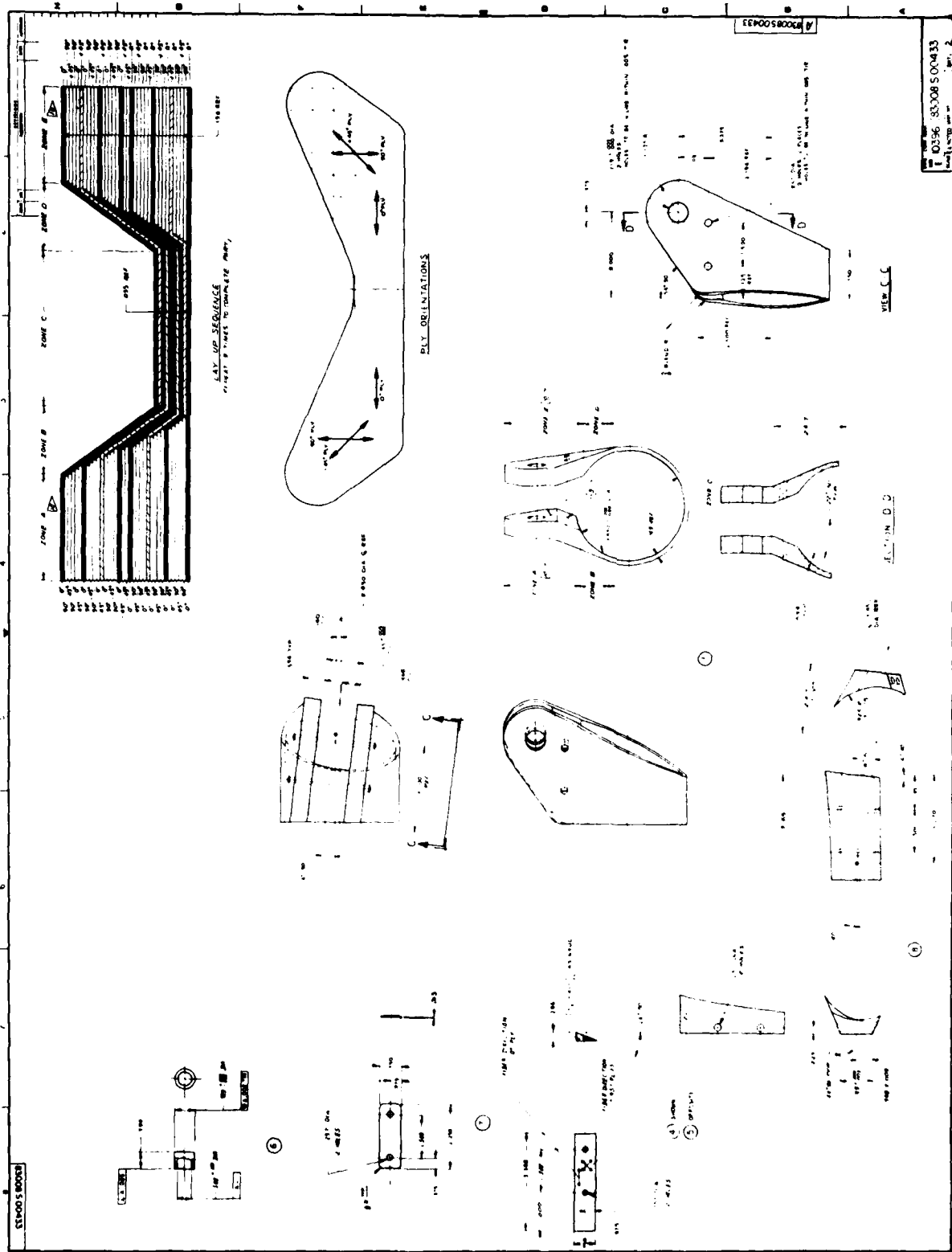
Using 3501-5/AS prepreg 3-in. tape, the following fabrication procedures were used:

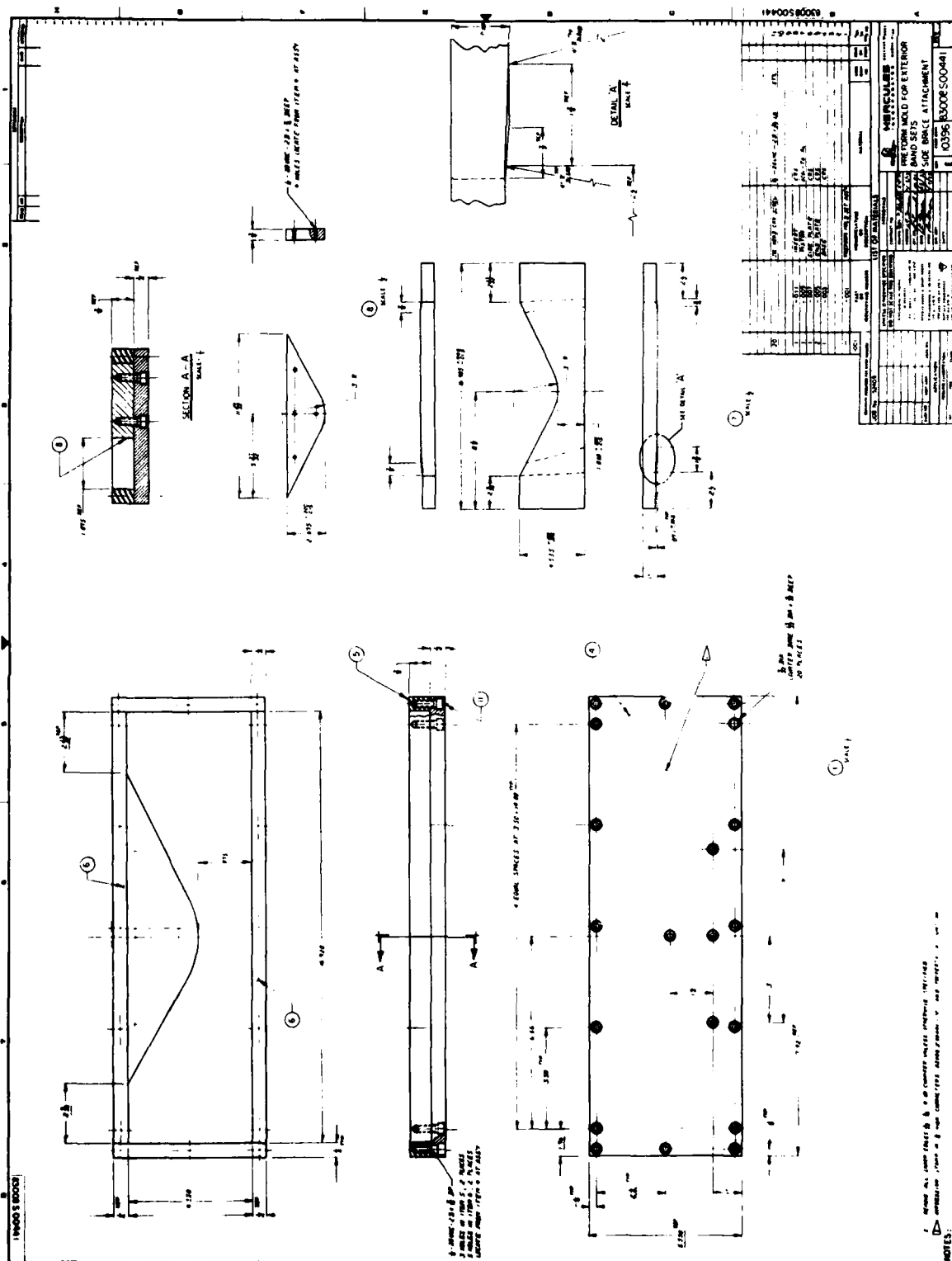
2.1 Side Brace Attachment Fabrication Procedure

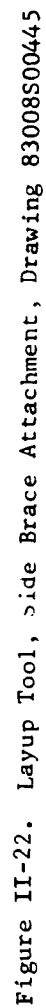
A. Exterior band sets (Item 3 of Drawing 83008S00433; Mold Drawing 83008S00441)

1. Clean mold with MEK and allow to dry.
2. Apply Frecote #33 mold release to contact surfaces.
3. Cut out and lay up preform set No. 1 in the mold. The orientation, length and ply number within the set are given in Table II-VI. The cutting pattern and layup sequence for the set are shown in Figures II-24 and II-25.
4. Place the piston in the mold and the assembly in the press. "B" stage at 200°F and 200 psi for 10 minutes. Cool under pressure.
5. Strip preform set from mold.
6. Fabricate preform set Nos. 3 and 5 by repeating Steps 1, 2, 3, 4, and 5.









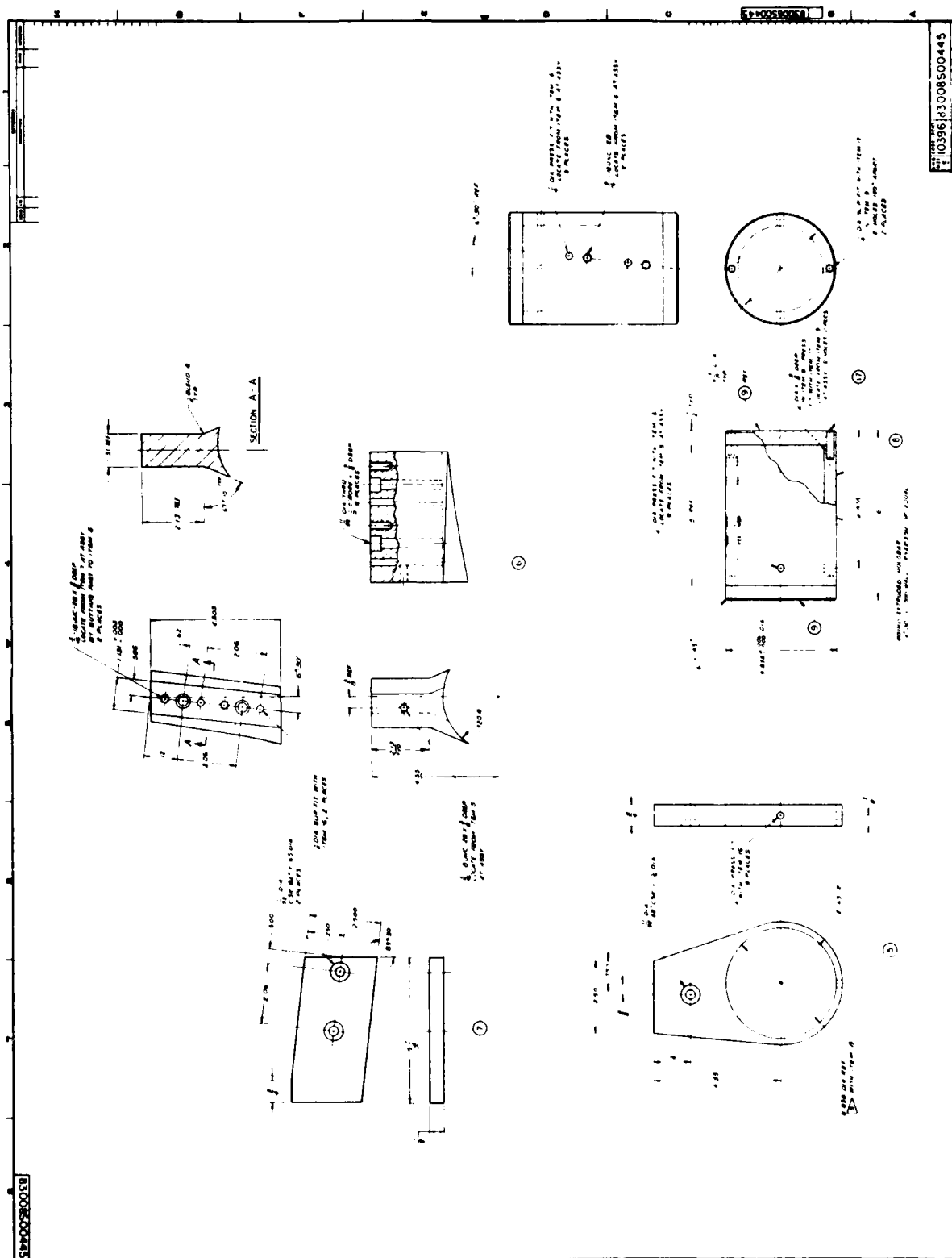


Figure II-23. Layup Tool, Side Brace Attachment, Drawing 83008S00445

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TECHNICAL APPENDICES(U) HERCULES INC MAGNA UT BACCHUS
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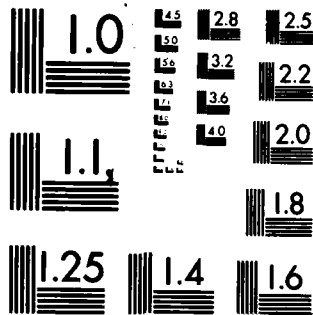
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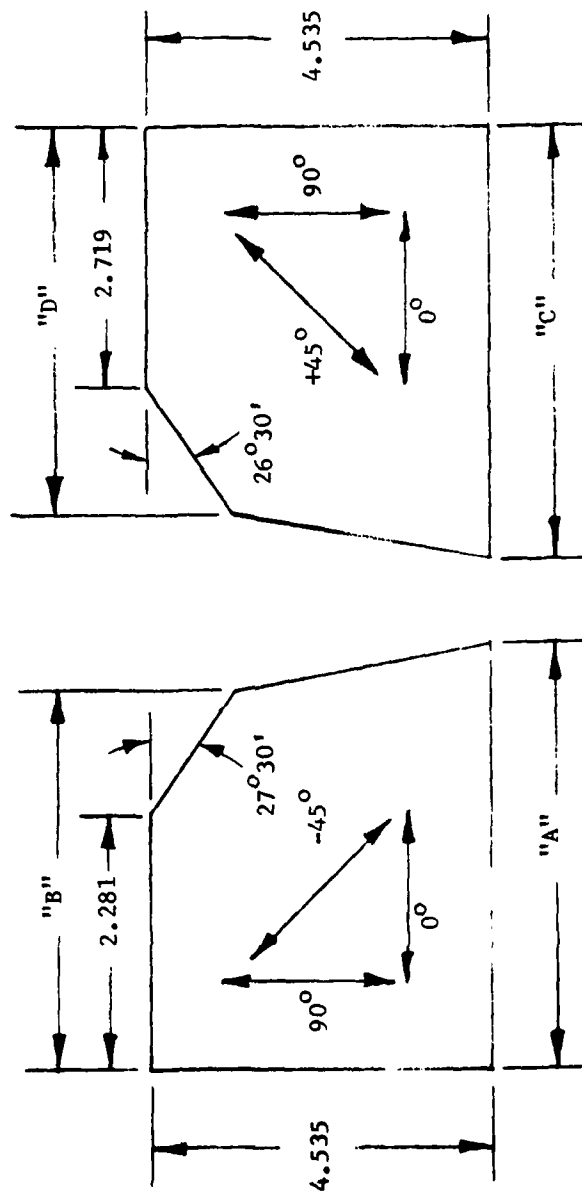


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

| Ply No. | Left Side | | | Right Side | | |
|---------|-------------------------|----------|-------------|-----------------------|----------|-------------|
| | Length A | Length B | Orientation | Length C | Length D | Orientation |
| 1 | Full Length | | 0° | Full Length | | 0° |
| 2 | 5.00 | 4.17 | 90° | 4.04 | 4.41 | 90° |
| 3 | 4.90 | 4.06 | -45° | 3.96 | 4.34 | +45° |
| 4 | 4.81 | 3.96 | 90° | 3.88 | 4.26 | 90° |
| 5 | 4.72 | 3.85 | 0° | 3.80 | 4.19 | 0° |
| 6 | 4.62 | 3.75 | -45° | Butt to Ply 2 on Left | | +45° |
| 7L-11R | Full Length | | 0° | Full Length | | 0° |
| 7R | -- | -- | -- | 3.72 | 4.11 | 0° |
| 8 | 4.53 | 3.64 | 90° | 3.64 | 4.04 | 90° |
| 9 | 4.44 | 3.54 | -45° | 3.56 | 3.96 | +45° |
| 10 | 4.34 | 3.44 | 90° | 3.48 | 3.88 | 90° |
| 11L | 4.25 | 3.33 | 0° | -- | -- | -- |
| 12 | Butt to Ply 12 on Right | | -45° | 3.40 | 3.81 | +45° |
| 13 | 4.15 | 3.23 | 0° | 3.32 | 3.73 | 0° |
| 14 | 4.06 | 3.12 | 90° | 3.24 | 3.66 | 90° |
| 15 | 3.97 | 3.02 | -45° | 3.16 | 3.58 | +45° |
| 16 | 3.87 | 2.91 | 90° | 3.08 | 3.51 | 90° |
| 17 | Full Length | | 0° | Full Length | | 0° |
| 18 | 3.78 | 2.81 | -45° | 3.00 | 3.43 | +45° |

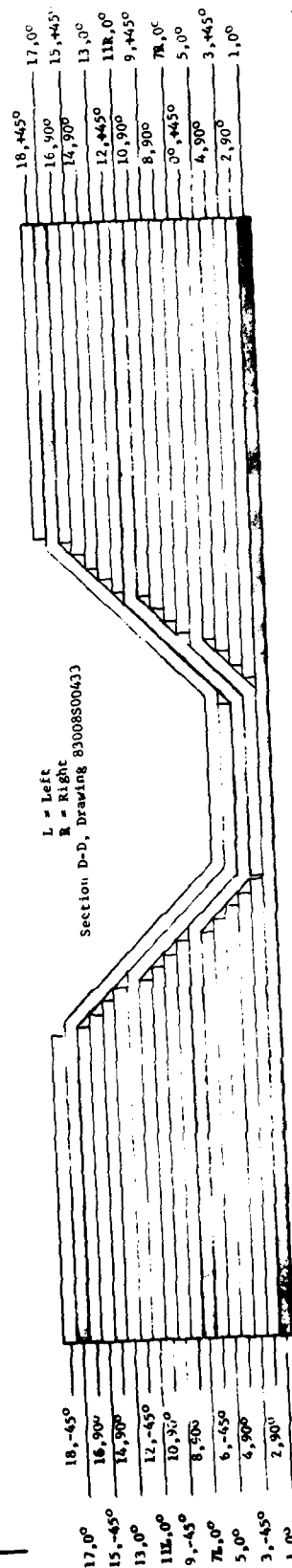
TABLE II-VI

EXTERIOR BAND SETS, SIDE BRACE ATTACHMENT
SETS NO. 1, 3 AND 5, PLY LENGTH VERSUS ORIENTATION



Cutting Pattern
Sets 1, 2, 3, 4, 5 and 6

Figure II-24



Side Brace Attachment
Sets No. 1, 3 and 5
Layup Sequence

Figure II-25

7. Repeat Steps 1 and 2.
8. Cut out and lay up preform set No. 2 in the mold. The orientation, length and ply number within the set are given in Table II-VII. The cutting pattern and layup sequence for the set are shown in Figures II-24 and II-25.
9. Repeat Steps 4 and 5.
10. Fabricate preform sets Nos. 4 and 6 by repeating Steps 1, 2, 8, 4 and 5.

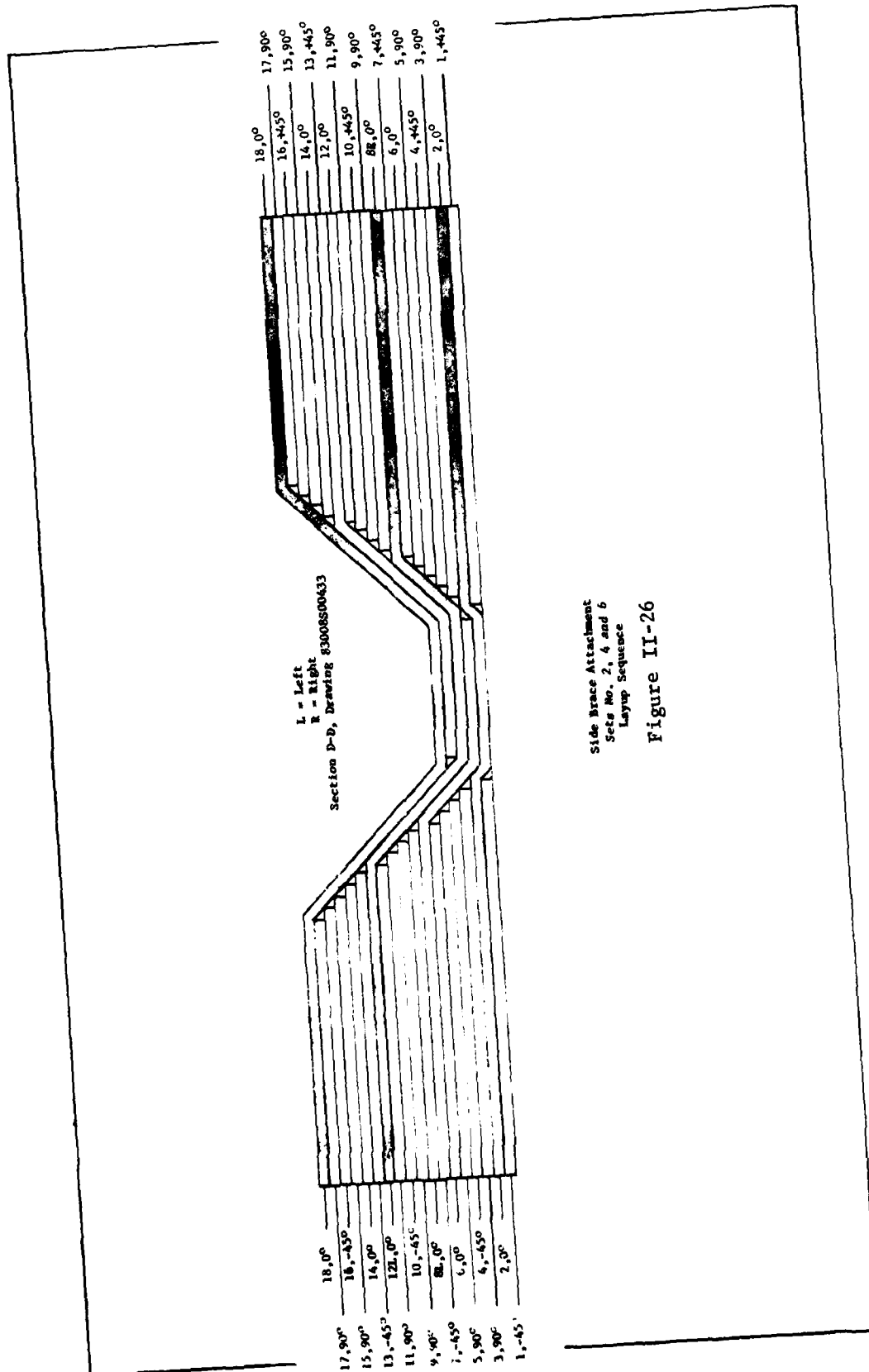
B. Acute corner preform

1. Due to the sharp angle formed by the $60^{\circ}30'$ requirement, the layup mandrel requires an "acute corner preform" to preclude wrinkling of the exterior band sets during cure. The location of this preform on the layup mandrel is shown in Figures II-27 and II-28.
2. Obtain a flat metal surface at least 2 in. x 5 in.
3. Clean surface with MEK.
4. Cut out and lay up on the flat surface an "acute corner preform". The orientation, length and ply number within the set are given in Table II-VIII. The cutting pattern and layup sequence for the preforms are shown in Figure II-29.
6. After plies are laid up as in Figure II-29, place the preform assembly against the mold as shown in Figures II-27 and II-28 with ply No. 17 against the crease of the angle of the mold.
7. Place TX-1040 cloth over the preform and place a vacuum bag over the assembly.
8. While under vacuum, place the assembly in the oven at 200°F for 10 minutes.
9. Remove from oven and cool down while maintaining vacuum.
10. Disassemble vacuum bag and TX-1040 and remove preform. Trim the preform to a blend shape with the mold surfaces with sandpaper. This blend shape should form a smooth transition between the straight side and cylinder portion of the mandrel.

| Ply No. | Left Side | | | Right Side | | |
|---------|------------------------|----------|-------------|------------------------|----------|-------------|
| | Length A | Length B | Orientation | Length C | Length D | Orientation |
| 1 | 5.00 | 4.17 | -45° | 4.04 | 4.41 | +45° |
| 2 | Full Length | | 0° | Full Length | | 0° |
| 3 | 4.90 | 4.06 | 90° | 3.96 | 4.34 | 90° |
| 4 | 4.81 | 3.96 | -45° | 3.88 | 4.26 | +45° |
| 5 | 4.72 | 3.85 | 90° | 3.80 | 4.19 | 90° |
| 6 | 4.62 | 3.75 | 0° | 3.72 | 4.11 | 0° |
| 7 | Butt to Ply 3 on Right | | -45° | 3.64 | 4.04 | +45° |
| 8L | 4.53 | 3.64 | 0° | -- | -- | -- |
| 8R-12L | Full Length | | 0° | Full Length | | 0° |
| 9 | 4.44 | 3.54 | 90° | 3.56 | 3.96 | 90° |
| 10 | 4.34 | 3.44 | -45° | 3.48 | 3.88 | +45° |
| 11 | 4.25 | 3.33 | 90° | 3.40 | 3.81 | 90° |
| 12R | -- | -- | -- | 3.32 | 3.73 | 0° |
| 13 | 4.15 | 3.23 | -45° | Butt to Ply 13 on Left | | +45° |
| 14 | 4.06 | 3.12 | 0° | 3.24 | 3.66 | 0° |
| 15 | 3.97 | 3.02 | 90° | 3.16 | 3.58 | 90° |
| 16 | 3.87 | 2.91 | -45° | 3.08 | 3.51 | +45° |
| 17 | 3.78 | 2.81 | 90° | 3.00 | 3.43 | 90° |
| 18 | Full Length | | 0° | Full Length | | 0° |

TABLE II-VII

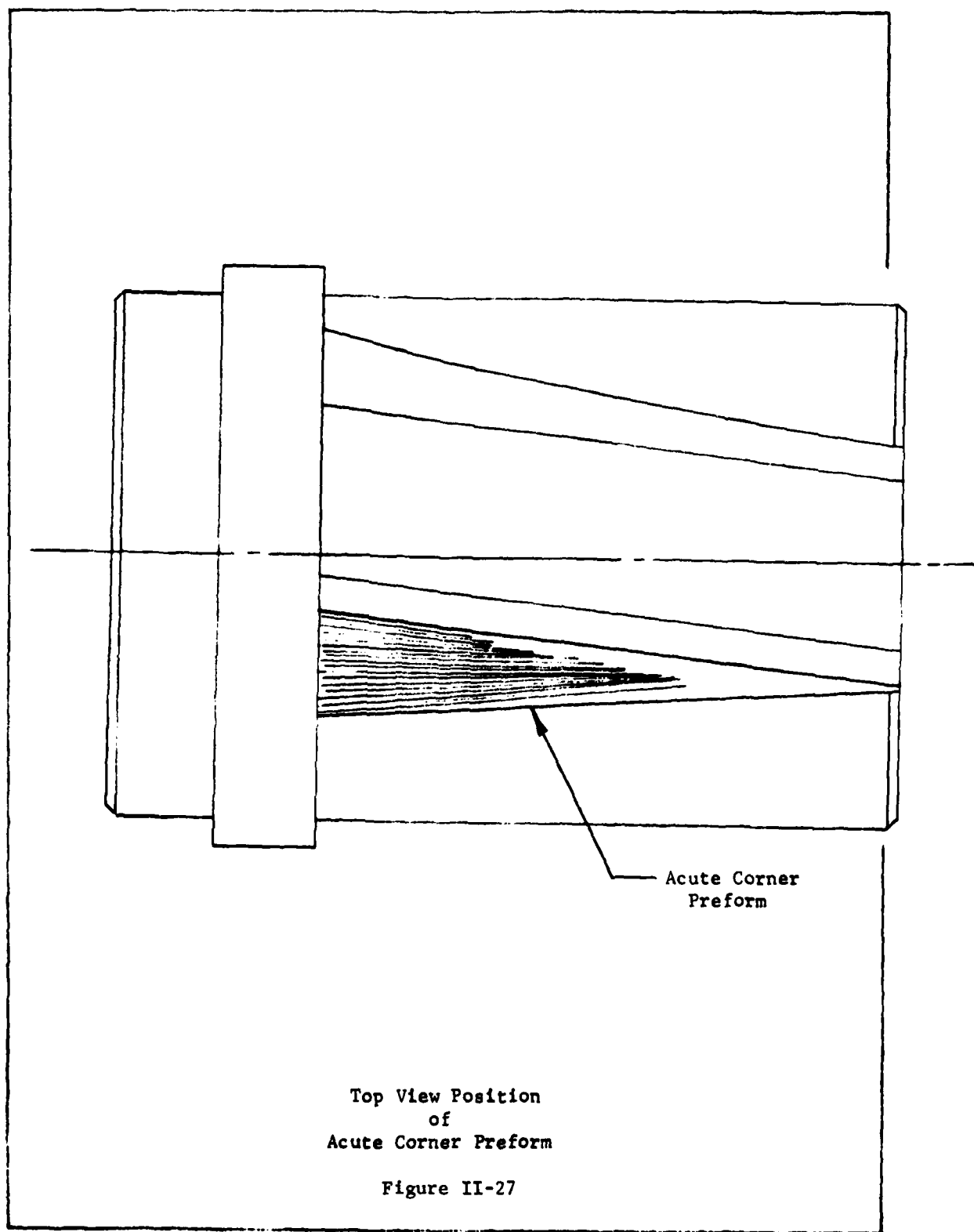
EXTERIOR BAND SETS, SIDE BRACE ATTACHMENT
SETS NO. 2, 4 AND 6, PLY LENGTH VERSUS ORIENTATION

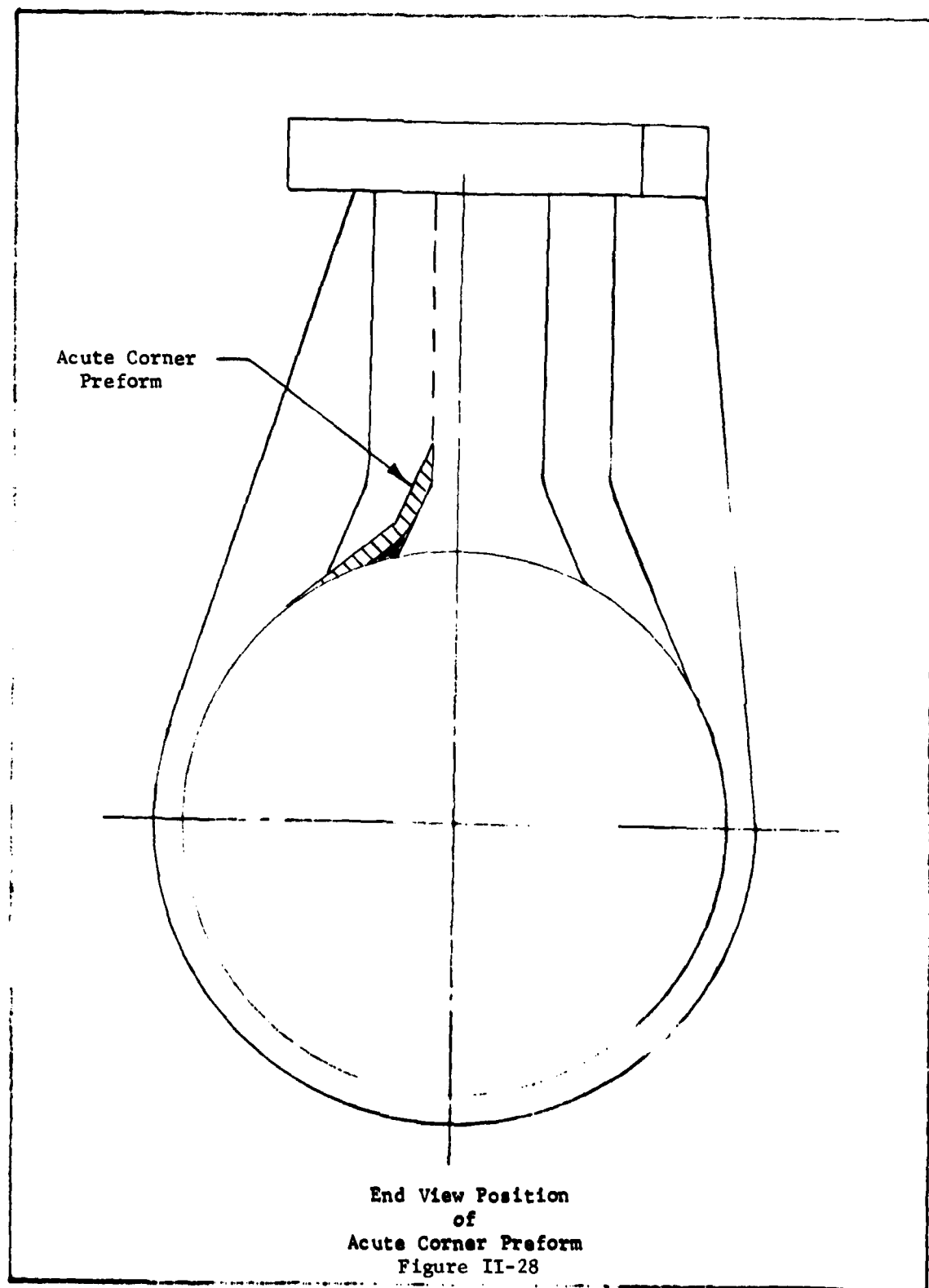


L - Left
R - Right
Section D-B, Drawing 83008S00433

Side Brace Attachment
Sets No. 2, 4 and 6
Layup Sequence

Figure II-26

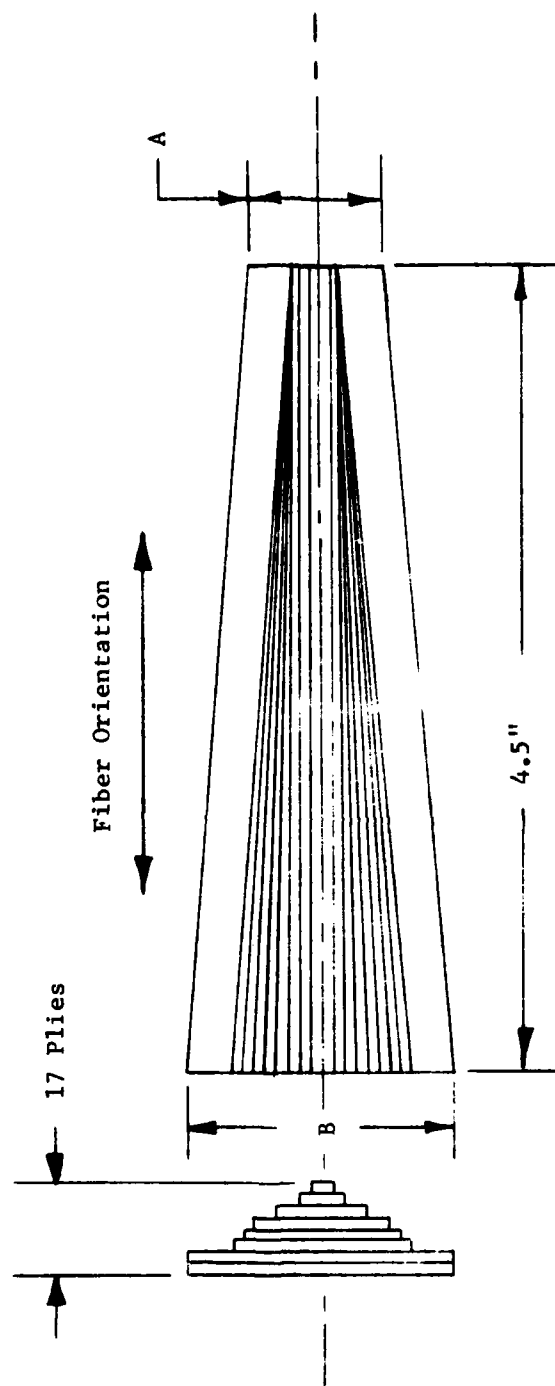




| Ply No. | Length "A" | Length "B" |
|---------|------------|------------|
| 1 | 0.75 | 1.50 |
| 2 | 0.75 | 1.50 |
| 3 | 0.25 | 1.00 |
| 4 | 0.25 | 0.90 |
| 5 | 0.25 | 0.80 |
| 6 | 0.25 | 0.70 |
| 7 | 0.25 | 0.60 |
| 8 | 0.20 | 0.50 |
| 9 | 0.20 | 0.40 |
| 10 | 0.20 | 0.35 |
| 11 | 0.15 | 0.30 |
| 12 | 0.15 | 0.25 |
| 13 | 0.15 | 0.20 |
| 14 | 0.10 | 0.15 |
| 15 | 0.10 | 0.10 |
| 16 | 0.10 | 0.10 |
| 17 | 0.05 | 0.10 |

TABLE II-VIII

ACUTE CORNER PREFORM
PLY LENGTH VERSUS ORIENTATION



Cutting Pattern and Layup Sequence
for
Acute Corner Preform

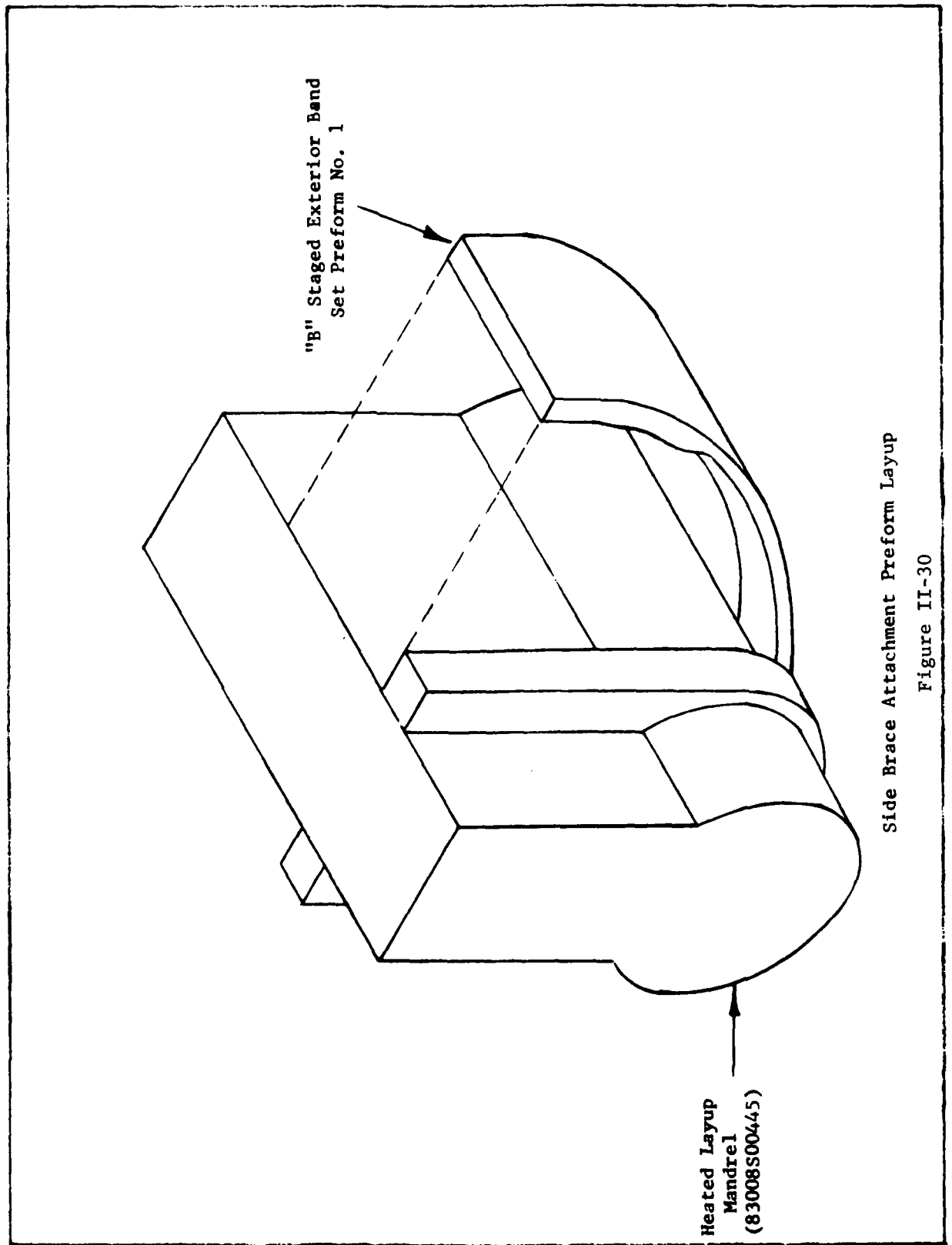
Figure II-29

C. Forming exterior band sets on layup mandrel (Mandrel Drawing 83008S00445)

1. Place layup mandrel in oven and heat to 200°F.
2. Place the "acute corner preform" on the mold as shown in Figures II-27 and II-28.
3. Using the hot mandrel, drape each exterior band set (fabricated in Section A) over the mandrel so that they conform approximately to the shape of the mandrel. This is a rough forming operation so each set will be about the same shape.

D. Final assembly (Mandrel Drawing 83008S00439)

1. Fabricate an exterior aluminum sheet metal (.050 in.) caul plate that will conform to the outside dimensions of the cured band sets. Refer to Drawing 83008S00433 for dimensions.
2. Heat the layup mandrel to 200°F and place the "acute corner preform" in its proper place (Step C2).
3. Place exterior band set No. 1 in position (see Figure II-30) and sequentially add band sets 2, 3, 4, 5 and 6.
4. Place the caul plate over band set No. 6.
5. Wrap the assembly with TX-1040 release fabric.
6. Wrap this assembly with 12 end glass roving using the No. 21 Winding Machine to rotate the mandrel. Set the torque motor at 70 units to apply proper roving tension.
7. Cool the assembly and remove the glass roving, TX-1040 and caul plate.
8. Trim excess prepreg at top of mandrel and place end plate (Item 7 of Drawing 83008S00445) on mandrel.



Side Brace Attachment Preform Layup

Figure II-30

E. Final cure

1. Replace caul plate and TX-1040 and wrap assembly with 12 end glass roving.
2. Install vacuum bag over this assembly and cure in autoclave.
3. Cure cycle:
 - a. Hold vacuum throughout cycle.
 - b. Raise temperature 3° /minute to 250°F .
 - c. Apply 100 psi at 200°F level.
 - d. Hold at 250°F for 4 hours.
 - e. Raise temperature at 3° /minute to 300°F .
 - f. Hold for 1 hour at 300°F and 100 psi.
 - g. Cool down with 100 psi pressure to room temperature (or 150°F maximum).

F. Spacing block fabrication (Item 8 of Drawing 83008S00433)

1. Cut up 5 lbs of 3501/AS prepreg (.005 in. thick) into $1/2$ in. x $1/2$ in. pieces.
2. Using a standard 4.75 in. diameter slug mold, pack the cavity with 5 lbs of chopped 3501/AS prepreg.
3. Place piston in mold and place assembly in press.
4. Raise temperature to 250°F and apply 2000 psi for $1/2$ hour.
5. Raise temperature to 350°F and apply 2000 psi for 2 hours.
6. Cool down and strip billet from mold.
7. Machine billet to configuration of Item 8 of Drawing 83008S00433.

3.0 Inner Cylinder

The inner cylinder is shown on Drawing LCJ37001 (Figure II-31) and was fabricated on a solid aluminum mandrel as shown on Drawing LCJ3002 (Figure II-32). Slit 3501-5/AS prepreg tape was used with the following procedure to fabricate this component.

3.1 Inner Cylinder Fabrication Process

A. Cylinder Wall Layup

1. Clean mandrel (LCJ370002) with Alcanox cleaner and water and allow to dry thoroughly.
2. Apply Frekote #33 release agent to mandrel and bake in 350° oven for 1 hour.
3. Place mandrel in winding machine.
4. Begin layup in Zone A (Figure II-33) by fitting ply No. 1 of Table II-IX (+45°) to mandrel. All angle plies will continue spirally around the mandrel for the full length of the zone. All tape edges shall be built jointed. Make sure all plies are against the shoulder of the mandrel.
5. Compact with overwind material.
6. Lay up Ply No. 2, Table II-IX (-45°) in Zone A (Figure II-33).
7. Apply bleeder overwrap material and overwind with tension control set at 70 to 80 units. Apply low heat with heat gun during overwind.
8. Cool to room temperature before removing compaction material.
9. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.
10. Lay up Plies No. 3 and 4, Table II-IX (0°) in Zone A. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.
11. Repeat steps 7, 8, and 9 for compaction.

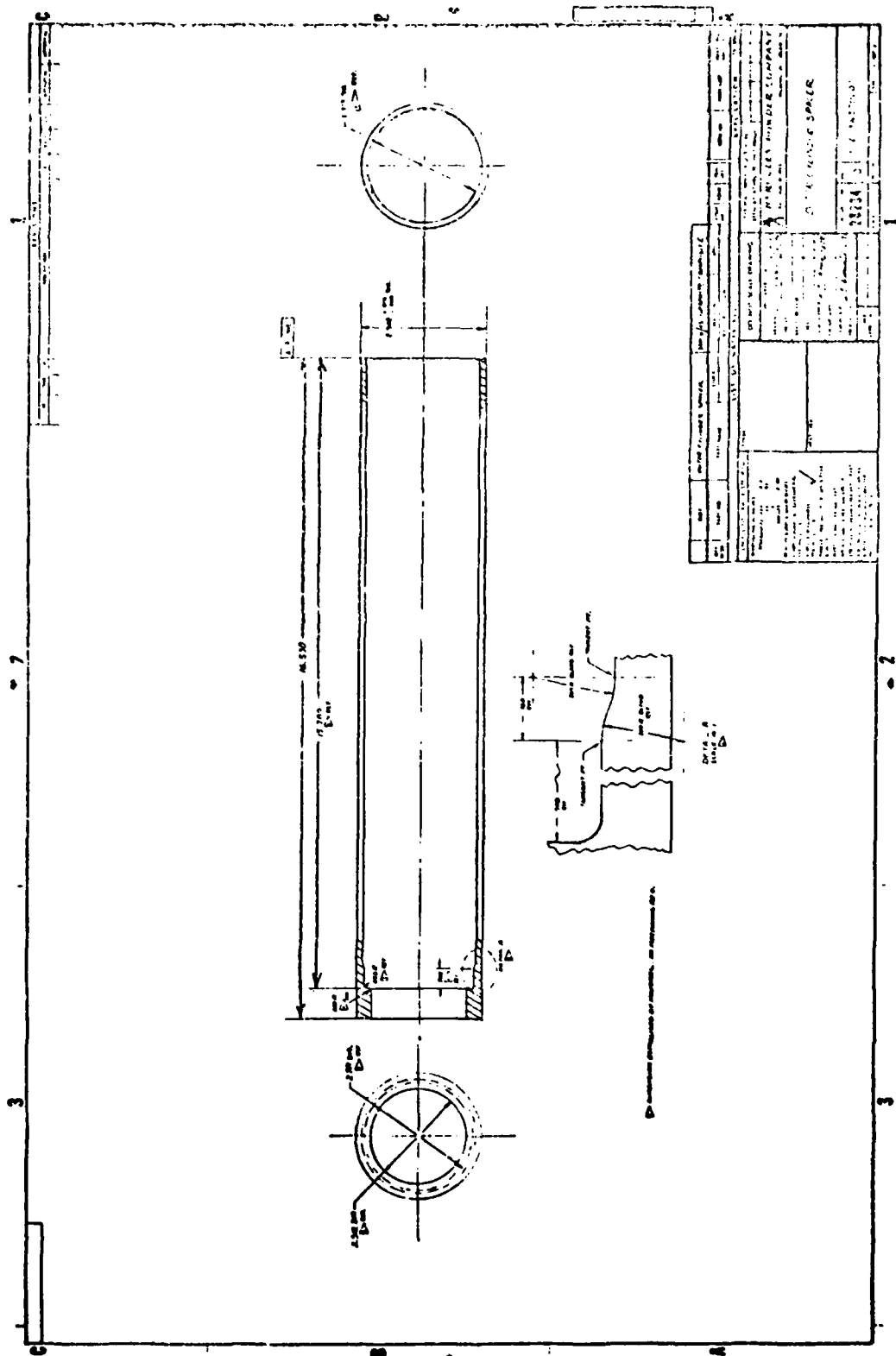


Figure II-31. Inner Cylinder

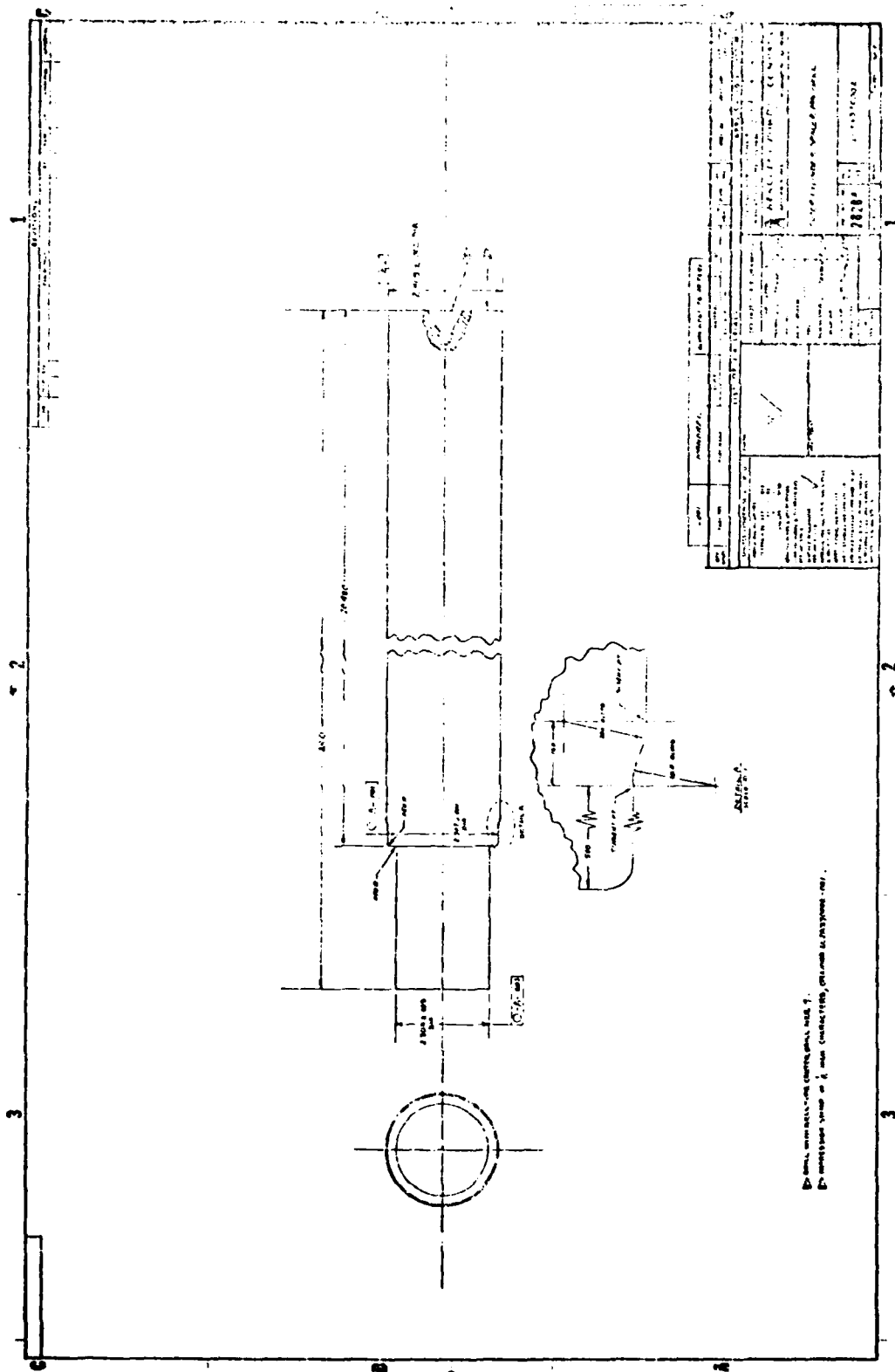


Figure II-32. Inner Cylinder M 1rel

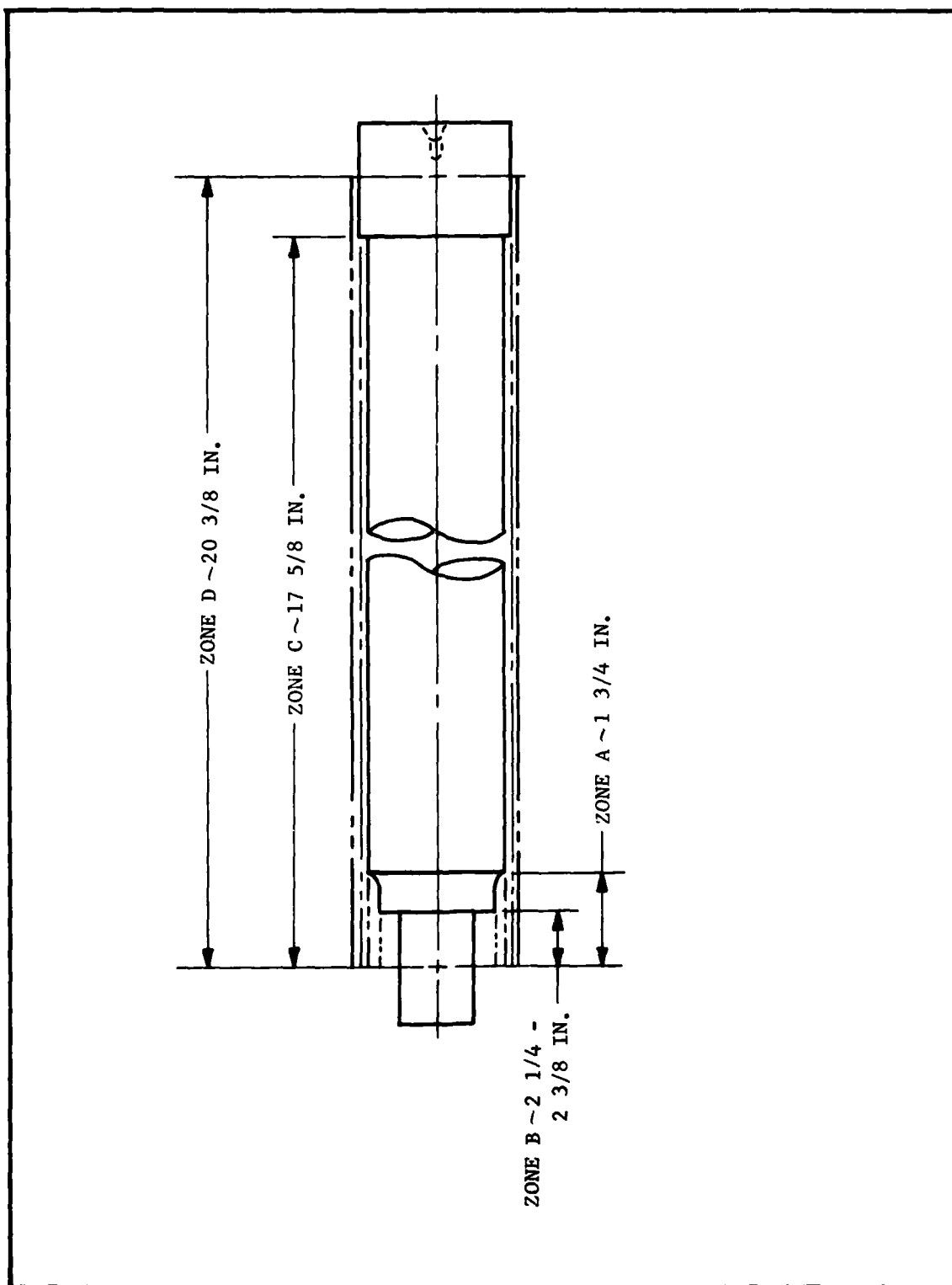


Figure II-33. Layout Zones for Inner Sleeve

TABLE II-IX

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER ZONE A

| Ply No. | Orientation Starting At ID | Width Longitudinal | Length Circumferential |
|---------|----------------------------|--------------------|--------------------------------------|
| 1 | + 45° | ~ 1-3/4 in. | Cut as required to form a butt joint |
| 2 | - 45° | " | " |
| 3 | 0° | " | " |
| 4 | 0° | " | " |
| 5 | - 45° | " | " |
| 6 | + 45° | " | " |
| 7 | 0° | " | " |
| 8 | 0° | " | " |
| 9 | + 45° | " | " |
| 10 | - 45° | " | " |
| 11 | 0° | " | " |
| 12 | 0° | " | " |
| 13 | - 45° | " | " |
| 14 | + 45° | " | " |
| 15 | 0° | " | " |
| 16 | 0° | " | " |
| 17 | + 45° | " | " |
| 18 | - 45° | " | " |
| 19 | 0° | " | " |
| 20 | 0° | " | " |
| 21 | - 45° | " | " |
| 22 | + 45° | " | " |
| 23 | 0° | " | " |
| 24 | 0° | " | " |
| 25 | + 45° | " | " |
| 26 | - 45° | " | " |
| 27 | 0° | " | " |
| 28 | 0° | " | " |
| 29 | - 45° | " | " |
| 30 | + 45° | " | " |
| 31 | 0° | " | " |
| 32 | 0° | " | " |
| 33 | + 45° | " | " |
| 34 | - 45° | " | " |
| 35 | 0° | " | " |
| 36 | 0° | " | " |
| 37 | - 45° | " | " |
| 38 | + 45° | " | " |
| 39 | 0° | " | " |
| 40 | 0° | " | " |

12. Lay up Plies 5 and 6, Table II-IX ($\pm 45^\circ$) in Zone A. Make sure all plies are against shoulder of mandrel.
13. Repeat steps 7, 8, and 9 for compaction.
14. Continue lay up in Zone A in accordance with Table II-IX. Compact per steps 7, 8, and 9 every two plies.

NOTE: The 40 plies are a calculated number. The number of plies may be adjusted up or down to ensure that the last ply at the inboard edge of Zone A is approximately 0.010 in. above the level of the bare mandrel in Zone B. If adjustment is made, do not change sequence of orientation.

15. Begin layup of cylinder in Zone B by fitting Ply No. 41 of Table II-X ($+45^\circ$) to Zone B (Figure II-33) on the mandrel. All angle plies will continue spirally around the mandrel for the full length of the zone. All ply edges shall be butt jointed. Make sure all plies are against the shoulder of the mandrel.
16. Compact with overwind material.
17. Lay up Ply No. 42 of Table II-X (-45°) to Zone B (Figure II-33) on the mandrel.
18. Apply bleeder overwrap material and overwind with tension control set at 70 to 80 units. Apply low heat with heat gun during overwind.
19. Cool to room temperature before removing compaction material.
20. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.
21. Lay up Plies No. 43 and 44, Table II-X (0°) in Zone B. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.
22. Repeat steps 18, 19, and 20 for compaction.

TABLE II-X
PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER ZONE B

| Ply No. | Orientation Starting At ID | Width Longitudinal | Length Circumferential |
|---------|----------------------------|--------------------------------|--------------------------------------|
| 41 | + 45° | Varies from 2-1/4 to 2-3/8 in. | Cut as required to form a butt joint |
| 42 | - 45° | " | " |
| 43 | 0° | " | " |
| 44 | 0° | " | " |
| 45 | - 45° | " | " |

23. Lay up Plies No. 45 and 46, Table II-X (+45°) in Zone B. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.
24. Repeat steps 18, 19, and 20 for compaction.
25. Continue layups in Zone B in accordance with Table II-X. Compact per steps 18, 19, and 20.
26. Apply porous scrim cloth over entire area of Zone B. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and place in vacuum bag. Draw vacuum and heat to $200 \pm 10^\circ$ F until excess resin migrates into bleeder. Cool to room temperature under vacuum.
27. Remove bleeder material.
28. Begin layup over Zone C by fitting Ply No. 46 of Table II-XI (+45°). All angle plies will continue spirally around the mandrel for the full length of the zone. Ply edges shall be butt jointed. Make sure ends of plies are against shoulder of mandrel.
29. Compact with overwind material.

TABLE II-XI

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER ZONE C

| Ply No. | Orientation Starting At ID | Width Longitudinal | Length Circumferential |
|---------|----------------------------|--------------------|--------------------------------------|
| 46 | + 45° | ~ 17-5/8 in. | Cut as required to form a butt joint |
| 47 | 0° | " | " |
| 48 | 0° | " | " |
| 49 | + 45° | " | " |
| 50 | - 45° | " | " |
| 51 | 0° | " | " |
| 52 | 0° | " | " |
| 53 | - 45° | " | " |
| 54 | + 45° | " | " |
| 55 | 0° | " | " |
| 56 | 0° | " | " |
| 57 | + 45° | " | " |
| 58 | 45° | " | " |
| 59 | 0° | " | " |
| 60 | 0° | " | " |

30. Lay up Plies No. 47 and 48, Table II-XI (0°) over Zone C. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.
31. Apply bleeder overwrap and overwind with tension control set at 70 to 80 units. Apply low heat to prepreg with heat gun during overwind.
32. Cool to room temperature before removing compaction material.
33. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervision approval is required before proceeding to next step.
34. Lay up Plies No. 49 and 50, Table II-XI (0°) over Zone C. All ply edges shall be butt jointed. Make sure all plies are against shoulder of mandrel.
35. Repeat steps 31, 32, and 33 for compaction.
36. Continue layup in Zone C in accordance with Table II-XI. Compact per steps 31, 32, and 33 every two plies.
37. Begin layup over Zone D by fitting Ply No. 61 of Table II-XII (-45°). All angle plies shall continue spirally around the mandrel over the entire length of the zone. Ply edges shall be butt jointed.
38. Compact with overwind.
39. Lay up Ply No. 62 of Table II-XII ($+45^{\circ}$) over Zone D.
40. Apply porous scrim cloth over entire area of Zone D. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and place in vacuum bag. Draw vacuum and heat to $200 \pm 10^{\circ}$ F until excess resin migrates into bleeder. Cool to room temperature under vacuum.
41. Remove compaction material.

TABLE II-XII

PLY NUMBER, ORIENTATION AND DIMENSIONS FOR
INNER CYLINDER, ZONE D

| Ply No. | Orientation Starting at ID | Width Longitudinal | Length Circumferential |
|---------|----------------------------|--------------------|--------------------------------------|
| 61 | - 45° | ~20-3/8 in. | Cut as required to form a butt joint |
| 62 | + 45° | " | " |
| 63 | 0° | " | " |
| 64 | 0° | " | " |
| 65 | + 45° | " | " |
| 66 | - 45° | " | " |
| 67 | 0° | " | " |
| 68 | 0° | " | " |
| 69 | - 45° | " | " |

42. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor while applying low heat from heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.
43. Lay up Plies No. 63 and 64 over Zone D. All ply edges shall be butt jointed.
44. Repeat steps 40, 41, and 42 for compaction.
45. Continue layup in Zone D in accordance with Table II-XII. Compact every two plies per steps 40, 41, and 42.
46. Lay up Ply No. 69, Table II-XII (-45°) over Zone D.

47. Apply porous scrim cloth over entire area of Zone D. Wrap one heavy Armalon ply around mandrel. Overwind with tension control set at 70 to 80 units while applying low heat to prepreg with heat gun. Install thermocouple and install in vacuum bag.
48. Install in autoclave, draw vacuum, and apply pressure. Heat to $250^{\circ} \pm 10^{\circ}$ F. Maintain pressure and vacuum during cooldown to room temperature.
49. Remove compaction material.

B. Inner Cylinder Cure

1. Apply porous scrim over entire layup.
2. Overwind using a tension setting of 70 to 80 units while applying low heat with heat gun.
3. Install thermocouple, vacuum line, and vacuum bag.
4. Place in autoclave.
5. Hold vacuum throughout cure cycle
6. Apply 100 psi pressure initially.
7. Raise temperature 3° /minute to 250° F.
8. Hold at 250° F for 1 hour
9. Raise temperature at 3° /minute to 300° F.
10. Hold for 1/2 hour at 300° F.
11. Raise temperature at 3° /minute to 350° F.
12. Hold for 2 hours at 350° F.
13. Cool down to 150° F under pressure.
14. Remove from autoclave at 150° F or below.
15. Remove from mandrel.
16. Postcure for 2 hours at 400° F.

4.0 Outer Cylinder Trunnion

The outer cylinder/trunnion is shown in Figure II-34. Fabrication was performed using the trunnion mandrel assembly seen in Figures II-35 and II-36. Using 3501-5/AS prepreg tape, the following fabrication procedure was used.

4.1 Outer Cylinder/Trunnion Fabrication Process

A. Outer Cylinder/Trunnion Wall Layup

1. Thoroughly clean the mandrel with Alconox and water. Allow to dry.
2. Apply Frekote No. 33 release agent and bake at 350° F for 1 hour. Cool to room temperature.
3. Brush a coat of 3501-5 resin on the mandrel and air dry for approximately 20 minutes.
4. Using 3-inch tape, start the layup of Ply No. 1, Figure II-37 (-45°). The layup will start at the chuck end of the outer cylinder and continue to the beginning of the ramp area. Ply will be completed with edges of tape butt jointed. Use heat gun to hold tape in place, if required.
5. Starting where the outer cylinder layup stopped, continue -45° layup for the ramp area and flat surfaces. Cut the 3-inch tape as required to maintain 45° angle on the ramp area. At the point where the cylinder layup stops and the ramp and flat surface layups start, maintain 1/4 inch overlap throughout. Stagger this overlap on future plies. (Figure II-38.)
6. Lay up Ply No. 2 (+45°) by repeating steps 4 and 5, except Ply No. 2 is 90° from Ply No. 1 (Figure II-38).
7. Lay up Ply No. 3a (0°) using prepreg slit to a width that can be easily worked without wrinkling (approximately 1/4 inch or wider depending on location). Layup this ply so that "B" and "C" dimensions of Figure II-39 and Table II-XIII are satisfied.
8. Finish Ply No. 3a (0°) in the flat areas by laying over ply of 3 inch tape or wider per Figure II-39 and Table II-XIII.

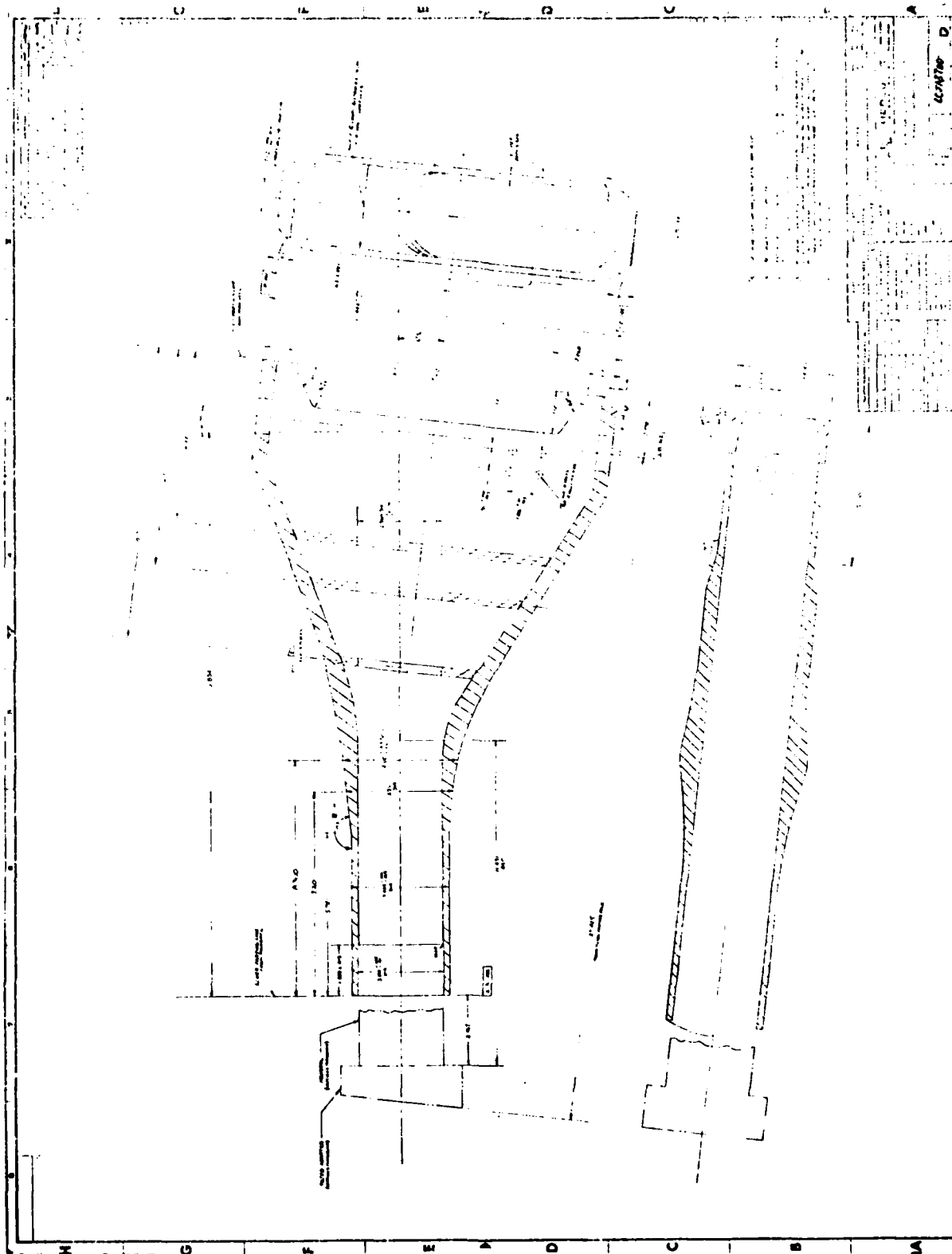


Figure II-34. Outer Cylinder/Trunnion

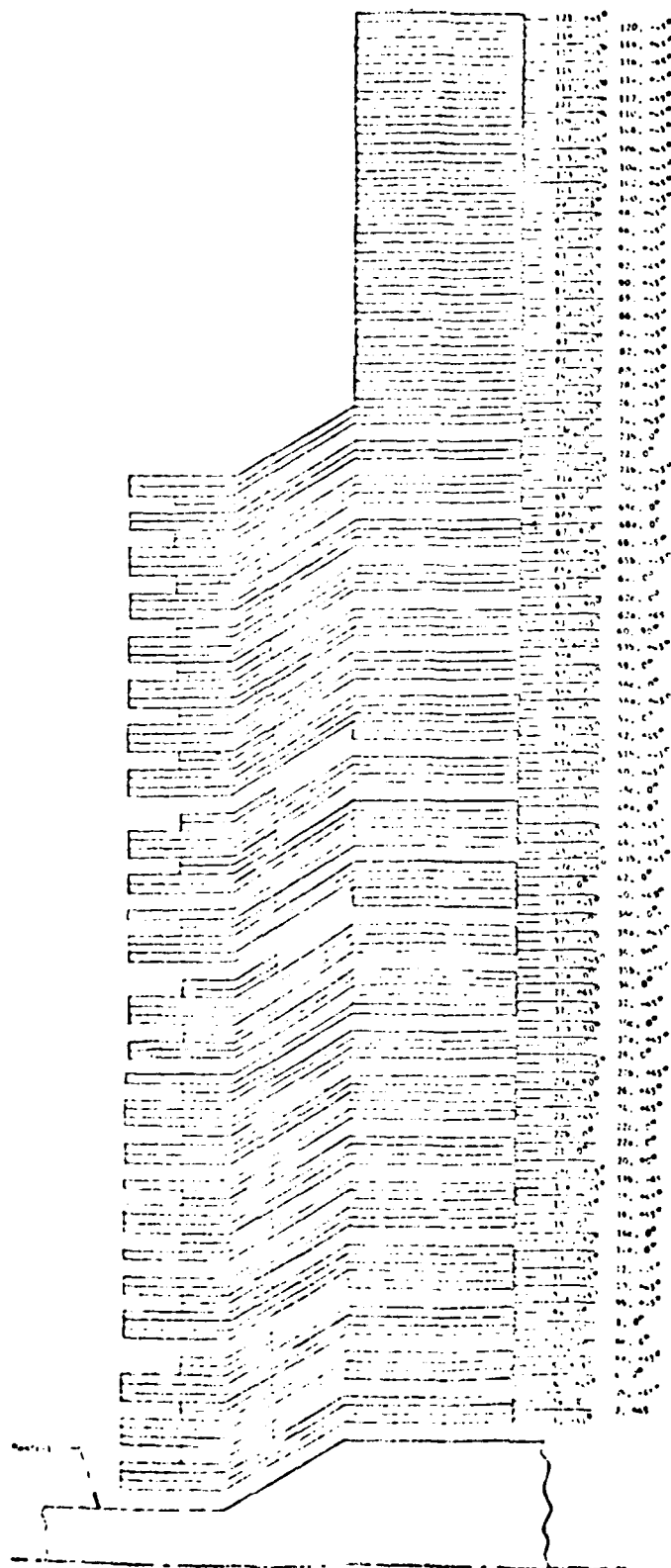
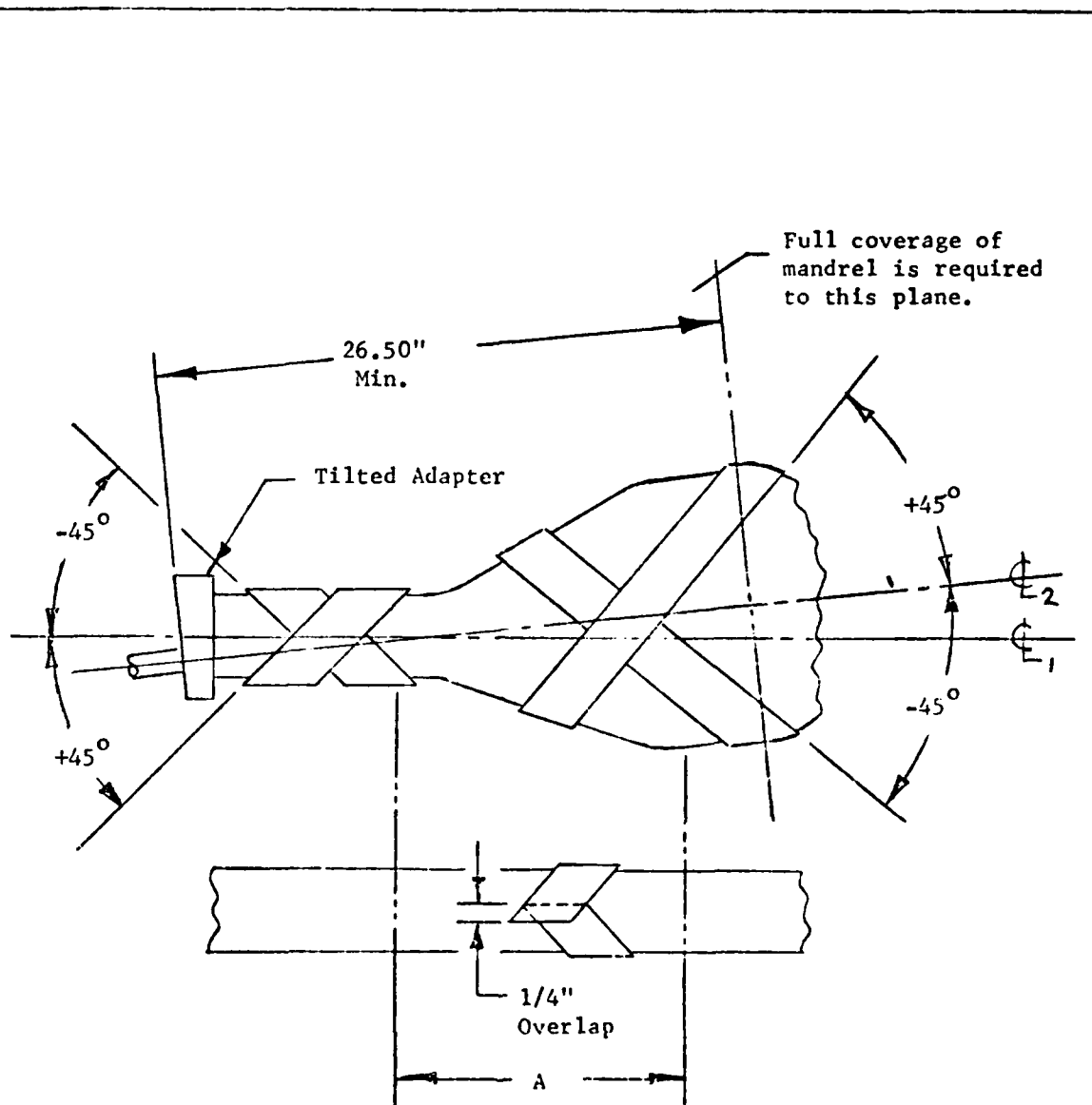


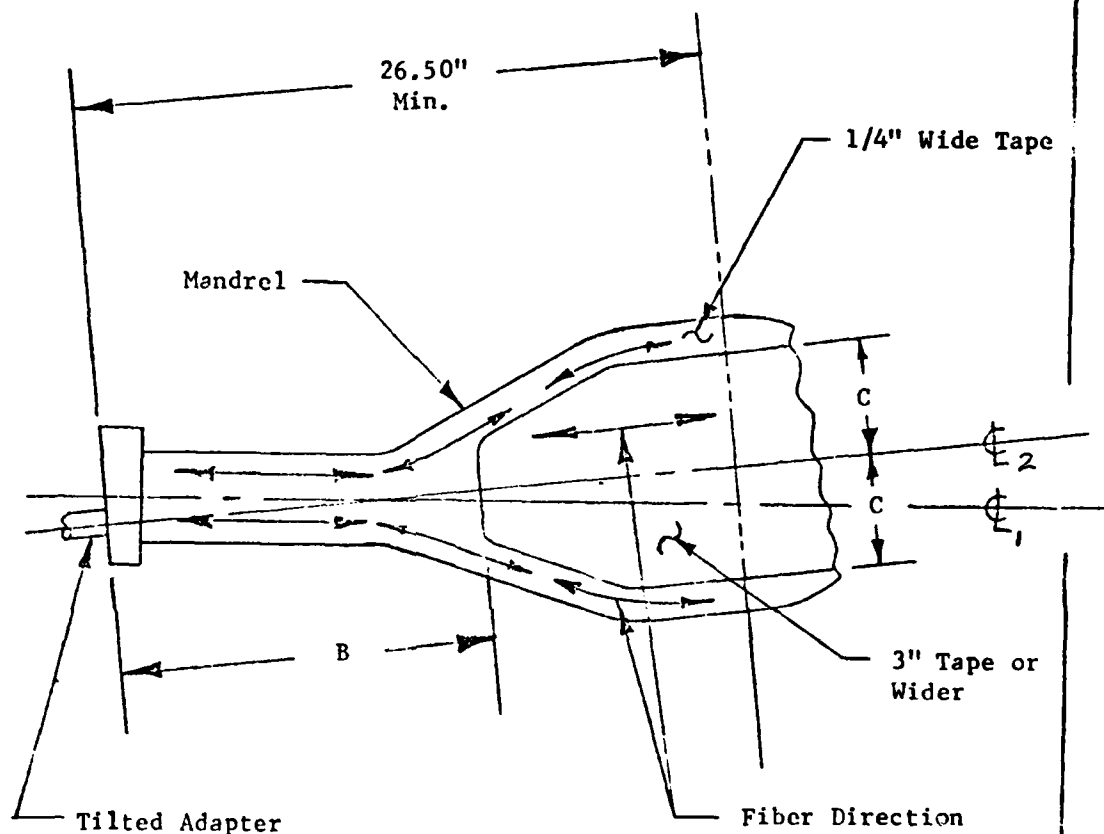
Figure II-37. Trunnion Lay Up Sequence



To maintain 45° angle in Zone A,
cut 3" tape as required. Overlap
tape as shown.

Trunnion Layup Detail
for
+45° Plies, Full Coverage

Figure II-38



Layup Procedure

1. Lay slit tape on mandrel until the C dimension is satisfied.
2. Lay slit tape on mandrel until the B dimension is satisfied.
3. Lay 3" or wider tape (1 ply) in area shown in above sketch.

Trunnion Layup Detail
for
0° Plies

Figure II-39

TABLE II-XIII

0° PLIES

| Ply No. | "B" Dimension (in.) | "C" Dimension (in.) |
|---------|---------------------|---------------------|
| 3a | 15.15 | 3.00 |
| 4 | 15.15 | 3.00 |
| 8 | 14.45 | 4.12 |
| 9 | 14.45 | 4.12 |
| 14a | 15.05 | 3.16 |
| 21 | 14.35 | 4.28 |
| 22a | 14.35 | 4.28 |
| 28 | 14.95 | 3.32 |
| 29 | 14.95 | 3.32 |
| 34 | 14.25 | 4.44 |
| 35a | 14.25 | 4.44 |
| 41 | 14.85 | 3.48 |
| 42 | 14.85 | 3.48 |
| 47 | 15.15 | 4.60 |
| 48a | 15.15 | 4.60 |
| 54 | 14.75 | 3.64 |
| 55 | 14.75 | 3.64 |
| 58 | 14.05 | 4.76 |
| 59a | 14.05 | 4.76 |
| 63 | 14.65 | 3.80 |
| 64 | 14.65 | 3.80 |
| 68a | 13.95 | 4.92 |
| 69 | 13.95 | 4.92 |
| 72 | 14.55 | 3.96 |
| 73a | 14.55 | 3.96 |

9. Lay up Ply No. 36 (-45°) and 3c ($+45^{\circ}$) per Figure II-40 using prepreg slit to a width that can be easily worked without wrinkling to meet dimensions "M" and "N" of Table II-XIV. Use heat gun to hold tape in place as required. Trim the tape so that no more than 1/4 inch overlap is obtained. Stagger the overlap on future plies.
10. Lay up Ply No. 4 (0°) by repeating steps 7 and 8 per Figure II-39 and Table II-XIII.
11. Apply a layer of porous scrim cloth and one layer of Machburg cloth over the entire layup. Starting at the bottom of the ramp, wind 90° glass roving on the cylinder section towards the chuck using a tension setting of 70 to 80 units. In the ramp area only, apply double face tape. Starting at the bottom of the ramp, wind 90° glass roving toward the tail stock with a tension setting of 70 to 80 units.
12. Place a thermocouple onto the prepreg, install blue peel, vacuum line, and vacuum bag.
13. Place assembly in autoclave. Heat part to $200 \pm 15^{\circ}$ and apply pressure for 20 minutes. Turn off heat and pressure and open autoclave door. Leave vacuum on for a minimum of 12 hours before starting the next step. Record time assembly was placed in and taken out of heat source.
14. Remove compaction materials. Any wrinkles that are visible after compaction shall be worked out with a tongue depressor and heat gun. After wrinkles are removed, supervisor approval is required before proceeding to next step.
15. Lay up Ply No. 5 ($+45^{\circ}$) and Ply No. 6 (-45°) by repeating steps 4, 5, and 6.
16. Lay up Plies No. 6b (0°) and No. 6c (0°) per Figure II-41 and Table II-XVI by repeating technique of step 9.
17. Using 1/4 inch wide prepreg, wind ply No. 7 (90°) according to Figure II-42 and Table II-XV. Start at the bottom of the ramp and wind on the cylinder towards the chuck using Centerline No. 1. For the elliptical section, start at the bottom of the ramp and wind towards the tail stock using Centerline No. 2. Tension control shall be set at 35 to 40 units.

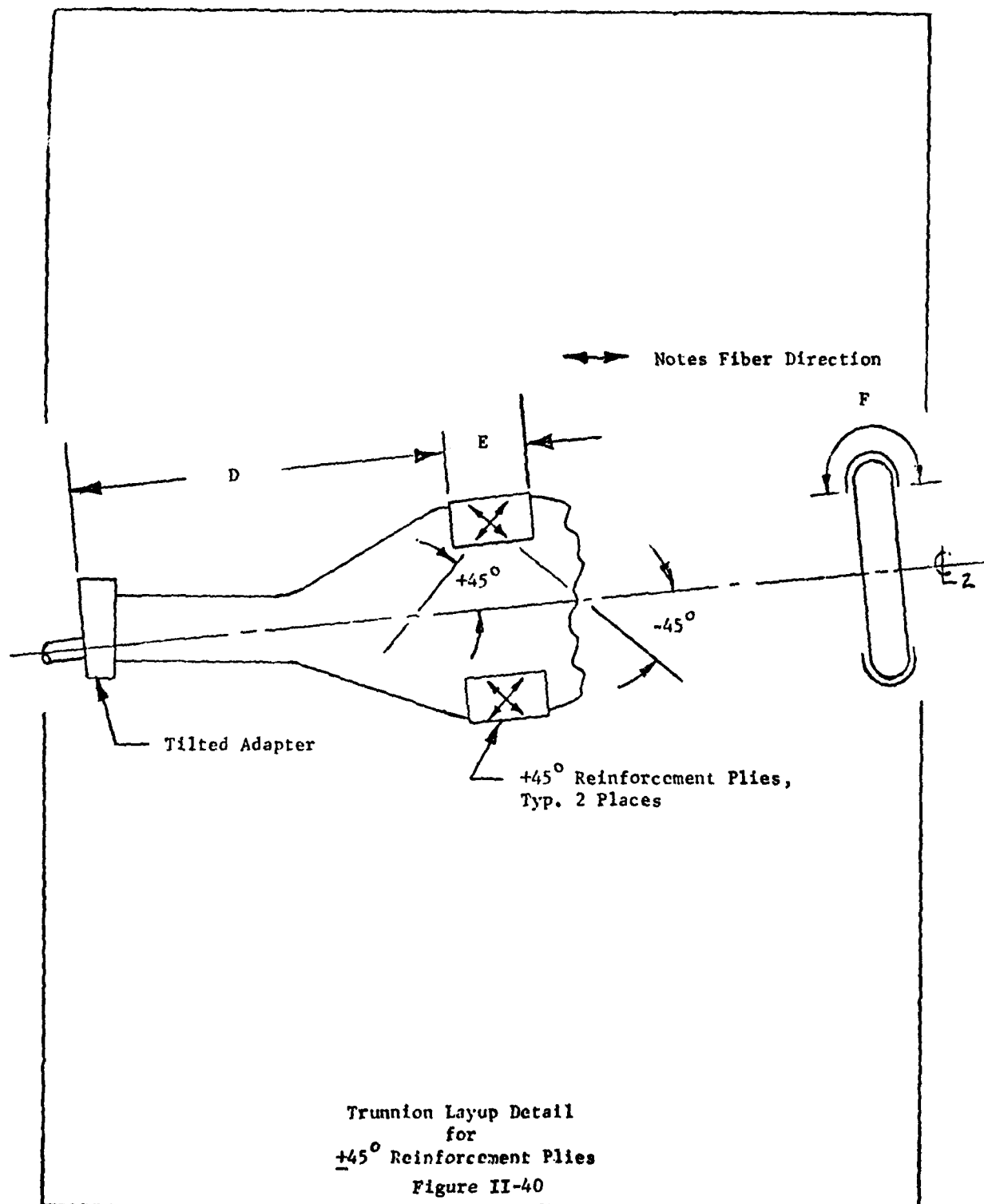


TABLE II-XIV

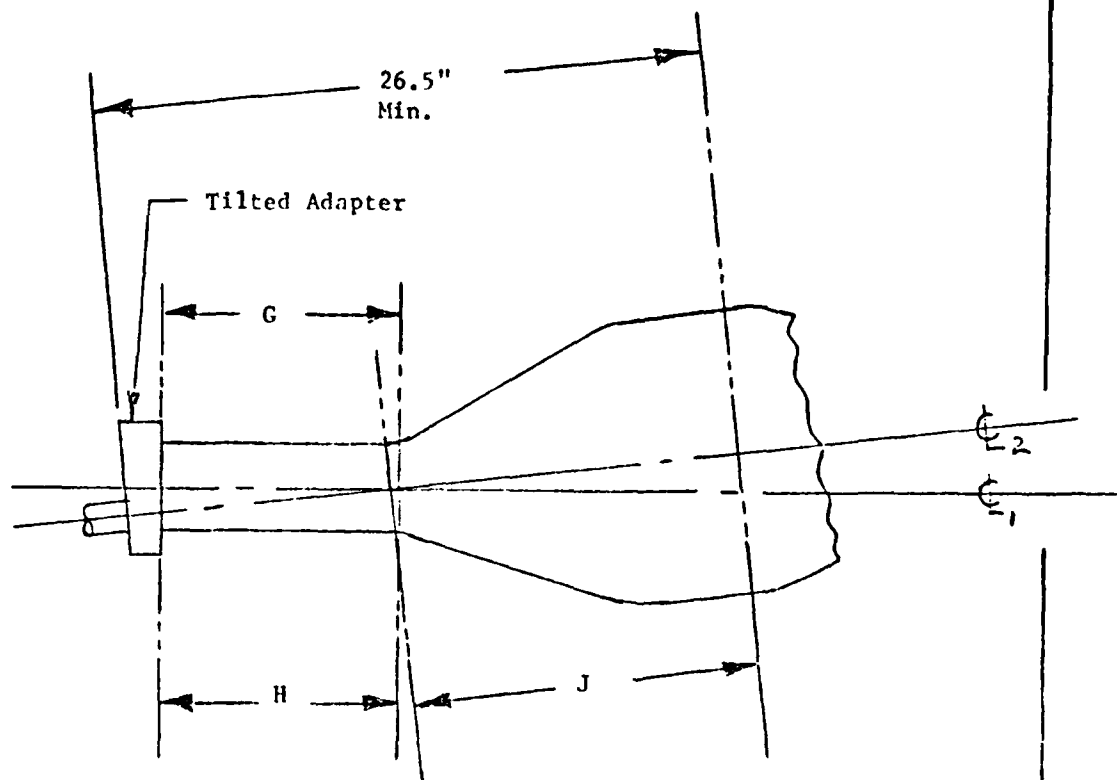
45° REINFORCEMENT PLIES

| Ply No. | "D" Dimension
(in.) | "E" Dimension
(in.) | "F" Dimension
(in.) |
|---------|------------------------|------------------------|------------------------|
| 10 | 21.15 | 5.49 | 6.48 |
| 11 | 21.15 | 5.49 | 6.48 |
| 17 | 21.22 | 5.37 | 6.31 |
| 18 | 21.22 | 5.37 | 6.31 |
| 24 | 21.29 | 5.25 | 6.14 |
| 25 | 21.29 | 5.25 | 6.14 |
| 32 | 21.36 | 5.13 | 5.97 |
| 33 | 21.36 | 5.13 | 5.97 |
| 39 | 21.43 | 5.02 | 5.80 |
| 40 | 21.43 | 5.01 | 5.80 |
| 45 | 21.50 | 4.89 | 5.63 |
| 46 | 21.50 | 4.89 | 5.63 |
| 52 | 21.57 | 4.77 | 5.46 |
| 53 | 21.57 | 4.77 | 5.46 |
| 76 | 21.64 | 4.65 | 5.29 |
| 77 | 21.64 | 4.65 | 5.29 |
| 78 | 21.71 | 4.53 | 5.12 |
| 79 | 21.71 | 4.53 | 5.12 |
| 80 | 21.78 | 4.41 | 4.95 |
| 81 | 21.78 | 4.41 | 4.95 |
| 82 | 21.85 | 4.29 | 4.78 |
| 83 | 21.85 | 4.29 | 4.78 |
| 84 | 21.92 | 4.17 | 4.61 |
| 85 | 21.92 | 4.17 | 4.61 |
| 86 | 21.99 | 4.05 | 4.44 |
| 87 | 21.99 | 4.05 | 4.44 |
| 88 | 22.06 | 3.93 | 4.27 |
| 89 | 22.06 | 3.93 | 4.27 |
| 90 | 22.13 | 3.81 | 4.00 |
| 91 | 22.13 | 3.81 | 4.10 |
| 92 | 22.20 | 3.69 | 3.93 |
| 93 | 22.20 | 3.69 | 3.93 |
| 94 | 22.27 | 3.57 | 3.76 |
| 95 | 22.27 | 3.57 | 3.76 |
| 96 | 22.34 | 3.45 | 3.59 |
| 97 | 22.34 | 3.45 | 3.59 |
| 98 | 22.41 | 3.33 | 3.42 |
| 99 | 22.41 | 3.33 | 3.42 |
| 100 | 22.48 | 3.21 | 3.25 |
| 101 | 22.48 | 3.21 | 3.25 |

TABLE II-XIV (Cont)

45° REINFORCEMENT PLIES

| Ply No. | "D" Dimension
(in.) | "E" Dimension
(in.) | "F" Dimension
(in.) |
|---------|------------------------|------------------------|------------------------|
| 102 | 22.55 | 3.09 | 3.08 |
| 103 | 22.55 | 3.09 | 3.08 |
| 104 | 22.62 | 2.97 | 2.91 |
| 105 | 22.62 | 2.97 | 2.91 |
| 106 | 22.69 | 2.85 | 2.74 |
| 107 | 22.69 | 2.85 | 2.74 |
| 108 | 22.76 | 2.73 | 2.57 |
| 109 | 22.76 | 2.73 | 2.57 |
| 110 | 22.83 | 2.61 | 2.40 |
| 111 | 22.83 | 2.61 | 2.40 |
| 112 | 22.90 | 2.49 | 2.23 |
| 113 | 22.90 | 2.49 | 2.23 |
| 114 | 22.97 | 2.37 | 2.06 |
| 115 | 22.97 | 2.37 | 2.06 |
| 116 | 23.04 | 2.25 | 1.89 |
| 117 | 23.04 | 2.25 | 1.89 |
| 118 | 23.11 | 2.13 | 1.72 |
| 119 | 23.11 | 2.13 | 1.72 |
| 120 | 23.18 | 2.01 | 1.55 |
| 121 | 23.18 | 2.01 | 1.55 |

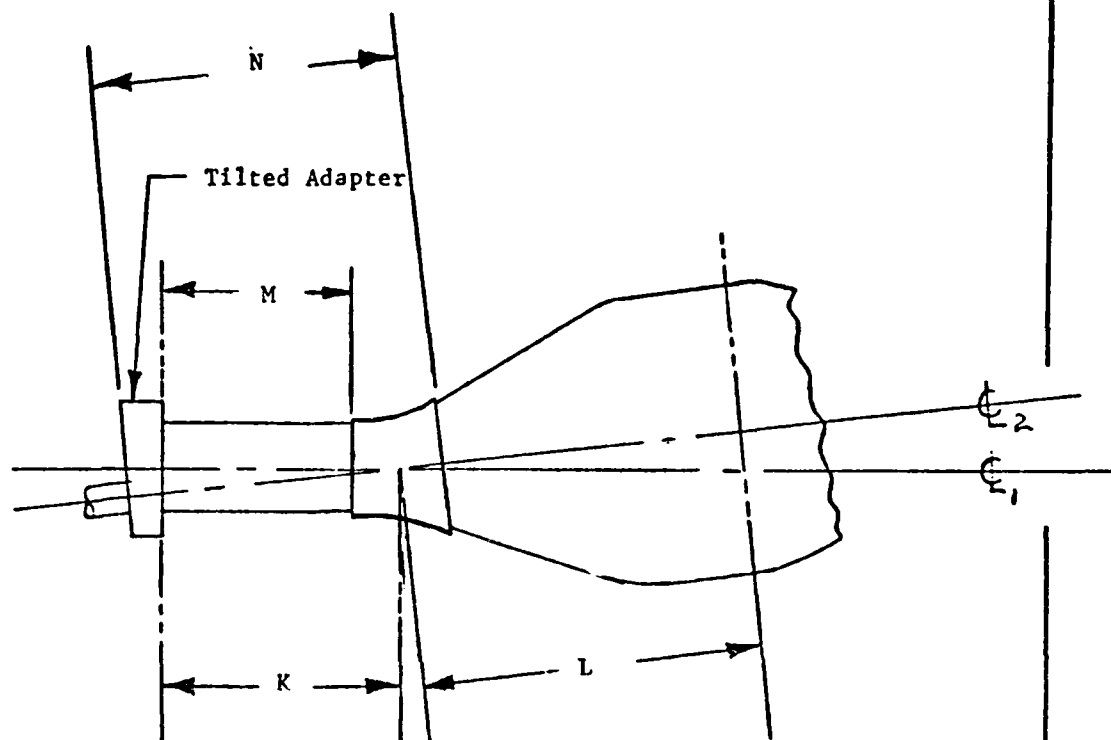


90° plies in Zone H to be wound about C_1 .

90° plies in Zone J to be wound about C_2 .

Trunnion Layup Detail
for
90° Plies, Full Coverage

Figure II-41



Plies in Zone K to be wound about C_1 .

Plies in Zone L to be wound about C_2 .

Trunnion Layup Detail
for
Reinforcement Plies

Figure II-42

TABLE II-XV
FULL COVERAGE 90° PLIES

| Ply No. | "G" Dimension (in.) |
|---------|---------------------|
| 7 | 12.10 |
| 20 | 11.66 |
| 27a | 11.22 |
| 36 | 10.78 |
| 49 | 10.34 |
| 60 | 9.90 |
| 67 | 9.46 |

18. Compact in accordance with steps 11, 12, 13, and 14.
19. Repeat steps 7 and 8 for layup of Plies No. 8 (0°) and 9a (0°) per Figure II-39 and Table II-XIII.
20. Repeat step 9 for layup of Plies No. 9b ($+45^{\circ}$) and 9c (-45°) in accordance with Figure II-42 and Table II-XVI).
21. Lay up Plies No. 10 ($+45^{\circ}$) and 11 (-45°) in accordance with Figure II-40 and Table II-XIV.
22. Repeat steps 4 and 5 for Ply No. 12 (-45°) layup per Figures II-37 and II-38.
23. Compact by repeating steps 11, 12, 13, and 14.
24. Repeat step 6 for Ply No. 13 ($+45^{\circ}$) per Figures II-37 and II-38.
25. Lay up Ply No. 14a (0°) by repeating steps 7 and 8 in accordance with Figure II-39 and Table II-XIII.
26. Lay up Ply No. 14b (90°) per Figure II-42 and Table II-XVI by repeating step 9.
27. Lay up Ply No. 14c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
28. Lay up Ply No. 15 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
29. Compact by repeating steps 11, 12, 13, and 14.
30. Lay up Ply No. 16 ($+45^{\circ}$) per Figures II-37 and II-38 by repeating step 6.
31. Lay up Plies No. 17 (-45°) and 18 ($+45^{\circ}$) in accordance with Figures II-40 and Table II-XIV.
32. Lay up Ply No. 19a (-45°) per Figures II-37 and II-38 by repeating steps 4 and 5.
33. Lay up Plies No. 16b (-45°) and 19c ($+45^{\circ}$) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
34. Wind Ply No. 20 (90°) according to Figure II-41 and Table II-XV by repeating step 17.

TABLE II-XVI

LOCAL REINFORCEMENT PLIES

| Ply No. | Orientation
(Deg) | "M" Dimension
(in.) | "N" Dimension
(in.) |
|---------|----------------------|------------------------|------------------------|
| 3b | -45 | 11.77 | 13.39 |
| 3c | +45 | 11.77 | 13.39 |
| 6b | 0 | 11.645 | 13.515 |
| 6c | 0 | 11.645 | 13.515 |
| 9b | +45 | 11.520 | 13.640 |
| 9c | -45 | 11.520 | 13.640 |
| 14b | 90 | 11.395 | 13.765 |
| 14c | 0 | 11.395 | 13.765 |
| 19b | -45 | 11.270 | 13.890 |
| 19c | +45 | 11.270 | 13.890 |
| 22b | 0 | 11.145 | 14.015 |
| 22c | 0 | 11.145 | 14.015 |
| 27b | +45 | 11.020 | 14.140 |
| 27c | -45 | 11.020 | 14.140 |
| 30b | 90 | 10.895 | 14.265 |
| 30c | 0 | 10.895 | 14.265 |
| 35b | -45 | 10.770 | 14.390 |
| 35c | +45 | 10.770 | 14.390 |
| 38b | 0 | 10.645 | 14.515 |
| 38c | 0 | 10.645 | 14.515 |
| 43b | +45 | 10.520 | 14.640 |
| 43c | -45 | 10.520 | 14.640 |
| 48b | 90 | 10.395 | 14.765 |
| 48c | 0 | 10.395 | 14.765 |
| 51b | -45 | 10.270 | 14.890 |
| 51c | +45 | 10.270 | 14.890 |
| 56b | 0 | 10.145 | 15.015 |
| 56c | 0 | 10.145 | 15.015 |
| 59b | +45 | 10.020 | 15.140 |
| 59c | -45 | 10.020 | 15.140 |
| 62b | 90 | 9.895 | 15.265 |
| 62c | 0 | 9.895 | 15.265 |
| 65b | -45 | 9.770 | 15.390 |
| 65c | +45 | 9.770 | 15.390 |
| 68b | 0 | 9.045 | 15.515 |
| 68c | 0 | 9.045 | 15.515 |
| 71b | +45 | 9.520 | 15.640 |
| 71c | -45 | 9.520 | 15.640 |
| 73b | 0 | 9.020 | 16.140 |
| 73c | 0 | 9.020 | 16.140 |

35. Compact by repeating steps 11, 12, 13, and 14.
36. Lay up Plies No. 21 (0°) and 22a (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
37. Lay up Plies No. 22b (0°) and 22c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
38. Lay up Ply No. 23 (-45°) per Figures II-37 and II-38 by repeating steps 4 and 5.
39. Compact by repeating steps 11, 12, 13, and 14.
40. Lay up Plies No. 24 ($+45^{\circ}$) and 25 (-45°) per Figure II-40 and Table II-XIV.
41. Lay up Ply No. 26 ($+45^{\circ}$) per Figures II-37 and II-38 by repeating step 6.
42. Wind Ply No. 27 a (90°) per Figure II-41 and Table II-XV by repeating step 17.
43. Lay up Plies No. 27b ($+45^{\circ}$) and 27c (-45°) per Figure II-42 and Table II-XVI by repeating step 9.
44. Lay up Ply No. 28 (0°) by repeating steps 7 and 8 in accordance with Figure II-3a and Table II-XIII.
45. Compact by repeating steps 11, 12, 13, and 14.
46. Lay up Ply No. 29 (0°) by repeating steps 7 and 8 in accordance with Figure II-39 and Table II-XIII.
47. Lay up Ply No. 30a ($+45^{\circ}$) in accordance with Figure II-39 and II-40 by repeating step 6.
48. Lay up Plies No. 30b (90°) and 30c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
49. Lay up Ply No. 31 (-45°) in accordance with Figures II-39 and II-40 by repeating steps 4 and 5.
50. Lay up Plies No. 32 (-45°) and 33 ($+45^{\circ}$) per Figure II-40 and Table II-XIV.
51. Compact by repeating steps 11, 12, 13, and 14.

52. Lay up Plies No. 34 (0°) and 35a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
53. Lay up Plies No. 35b (-45°) and 35c ($+45^{\circ}$) per Figure II-42 and Table II-XVI by repeating step 9.
54. Wind Ply No. 36 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.
55. Compact by repeating steps 11, 12, 13, and 14.
56. Lay up Plies No. 37 (-45°) and 38a ($+45^{\circ}$) in accordance with Figures II-37 and II-38 by repeating steps 4, 5, and 6.
57. Lay up Plies No. 38b (0°) and 38c (0°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
58. Lay up Plies No. 39 ($+45^{\circ}$) and 40 (-45°) per Figure II-40 and Table II-XIV.
59. Lay up Ply No. 41 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
60. Compact by repeating steps 11, 12, 13, and 14.
61. Lay up Ply No. 42 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
62. Lay up Ply No. 43a in accordance with Figures II-37 and KK-38 by repeating step 6.
63. Lay up Plies No. 43b ($+45^{\circ}$) and 43c (-45°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
64. Lay up Ply No. 44 (-45°) in accordance with Figure II-37 and II-38 by repeating steps 4 and 5.
65. Lay up Plies No. 45 (-45°) and 46 ($+45^{\circ}$) in accordance with Figure II-40 and Table II-XIV.
66. Compact by repeating steps 11, 12, 13, and 14.
67. Lay up Plies No. 47 (0°) and 48a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
68. Lay up Plies No. 48b (90°) and 48c (0°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.

69. Wind Ply No. 49 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.
70. Compact by repeating steps 11, 12, 13, and 14.
71. Lay up Plies No. 50 (-45°) and 51a ($+45^{\circ}$) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.
72. Lay up Plies No. 51b (-45°) and 51c ($+45^{\circ}$) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
73. Lay up Plies No. 52 ($+45^{\circ}$) and 53 (-45°) per Figure II-40 and Table II-XIV.
74. Lay up Ply No. 54 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
75. Compact by repeating steps 11, 12, 13, and 14.
76. Lay up Ply No. 55 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
77. Lay up Ply No. 56a ($+45^{\circ}$) in accordance with Figures II-37 and II-38 and step 6.
78. Lay up Plies No. 56b (0°) and 56c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
79. Lay up Ply No. 57 (-45°) in accordance with Figures II-37 and II-38.
80. Compact by repeating steps 11, 12, 13, and 14.
81. Lay up Plies No. 58 (0°) and 59a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
82. Lay up Plies No. 59b ($+45^{\circ}$) and 59c (-45°) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
83. Wind Ply No. 60 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.
84. Compact by repeating steps 11, 12, 13, and 14.
85. Lay up Plies No. 61 (-45°) and 62a ($+45^{\circ}$) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.

86. Lay up Plies No. 62b (90°) and 62c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
87. Lay up Ply No. 63 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
88. Compact by repeating steps 11, 12, 13, and 14.
89. Lay up Ply No. 64 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
90. Lay up Ply No. 65a ($+45^{\circ}$) per Figures II-37 and II-38, step 6.
91. Lay up Plies No. 65b (-45°) and 65c ($+45^{\circ}$) in accordance with Figure II-42 and Table II-XVI by repeating step 9.
92. Lay up Ply No. 66 (-45°) per Figures II-37 and II-38, steps 4 and 5.
93. Compact by repeating steps 11, 12, 13, and 14.
94. Wind Ply No. 67 (90°) in accordance with Figure II-41 and Table II-XV by repeating step 17.
95. Lay up Ply No. 68a (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
96. Lay up Plies No. 68b (0°) and 68c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
97. Lay up Ply No. 69 (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
98. Compact by repeating steps 11, 12, 13, and 14.
99. Lay up Plies No. 70 (-45°) and 71a ($+45^{\circ}$) in accordance with Figures II-37 and II-38, steps 4, 5, and 6.
100. Lay up Plies No. 71b ($+45^{\circ}$) and 71c (-45°) per Figure II-42 and Table II-XVI by repeating step 9.
101. Lay up Ply No. 72 (0°) per Figure II-39 and Table II-XIII by repeating steps 7 and 8.
102. Compact by repeating steps 11, 12, 13, and 14.

103. Lay up Ply No. 73a (0°) in accordance with Figure II-39 and Table II-XIII by repeating steps 7 and 8.
104. Lay up Plies No. 73b (0°) and 73c (0°) per Figure II-42 and Table II-XVI by repeating step 9.
105. Lay up Ply No. 74 ($+45^{\circ}$) in accordance with Figures II-37 and II-38, step 6.
106. Compact by repeating steps 11, 12, 13, and 14.
107. Lay up Ply No. 75 (-45°) in accordance with Figures II-37 and II-38, steps 4 and 5.
108. Lay up Plies No. 76 (-45°); 77 ($+45^{\circ}$); 78 ($+45^{\circ}$), 79 (-45°) per Figure II-40 and Table II-XIV.
109. Compact by placing Machburg cloth over patch area and overwind with glass roving while applying heat from heat gun. Allow to cool to room temperature before removing compaction material.
110. Lay up Plies No. 80 (-45°); 81 ($+45^{\circ}$); 82 ($+45^{\circ}$); 83 (-45°); 84 (-45°); 85 ($+45^{\circ}$); 86 ($+45^{\circ}$); 87 (-45°); 88 (-45°); 89 ($+45^{\circ}$); 90 ($+45^{\circ}$); 91 (-45°) in accordance with Figure II-40 and Table II-XIV.
111. Compact by repeating step 109.
112. Lay up Plies No. 92 (-45°); 93 ($+45^{\circ}$); 94 ($+45^{\circ}$); 95 (-45°); 96 (-45°); 97 ($+45^{\circ}$); 98 ($+45^{\circ}$); 99 (-45°); 100 (-45°); 101 ($+45^{\circ}$); 102 ($+45^{\circ}$); 103 (-45°) in accordance with Figure II-40 and Table II-XIV.
113. Compact by repeating step 109.
114. Lay up Plies No. 104 (-45°); 105 ($+45^{\circ}$); 106 ($+45^{\circ}$); 107 (-45°); 108 (-45°); 109 ($+45^{\circ}$); 110 ($+45^{\circ}$); 111 (-45°); 112 (-45°); 113 ($+45^{\circ}$); in accordance with Figure II-40 and Table II-XIV.
115. Compact by repeating step 109.
116. Lay up Plies No. 114 ($+45^{\circ}$); 115 (-45°); 116 (-45°); 117 ($+45^{\circ}$); 118 ($+45^{\circ}$); 119 (-45°); 120 (-45°); 121 ($+45^{\circ}$); in accordance with Figure II-40 and Table II-XIV.

117. Compact as follows: Apply porous scrim cloth over entire layup and cover with one ply of Machburg cloth; fix thermocouple onto prepreg; install vacuum bag; place in vacuum bag and position in autoclave; apply vacuum and pressure; heat part to $250^{\circ} \pm 15^{\circ}$ F; cool part to room temperature before releasing vacuum and pressure.

118. Repeat step 14.

B. Final Cure

1. Cover entire layup with porous scrim.
2. Apply double-faced tape to sloped areas of layup.
3. Wind compacting material over entire layup.
4. Apply thermocouple and install vacuum line.
5. Install in vacuum bag and check for leaks.
6. Place in autoclave.
7. The cure cycle is as follows:
 - a. Hold vacuum throughout cycle.
 - b. Apply 100 psi pressure initially.
 - c. Raise temperature 3° F/minute to 250° F.
 - d. Hold at 250° F for one hour.
 - e. Raise temperature at 3° F/minute to 300° F.
 - f. Hold at 300° F for 30 minutes.
 - g. Raise temperature at 3° F/minute to 350° F.
 - h. Hold for 2 hours at 350° F and 100 psi.
 - i. Cool down to 150° F while maintaining pressure and vacuum.
 - j. Remove from autoclave at 150° F or below.
 - k. Remove cure materials and equipment.

C. Machining

1. Machine in accordance with drawing (CJA37B10, Rev D).

END

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