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MAU-12A/A BOMB EJECTOR RACK

STRESS ANALYSIS

Final Report

Prepared by

D. E. O'Bannon

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Research and Technology Division
AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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Research and Technology Division
Air Force Systems Command
AIR FORCE WEAPONS LABORATORY
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New Mexico

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ABSTRACT

This report contains detail loads and stress analyses showing that the MAU-12A/A Bomb Ejector Rack is adequate for external carriage of stores on US Air Force aircraft. It was determined that carrying a 20-inch-diameter store on the 30-inch shackles produces the largest stress in the components of the rack. Therefore, these conditions were used exclusively in the analysis.

The load conditions for the 14-inch shackles were investigated to ensure that no critical local stress problems are produced. Determination of the allowable ultimate vertical load for these shackles is included.

Stress analyses are presented for critical conditions of each component.

PUBLICATION REVIEW

RAYMOND J. SWAIM
Major USAF
Project Officer

LUTHER C. COX
Lt Colonel USAF
Chief, Components Development Branch

R. A. HOUSE
Colonel USAF
Chief, Development Division

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60C46538	Clevis, Guide, Over-Center Spring
60C46540	Trunnion, Clevis
60C46541	Bellcrank, Inflight, Safety Lock
63C14370	Rod, Shackle Actuating, Forward
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60D46528	Shackle, 30-inch Spacing
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63J14363	Shackle, 14-inch Spacing
63D14369	Fitting, Drag, Vertical, Assembly of

SUMMARY OF MINIMUM MARGINS OF SAFETY

Part	Refer to page	Critical section	Type stress or loading	M.S.
Side plate	39	Section A-A	Bending and tension	+0.05
Swaybrace	41	Section D-D	Bending	+0.09
Swaybrace	42	Section E-E	Bending	+0.02 (Yield)
Swaybrace	43	Section F-F	Bending	+0.09 (Yield)
Swaybrace (Cylinder block)	44	Section G-G	Bending and compression	+0.07
Swaybrace (Cylinder block)	45	Aircraft attachment	Shear Bearing	+0.02 +0.22
Forward 30" shackle	49	Section A-A	Bending	+0.13
Forward 30" shackle	53	Section D-D	Bending, tension and shear	+0.11
Aft 30" shackle	54	Section A-A	Bending	+0.28
Aft 30" shackle	55	Section B-B	Bending	+0.24
Aft 30" shackle	57	Section D-D	Bending, tension and shear	+0.10
Forward link connector	59	Section A-A	Bearing	+1.89
Forward 14" shackle	61	Section B-B	Shear and bending	+0.10
Forward 14" shackle	62	Section C-C	Bending and compression	+0.15
Aft 14" shackle	65	Section B-B	Bending	+0.40
Aft 14" shackle	66	Section C-C	Bending and compression	+0.46
Forward actuating rod	68	Section A-A	Compression	+0.67
Forward actuating rod	69	Section B-B (Connecting pin)	Bending	+0.11
Center bellcrank	71	Section A-A	Bending and shear	+0.23
Center bellcrank	72	Lug analysis	Shear	+0.10
Safety lock bellcrank	76	Section B-B	Bending	+0.13
Clevis trunnion	80	Section A-A	Bending and shear	+0.85
Aft actuating rod	82	Section B-B	Compression and bending	+0.43

SUMMARY OF MINIMUM MARGINS OF SAFETY (cont'd)

Part	Refer to page	Critical section	Type stress or loading	M.S.
Vertical drag fitting	85	Side plate fastener	Shear	+0.01
Vertical drag fitting	86	Side plate attachment	Shear-out	+0.10
Breech	89	Section A-A	Tension	+0.01*
Slave piston	90		Compression	+0.32*
Slave piston plug	90	Thread area	Shear	+1.84*
Cartridge body retainer	91	Section B-B	Tension	+0.32*
Cartridge body retainer	91	"O" ring groove	Compression	+0.15*
Cartridge retainer cap	92	Thread area	Shear	+0.52*
Cartridge retainer cap	93	Section B-B	Shear	+0.32*
Tee gas tube	94	Section A-A	Tension	+0.42*
Tee gas tube	95	Section C-C	Tension	+0.06*
Gas tube	95		Tension	+0.14*
Tee gas tube	96	Side plate attachment	Shear	+0.06*

*The ultimate factor of safety is 2.5 times the gas pressure limit load for all Ballistic System components. Ultimate factor of safety of 1.5 times limit loads is used for all other components.

1. INTRODUCTION

This report presents the load and stress analysis of the MAU-12A/A Bomb Ejector Rack in accordance with the requirements listed in paragraph 3.7 of MIL-A-8868. Stress analyses are presented for critical conditions of each component.

The design for the bomb ejector rack was determined by loading conditions No. 2 and No. 6, shown in table 3, which produce the most critical local loads in the structural parts of the bomb rack.

Unless specifically noted, all loads, load factors, and allowables shown are ultimate values.* Included in the report is a Summary of Minimum Margins of Safety above ultimate values.

Since forces and moments presented refer to left- hand, wing-mounted store installations, all loads and stress analyses in this report also pertain to left-hand assemblies with right-hand values opposite, unless otherwise specifically noted.

2. STRUCTURAL DESCRIPTION

The MAU-12A/A Bomb Ejector Rack has been designed to function as a structural support and release mechanism for external carriage of stores on US Air Force aircraft. The rack is basically a ballistic-gas actuated mechanism which is enclosed by a structural body composed of side plates and close-out channels. The major gas system components (i.e., breech and piston blocks) also serve as primary structural members.

Within the housing, two sets of shackles are provided; one set on 30-inch spacing and the other on 14-inch spacing. The 30-inch and 14-inch shackles are designed so the drag load (longitudinal) applied to the store will be reacted by the end drag fitting or the provided section of the cylinder block respectively. The 30-inch shackles and 14-inch shackles are connected by compression links. From the shackles, load is transmitted through the compressing links to a central bellcrank. The link loads on the bellcrank are overcenter, producing an unbalanced moment on the bellcrank. This unbalanced moment is reacted

*The ultimate factor of safety is 1.5 times the limit load for all components except those in the gas system. The ultimate factor of safety for those components is 2.5.

by a tension link. Under normal conditions, a down load on the shackles tends to keep the linkage closed.

A breech block is provided which holds two ARD 446-1 cartridges. These cartridges fire, when subjected to a dc potential of 24 volts, furnishing a high-pressure gas source. Each cartridge is provided with a separate firing circuit. Should one cartridge fail to receive firing current, the other cartridge is capable of igniting it sympathetically.

From the breech, the high-pressure gas is used in two ways: (a) a small slave piston is actuated which contacts a striker block attached to the main bellcrank; this piston force produces sufficient moment to overcome the existing closing moment due to the link loads, thus opening the linkage; (b) The main portion of the gas is piped through a tee-shaped tube to the forward and aft cylinder block where the gas is then utilized to drive the ejection pistons down on the store. After the pistons have extended through their full stroke, trapped, high-pressure gas is used to return the pistons to their normal positions.

The rack is capable of varying thrust output to the ejection pistons by orificing the gas flow. Orificing is accomplished by the proper positioning of a slide containing two through-drilled holes. Two slides are located in the gas system, one each between the ends of the tee tube and the cylinder blocks. Through the use of these orifices, the peak thrust may be varied.

The rack design also includes an in-flight lock system which is composed primarily of a solenoid, locking pawl (bellcrank), and three rotary switches. The pawl is spring-loaded to the normally closed position and is actuated by an electrical impulse delivered to the solenoid.

3 LOAD ANALYSIS

a. Applied loads and store reactions

The loads and moments in table 1 which are used in this analysis are derived from data presented in MIL-A-8591. The moments and forces are reacted at the 30-inch spacing shackles and the 20-inch spacing swaybraces of the bomb rack. The reactions of the shackles and swaybraces are based upon the method of load distribution shown in MIL-A-8591 except for the

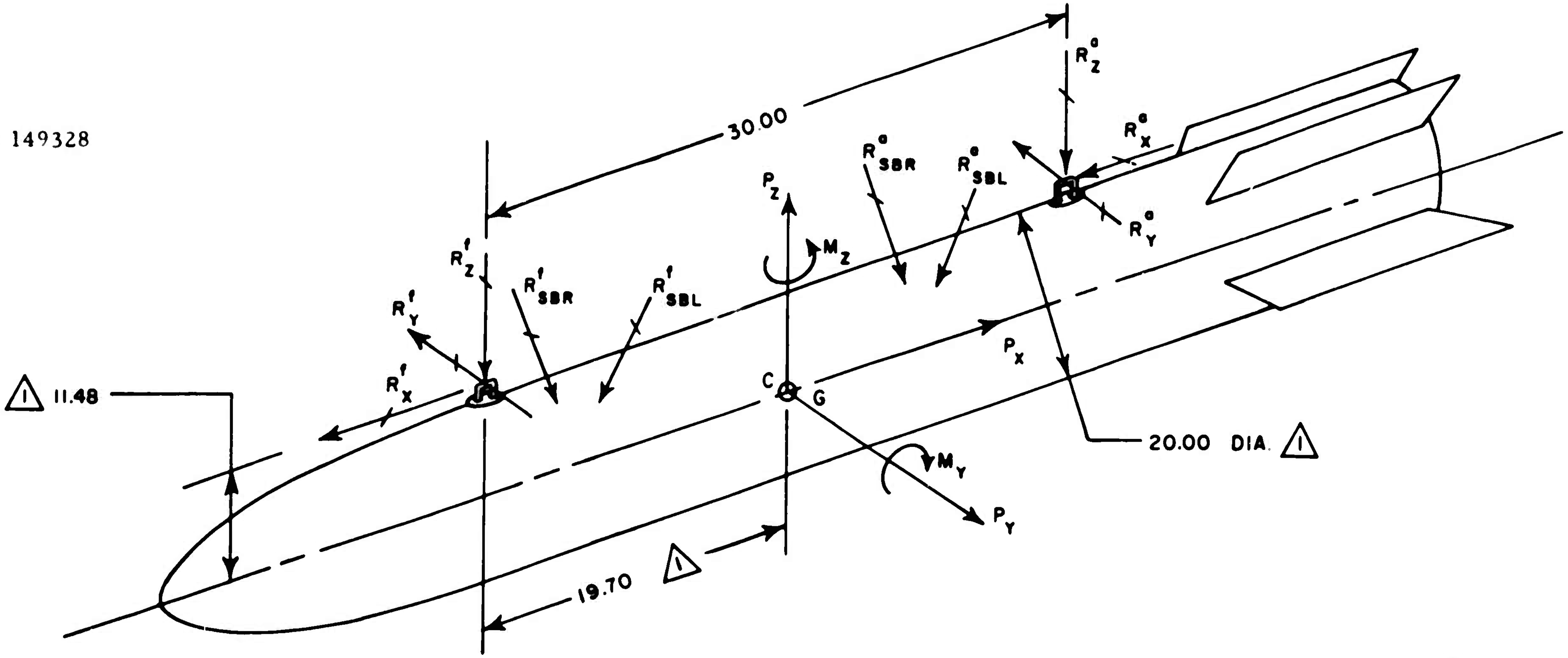
Table 1

APPLIED LOADS AND STORE REACTIONS (ULTIMATE)

Applied and reacting loads are shown in pounds. Moments are shown in inch-pounds.

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮
Condition	P_x	P_y	P_z	M_y	M_z	R^f_x	R^f_y	R^f_z	R^f_{SBL}	R^f_{SBR}	R^a_x	R^a_y	R^a_z	R^a_{SBL}	R^a_{SBR}
	← Ult loads applied at C. G. of the store →					← Reactions at the store lugs and swaybrace contact points →									
	lb	lb	lb	in-lb	in-lb	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb
1	1,440	3,400	-16,460	-194,000	410,600	0	8,212	30,935	21,500	0	1,440	-8,212	17,198	0	13,460
2	290	7,030	-16,200	-31,700	-451,800	0	-9,036	24,651	0	17,000	290	9,036	35,782	33,600	0
3	1,330	4,810	-17,900	-133,300	355,500	0	7,110	27,293	19,820	0	1,330	-7,110	16,141	0	8,450
4	1,330	3,360	-17,900	-133,300	453,800	0	9,076	31,244	23,600	0	1,330	-9,076	22,132	0	15,600
5	3,000	2,450	-18,900	-321,000	347,000	0	6,940	33,727	17,970	0	3,000	-6,940	12,432	0	12,150
6	3,000	26,900	-18,900	-321,000	267,000	0	5,340	45,744	29,500	0	3,000	-5,340	30,833	34,200	0
7	15,000	4,500	-9,000	0	0	0	0	12,148	2,840	0	15,000	0	6,492	7,850	0
8	-15,000	6,750	450	0	0	-15,000	0	0	4,395	155	0	0	15,120	11,750	0

Note ⚠1: Ref Sandia Corp Dwg No. 149328



reactions caused by the yawing moment distribution. In this analysis, 60 percent of the yawing moment applied at the C. G. of the store is assumed to be reacted by a couple at the 30-inch shackles, and 40 percent of the yawing moment is reacted by the swaybraces. This assumption is based upon empirical data obtained from static load tests conducted at the Sandia Corporation, Albuquerque, New Mexico. Thirty-three tests conducted on the MAU-12A/A Bomb Rack verifys the percentage of the yawing moment reacted by the swaybraces.

b. Aircraft attachment reactions

The calculated loads at the forward and aft shackles and swaybraces of the bomb rack (table 1) are reacted at the forward and aft aircraft attachment points. Calculations for the aircraft attachment reactions are based upon the following assumptions:

(1) Vertical and lateral reactions

The bomb rack is assumed equivalent to a simply supported beam.

(2) Longitudinal reactions

The longitudinal load applied in the aft direction is assumed to be reacted entirely at the aft aircraft attachment point, and when applied in the forward direction is assumed to be reacted entirely at the forward aircraft attachment point.

(3) Rolling moment reaction

The reacting rolling moments are due to the side loads applied to the shackles and loads applied to the swaybraces. Since the swaybrace is an integral of the part attached to the aircraft, the forward reacting rolling moment is assumed to be due to the loads applied to the forward shackle and swaybrace. The same assumption is used for the aft reacting rolling moment.

Sign convention, geometry, and general equations for calculation of aircraft attachment reactions are shown in figure 1 and on pages 9 and 10. Table 2 contains actual calculations of aircraft attachment reactions.

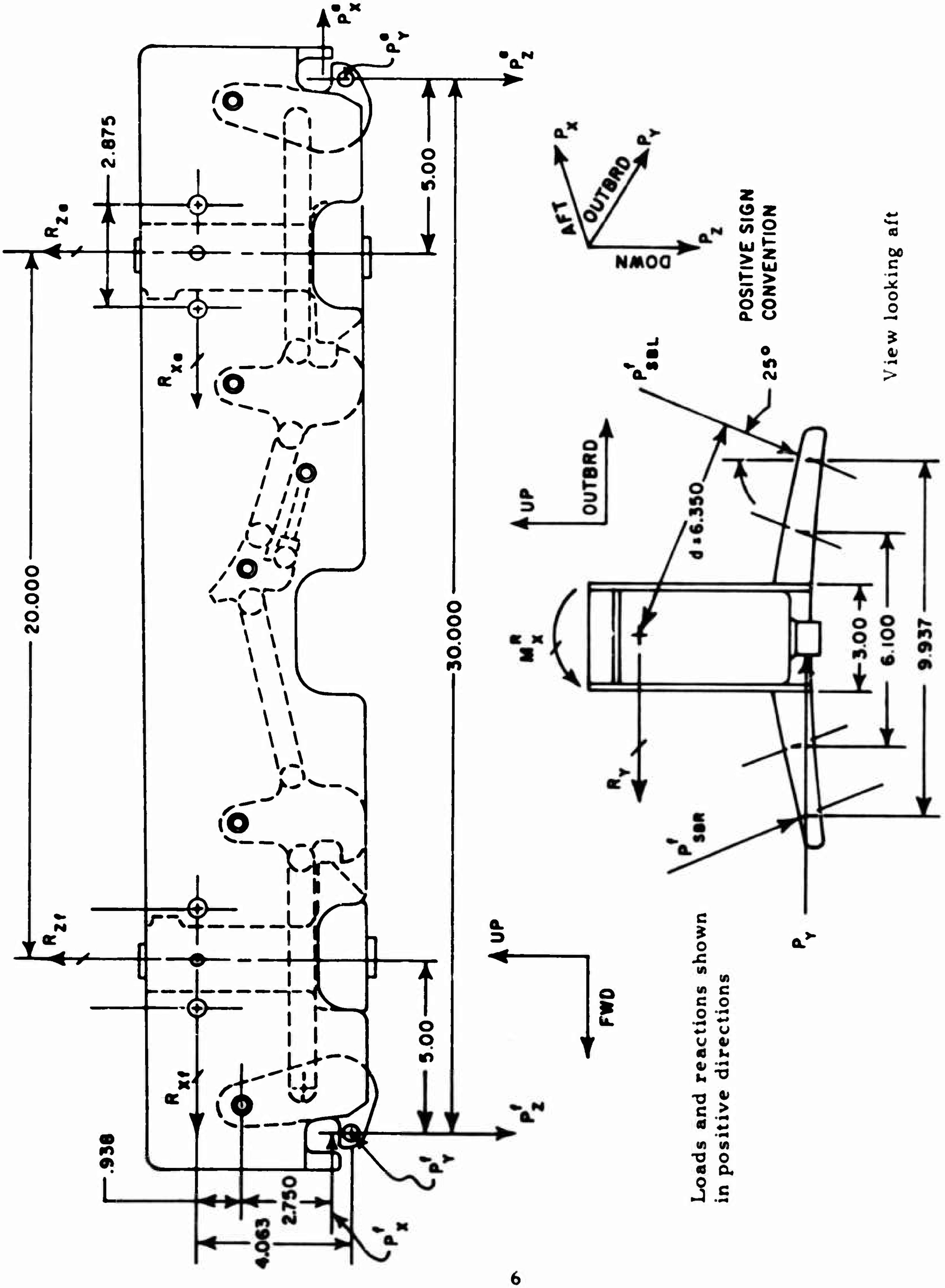


Figure 1. Sign convention geometry - aircraft attachment reactions

Table 2

CALCULATION OF AIRCRAFT ATTACHMENT

Applied and reacting loads are shown in pounds. M

NOTES: 1 For constants, reference figure 1 and g

2 For loads source, reference page 3

Condition	(1) P_x^f	(2) P_y^f	(3) P_z^f	(4) P_{SBL}^f	(5) P_{SBR}^f	(6) P_x^a	(7) P_y^a [2]	(8) P_z^a	(9) P_{SBL}^a
	← Ult loads applied at rack shackles and swaybraces								
1	0	8,212	30,935	-21,500	0	1,440	-8,212	17,198	0
2	0	-9,036	24,651	0	-17,000	290	9,036	35,782	-33,60
3	0	7,110	27,293	-19,820	0	1,330	-7,110	16,141	0
4	0	9,076	31,244	-23,600	0	1,330	-9,076	22,132	0
5	0	6,940	33,727	-17,970	0	3,000	-6,940	12,432	0
6	0	5,340	45,744	-29,500	0	3,000	-5,340	30,833	-34,20
7	0	0	12,148	-2,840	0	15,000	0	6,492	-7,85
8	-15,000	0	0	-4,395	-155	0	0	15,120	-11,75

Condition	(19) $\frac{(P_{SBR}^a - P_{SBL}^a)}{x(0.423)}$	(20) $4.063\ P_y^f$	(21) $\frac{(P_{SBR}^f - P_{SBL}^f)}{x(6.350)}$	(22) $4.063\ P_y^a$	(23) $\frac{(P_{SBR}^a - P_{SBL}^a)}{x(6.350)}$	(24) $0.25\ P_y^f$	(25) $1.25\ P_y^f$	(26) $0.25\ P_y^a$	(27) $1.25\ P_y^a$
	(0.423) [(10) (9)]	4.063 (2)	6.35 [(5) (4)]	4.063 (7)	6.35 [(10) (9)]	0.25 (2)	1.25 (2)	0.25 (7)	1.25 (7
1	-5,694	33,365	136,525	-33,365	-85,471	2,053	10,265	-2,053	-10,26
2	14,213	-36,713	-107,950	36,713	213,360	-2,259	-11,295	2,259	11,29
3	-3,574	28,888	125,857	-28,888	-53,657	1,777	8,887	-1,777	-8,88
4	-6,599	36,876	149,860	-36,876	-99,060	2,269	11,345	-2,269	-11,34
5	-5,139	28,197	114,109	-28,197	-77,152	1,735	8,675	-1,735	-8,67
6	14,467	21,696	187,325	-21,696	217,170	1,335	6,675	-1,335	-6,67
7	3,321	0	18,034	0	49,847	0	0	0	0
8	4,970	0	26,924	0	74,612	0	0	0	0

Table 2

CALCULATION OF AIRCRAFT ATTACHMENT REACTIONS (ULTIMATE)

pplied and reacting loads are shown in pounds. Moments are shown in inch-pounds.

TES: 1 For constants, reference figure 1 and general equations, pages 9 and 10

2 For loads source, reference page 3

(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
P^a_y	P^a_z	P^a_{SBL}	P^a_{SBR}	$1.25\,P^f_z$	$0.184(P^f_x+P^a_x)$	$(P^f_{SBR}+P^f_{SBL})$ x(0.906)	$0.25\,P^a_z$	$1.25\,P^a_z$	$(P^a_{SBR}+P^a_{SBL})$ x(0.906)
es (2) →				1.25 (3)	0.184[(1)+(6)]	0.906[(5)+(4)]	0.25 (8)	1.25 (8)	0.906[(10)+(9)]
-8,212	17,198	0	-13,460	38,669	265	-19,479	4,299	21,497	-12,195
9,036	35,782	-33,600	0	30,814	53	-15,402	8,945	44,727	-30,442
-7,110	16,141	0	-8,450	34,116	245	-17,957	4,035	20,176	-7,656
-9,076	22,132	0	-15,600	39,055	245	-21,382	5,533	27,665	-14,134
-6,940	12,432	0	-12,150	42,159	552	-16,281	3,108	15,540	-11,008
-5,340	30,833	-34,200	0	57,180	552	-26,727	7,708	38,541	-30,985
0	6,492	-7,850	0	15,185	2,760	-2,573	1,623	8,115	-7,112
0	15,120	-11,750	0	0	-2,760	-3,982	3,780	18,900	-10,645

(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
$1.25\,P^f_y$	$0.25\,P^a_y$	$1.25\,P^a_y$	R_{xf}	R_{yf}	R_{zf}	M_{xf}	R_{xa}	R_{ya}	R_{za}
			← Reactions at aircraft attachment points						
1.25 (2)	0.25 (7)	1.25 (7)	(1)	(25) - (26) + (18)	(11) + (12) + (13) - (14)	- (20) - (21)	(6)	(19) - (24) + (27)	(15) + (16) (12) - (17)
10,265	-2,053	-10,265	0	21,412	15,156	-169,890	1,440	-18,012	1,303
-11,295	2,259	11,295	0	-20,745	6,520	144,663	290	27,767	8,069
8,887	-1,777	-8,887	0	19.048	12,369	-154,745	1,330	-14,238	5,452
11,345	-2,269	-11,345	0	23,597	12,385	-186,736	1,330	-20,213	5,475
8,675	-1,735	-8,675	0	18,011	23,322	-142,306	3,000	-15,549	-4,452
6,675	-1,335	-6,675	0	20,488	23,297	-209,021	3,000	6,457	-4,432
0	0	0	0	1,201	13,749	-18,034	15,000	3,321	-4,794
0	0	0	-15,000	1,794	-10,522	-26,924	0	4,970	11,015

C

able 2

TACHMENT REACTIONS (ULTIMATE)

pounds. Moments are shown in inch-pounds.

ure 1 and general equations, pages 9 and 10

page 3

(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
P^a_{SBL}	P^a_{SBR}	$1.25\ P^f_z$	$0.184(P^f_x + P^a_x)$	$(P^f_{SBR} + P^f_{SBL})$ x(0.906)	$0.25\ P^a_z$	$1.25\ P^a_z$	$(P^a_{SBR} + P^a_{SBL})$ x(0.906)	$0.25\ P^f_z$	$(P^f_{SBR} - P^f_{SBL})$ (0.423)
		1.25 (3)	0.184[(1)+(6)]	0.906[(5)+(4)]	0.25 (8)	1.25 (8)	0.906[(10)+(9)]	0.25 (3)	(0.423)[(5)-(4)]
0	-13,460	38,669	265	-19,479	4,299	21,497	-12,195	7,734	9,094
-33,600	0	30,814	53	-15,402	8,945	44,727	-30,442	6,163	-7,191
0	-8,450	34,116	245	-17,957	4,035	20,176	-7,656	6,823	8,384
0	-15,600	39,055	245	-21,382	5,533	27,665	-14,134	7,811	9,983
0	-12,150	42,159	552	-16,281	3,108	15,540	-11,008	8,432	7,601
- 34,200	0	57,180	552	-26,727	7,708	38,541	-30,985	11,436	12,478
-7,850	0	15,185	2,760	-2,573	1,623	8,115	-7,112	3,037	1,201
-11,750	0	0	-2,760	-3,982	3,780	18,900	-10,645	0	1,794

Reactions at aircraft attachment points: (28) through (35)

(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)
$1.25\ P^a_y$	R_{xf}	R_{yf}	R_{zf}	M_{xf}	R_{xa}	R_{ya}	R_{za}	M_{xa}	
1.25 (7)	(1)	(25) - (26) + (18)	(11) + (12) + (13) - (14)	- (20) - (21)	(6)	(19) - (24) + (27)	(15) + (16) - (12) - (17)	- (22) - (23)	
-10,265	0	21,412	15,156	-169,890	1,440	-18,012	1,303	118,836	
11,295	0	-20,745	6,520	144,663	290	27,767	8,069	-250,073	
-8,887	0	19.048	12,369	-154,745	1,330	-14,238	5,452	82,545	
-11,345	0	23,597	12,385	-186,736	1,330	-20,213	5,475	135,936	
-8,675	0	18,011	23,322	-142,306	3,000	-15,549	-4,452	105,349	
-6,675	0	20,488	23,297	-209,021	3,000	6,457	-4,432	-195,474	
0	0	1,201	13,749	-18,034	15,000	3,321	-4,794	-49,847	
0	-15,000	1,794	-10,522	-26,924	0	4,970	11,015	-74,612	

AIRCRAFT ATTACHMENT REACTIONS

General Equations for Reactions

Vertical Reactions

$$P_z^f(25)+\left(P_x^f+P_x^a\right)(3.688)+\left(P_{SBR}^f+P_{SBL}^f\right)\cos 25^\circ(20)-P_z^a(5)-R_{zf}(20)=0$$

$$R_{zf}=1.25\,P_z^f+0.184\left(P_x^f+P_x^a\right)+0.906\left(P_{SBR}^f+P_{SBL}^f\right)-0.25\,P_z^a$$

$$P_z^a(25)-\left(P_x^f+P_z^a\right)(3.688)-P_z^f(5)+\left(P_{SBR}^a+P_{SBL}^a\right)\cos 25^\circ(20)-R_{za}(20)=0$$

$$R_{za}=1.25\,P_z^a-0.184\left(P_x^f+P_x^a\right)+0.906\left(P_{SBR}^a+P_{SBL}^a\right)-0.25\,P_z^f$$

Longitudinal Reactions

$$R_{xf}=P_x^f$$

$$R_{xa}=P_x^a$$

Lateral Reactions

$$P_y^f(25)+20\sin 25^\circ P_{SBR}^f-20\sin 25^\circ P_{SBL}^f-P_y^a(5)-R_{yf}(20)=0$$

$$R_{yf}=1.25\,P_y^f+0.423\left[P_{SBR}^f-P_{SBL}^f\right]-0.25\,P_y^a$$

$$P_y^a(25)+20\sin 25^\circ P_{SBR}^a-20\sin 25^\circ P_{SBL}^a-P_y^f(5)-R_{ya}(20)=0$$

$$R_{ya}=1.25\,P_y^a+0.423\left[P_{SBR}^a-P_{SBL}^a\right]-0.25\,P_y^f$$

(See figure 1 for dimensions and sign convention)

Rolling Moment Reactions

The reacting rolling moments are due to the sideloads applied to the 30-inch shackles and the swaybraces. Since the swaybrace is an integral of the part attached to the aircraft, the forward reacting rolling moment is assumed to be due to the loads applied to the forward shackle and swaybrace. The same assumption is used for the aft reacting rolling moment.

$$M_x^f + P_y^f(4.063) + \left(P_{SBR}^f - P_{SBL}^f\right)(6.350) = 0$$

$$M_x^f = -P_y^f(4.063) - \left(P_{SBR}^f - P_{SBL}^f\right)(6.350)$$

$$M_x^a + P_y^a(4.063) + \left(P_{SBR}^a - P_{SBL}^a\right)(6.350) = 0$$

$$M_x^a = -P_y^a(4.063) - \left(P_{SBR}^a - P_{SBL}^a\right)(6.350)$$

c. Linkage mechanism reactions

Loads and moments calculated for the linkage mechanism reactions are the vertical and side loads transmitted from the shackles to the central bellcrank. The longitudinal (drag) load is reacted by the end drag fitting (reference Structural Description, page 1).

Sign conventions, geometry, and general equations for calculation of the linkage mechanism reactions are shown in figure 2 and pages 13 through 24. Table 3 contains actual calculations for these reactions.

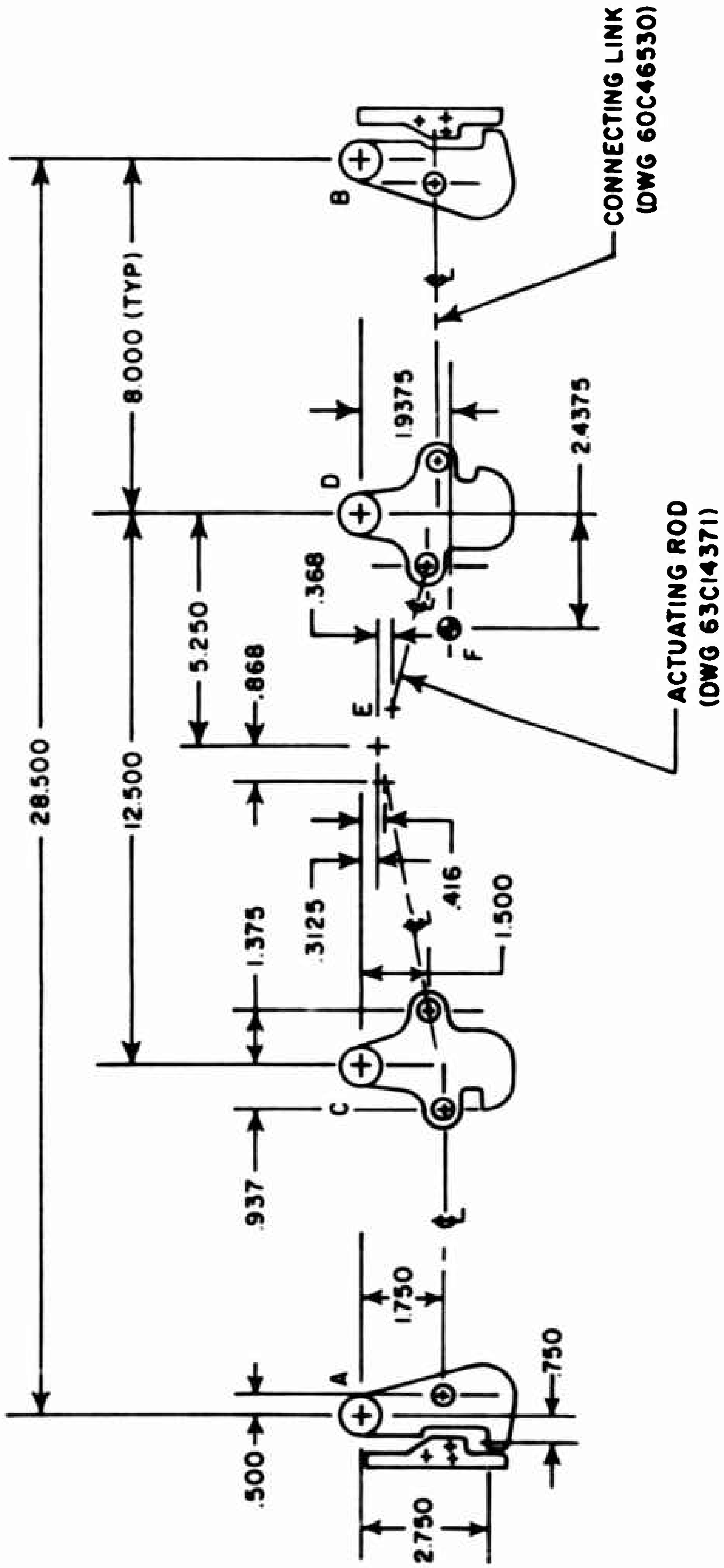
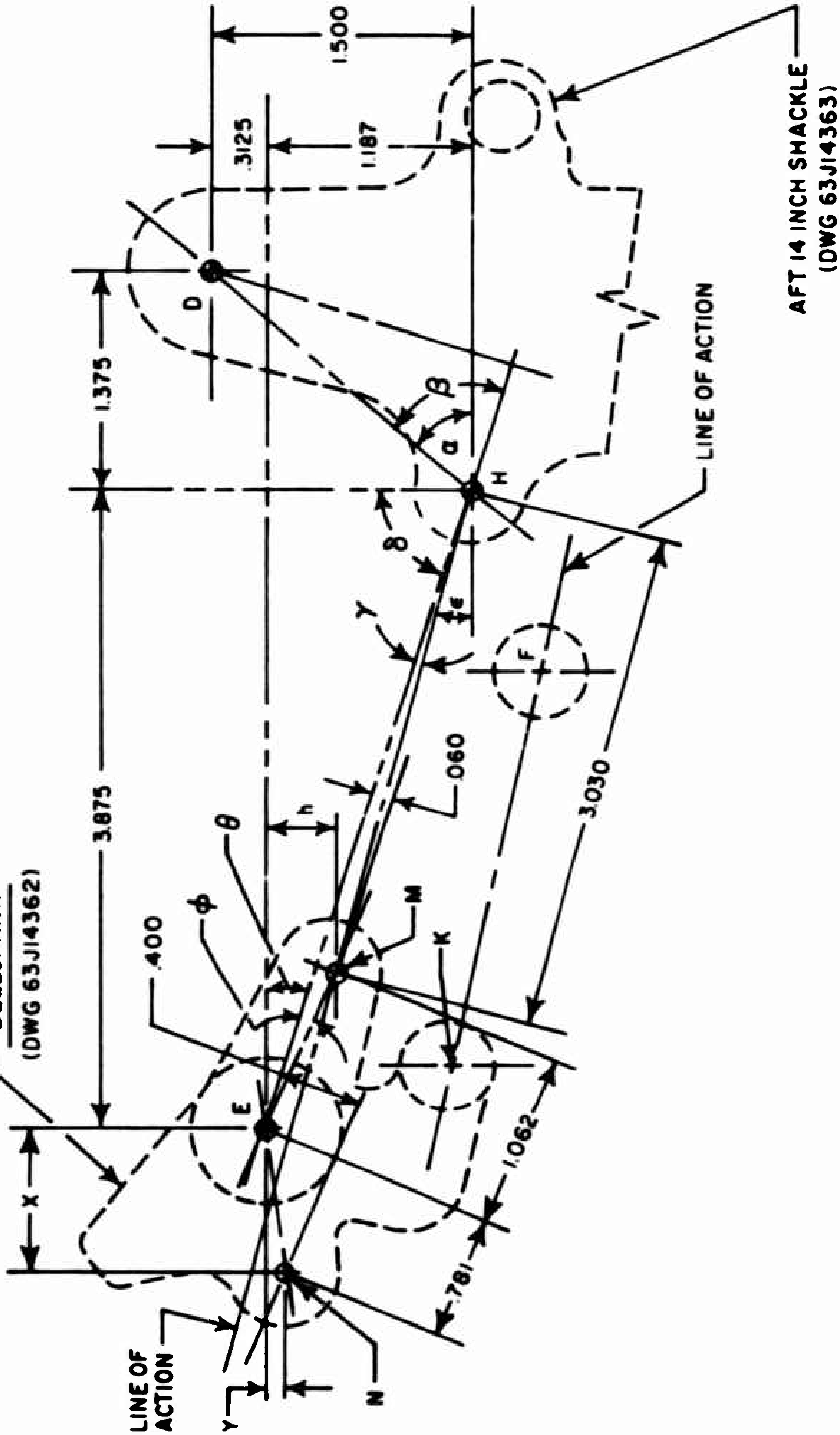


Figure 2. Linkage mechanism geometry



1.500
.3125
1.187
AFT 14 INCH SHACKLE
(DWG 63J14363)
LINE OF ACTION
1.375
3.875
3.030
.060
BELLCRANK
(DWG 63J14362)
.400
1.062
.781
LINE OF ACTION
D
H
E
M
K
F
N
X
Y
h

DIMENSION CALCULATIONS

(Reference page 13)

$$\tan\theta = \frac{1.187}{3.875}$$

$$\theta = \tan^{-1} 0.3063 = 17.04^\circ$$

$$\sin\varphi = \frac{0.060}{1.062} = 0.0565$$

$$\varphi = \sin^{-1} 0.0565 = 3.24^\circ$$

$$\delta = 90^\circ - \theta = 90 - 17.04$$

$$\delta = 72.96^\circ$$

$$\sin\gamma = \frac{0.060}{3.030} = 0.0198$$

$$\gamma = \sin^{-1} 0.0198 = 1.264^\circ$$

$$\tan\alpha = \frac{1.500}{1.375} = 1.090$$

$$\alpha = \tan^{-1} 1.090 = 47.48^\circ$$

$$\beta = \alpha + \theta - \gamma$$

$$= 47.48 + 17.04 - 1.26$$

$$\beta = 63.26^\circ$$

$$\varepsilon = \theta - \gamma$$

$$= 17.04 - 1.26 = 15.78^\circ$$

Distance -- X and Y:

$$\tan\omega = \frac{0.781}{0.400} = 1.952$$

$$\omega = \tan^{-1} 1.952 = 62.89$$

$$\theta' = 90 - [\varphi + \theta] - \omega$$

$$= 90 - [3.24 + 17.04] - 62.89$$

$$\theta' = 6.83^\circ$$

$$\overline{EN} = \sqrt{(0.781)^2 + (0.400)^2} = 0.878 \text{ in.}$$

$$\sin\theta' = \frac{Y}{\overline{EN}}$$

$$Y = \overline{EN} \sin\theta' = (0.878)(0.1189)$$

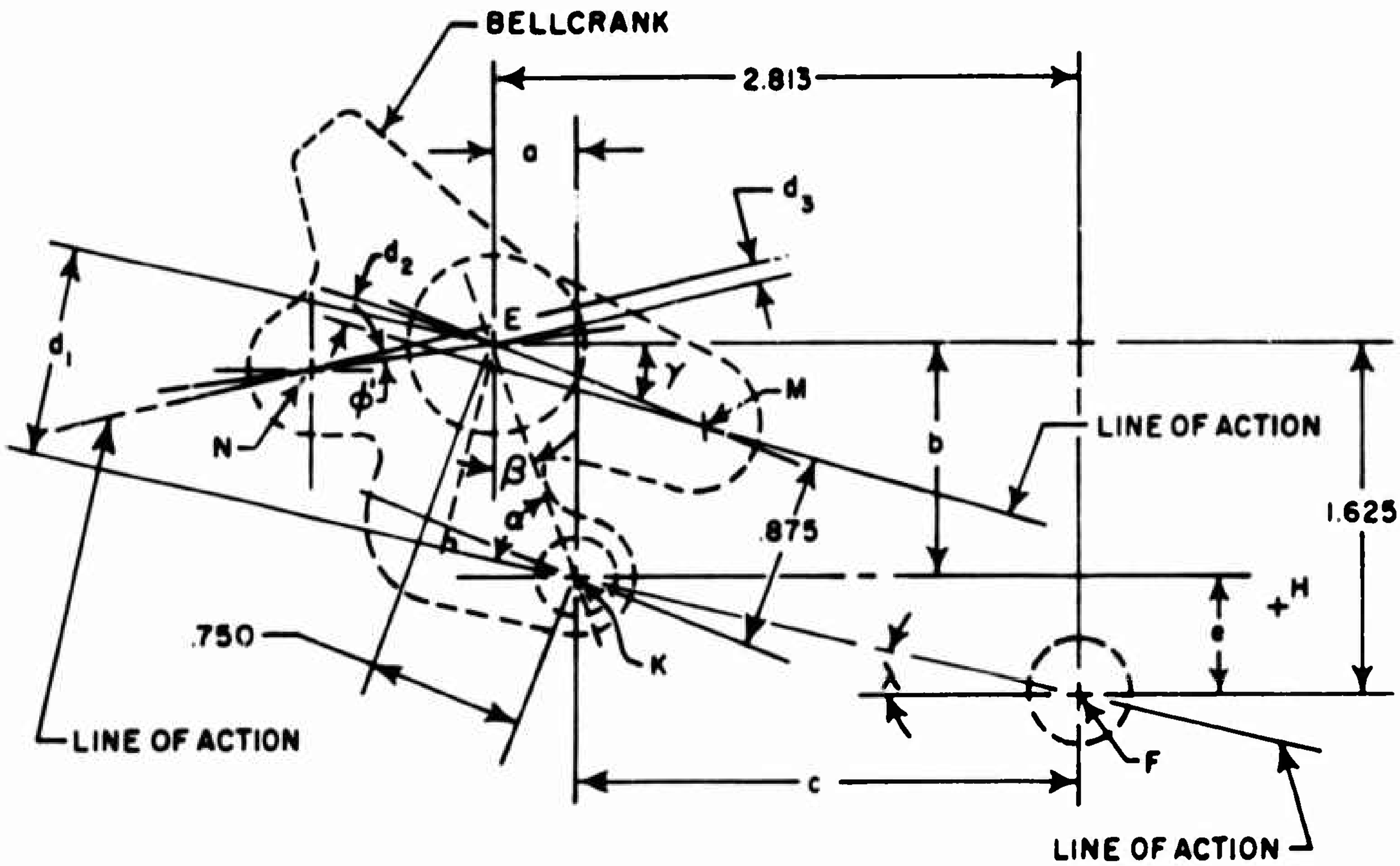
$$Y = 0.104 \text{ in.}$$

$$\tan\theta' = \frac{Y}{X}$$

$$X = \frac{0.104}{0.1198} = 0.868 \text{ in.}$$

$$\sin(\varphi + \theta) = \frac{h}{1.062}$$

$$h = 1.062(\sin 20.28) = 0.368 \text{ in.}$$



⊥ DISTANCE TO LINE OF ACTION FROM POINT E

$$\overline{EK} = \sqrt{(0.750)^2 + (0.875)^2} = 1.153 \text{ in.}$$

$$\gamma = \varphi + \theta = 3.24 + 17.04 = 20.28^\circ$$ (Reference page 14)

$$\tan \varepsilon = \frac{0.750}{0.875} = 0.857$$

$$\varepsilon = \tan^{-1} 0.857 = 40.60^\circ$$

$$\beta = \varepsilon - \gamma = 40.60 - 20.28 = 20.32^\circ$$

$$\sin \beta = \frac{a}{\overline{EK}}$$

$$a = (1.153)(0.347) = 0.400 \text{ in.}$$

$$\cos \beta = \frac{b}{\overline{EK}}$$

$$b = (1.153)(0.938) = 1.082 \text{ in.}$$

$$c = 2.813 - a = 2.813 - 0.400$$

$$c = 2.413 \text{ in.}$$

$$e = 1.625 - b = 1.625 - 1.082$$

$$e = 0.543$$

$$\tan \lambda = \frac{0.543}{2.413} = 0.225$$

$$\lambda = \tan^{-1} 0.225 = 12.68^\circ$$

⊥ DISTANCE TO LINE OF ACTION FROM POINT E

(Reference page 15)

$$\sin \alpha = \frac{d_1}{\overline{EK}}$$

$\alpha = 90 - [\beta + \lambda] = 90 - [20.32 + 12.68]$ (Reference page 15)

$\alpha = 90.00 - 33.00 = 57.00^\circ$

$d_1 = \overline{EK} \sin 57^\circ = (1.153)(0.838) = 0.968$ in.

$\overline{EH} = \sqrt{(3.875)^2 + (1.187)^2} = 4.05$ in. (Reference page 13)

$\sin \gamma = \dfrac{d_2}{\overline{EH}}$ $\gamma = 1.264^\circ$ (Reference pages 13 & 14)

$d_2 = \overline{EH} \sin 1.264^\circ = (4.05)(0.0198) = 0.080$ in.

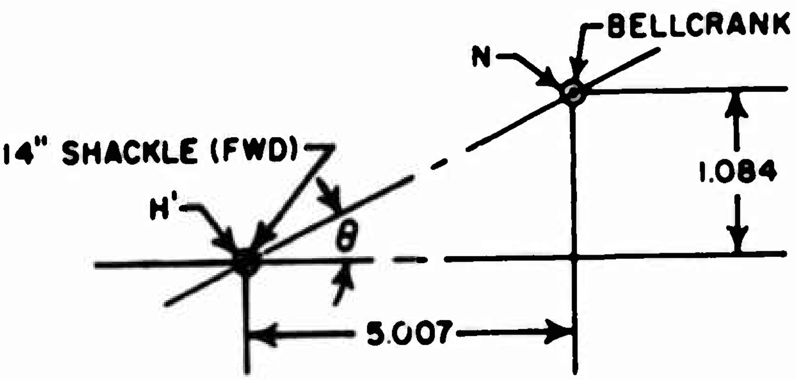
$\tan \theta = \dfrac{1.084}{5.007} = 0.217$

$\theta = \tan^{-1} 0.217 = 12.24^\circ$

$\varphi' = \theta - \theta'$ $\theta' = 6.83^\circ$
(Reference page 14)

$\varphi' = 12.24 - 6.83$

$= 5.41^\circ$

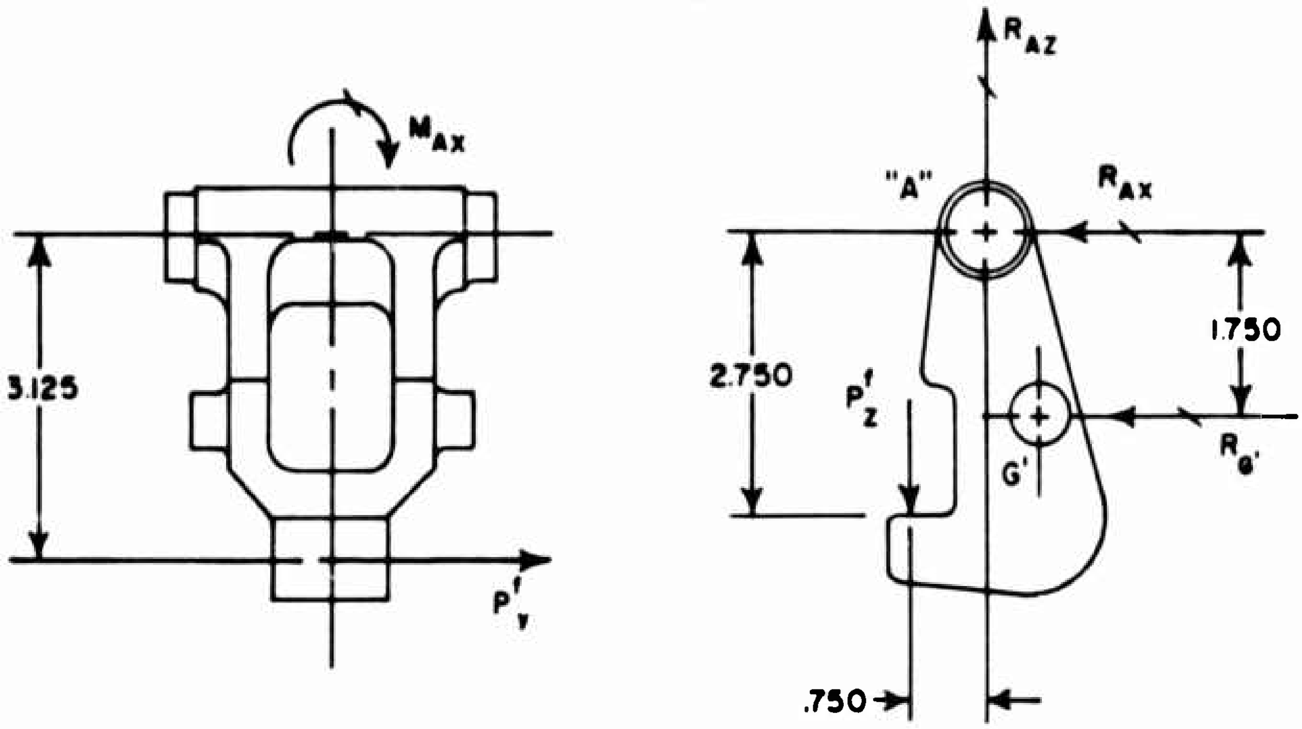


$\sin \varphi' = \dfrac{d_3}{\overline{EN}}$ $\overline{EN} = 0.878$ in. (Reference page 14)

$d_3 = \overline{EN} \sin 5.41 = (0.878)(0.0943) = 0.083$ in.

FORWARD 30-INCH SHACKLE REACTIONS

(Reference Drawing 60D46528)



Loads and reactions shown in positive direction

General Equations for Reactions

$$\Sigma M_A = 0 \quad : \quad 0.750\, P^f_z - 1.750\, R_{G'} = 0$$

$$R_{G'} = \frac{0.750}{1.750} P^f_z = \underline{\underline{0.428\, P^f_z}}$$

$$\Sigma F_z = 0 \uparrow^{+} \quad : \quad R_{Az} = P^f_z$$

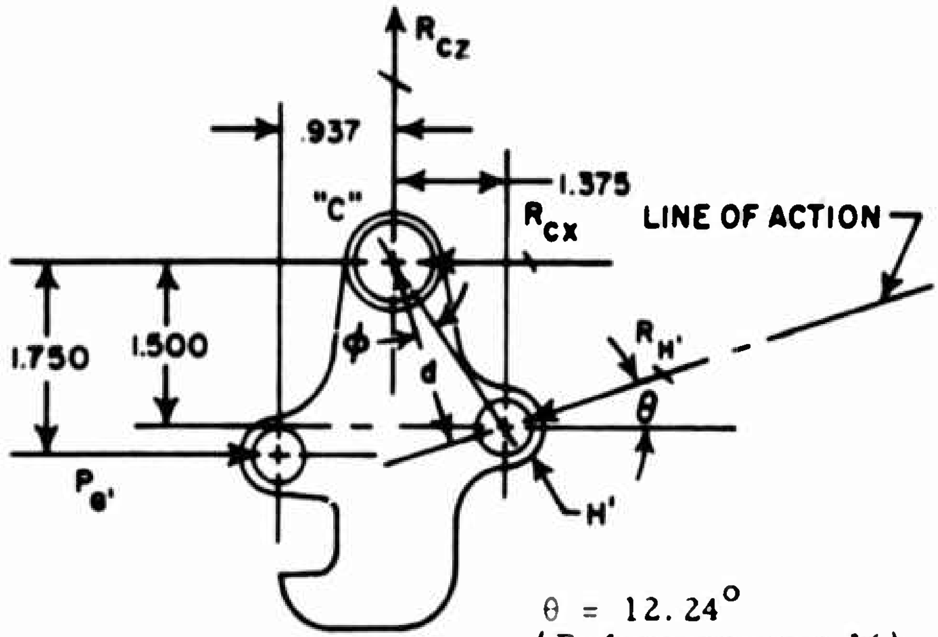
$$\Sigma F_x = \overset{+}{\leftarrow} 0 \quad : \quad R_{G'} + R_{Ax} = 0$$

$$R_{Ax} = -R_{G'} = \underline{\underline{-0.428\, P^f_z}}$$

$$M_{Ax} = \underline{\underline{3.125\, P^f_y}}$$

FORWARD 14-INCH SHACKLE REACTION

(Reference Drawing 63J14363)



θ = 12.24°
(Reference page 16)

Loads and reactions shown in positive directions

General Equation for Reactions

$$\overline{CH'} = \sqrt{(1.375)^2 + (1.500)^2}$$

$$= 2.07 \text{ in.}$$

$$\measuredangle C = \tan^{-1} \frac{1.500}{1.375} = \tan^{-1} 1.090$$

$$\measuredangle C = 47.48^{\circ}$$

$$\therefore \varphi = 90 - [\measuredangle C + \theta]$$

$$= 90 - [47.48 + 12.24]$$

$$\varphi = 30.28^{\circ}$$

$$d = \overline{CH'} \cos \varphi = (2.07)(0.864)$$

$$d = 1.788 \text{ in.}$$

$$\overset{\curvearrowleft +}{\Sigma M_c} = 0 \quad : \quad 1.750\ P_{G'} - 1.788\ R_{H'} = 0$$

$$R_{H'} = \frac{1.750}{1.788}\ P_{G'} = 0.980\ P_{G'}$$

$$\therefore R_{H'} = 0.980\ \left[0.428\ P_z^f\right] = \underline{\underline{0.4195\ P_z^f}}$$

$$\Sigma F_z = 0 \uparrow^{+} \quad : \quad R_{cz} = R_{H'}\ \sin\theta$$

$$= 0.212\ R_{H'}$$

$$\therefore R_{cz} = 0.212\ \left[0.4195\ P_z^f\right]$$

$$= \underline{\underline{0.0889\ P_z^f}}$$

$$\overset{\overset{+}{\leftarrow}}{\Sigma F_x} = 0 \quad : \quad R_{cx} + R_{H'}\ \cos\theta - P_{G'} = 0$$

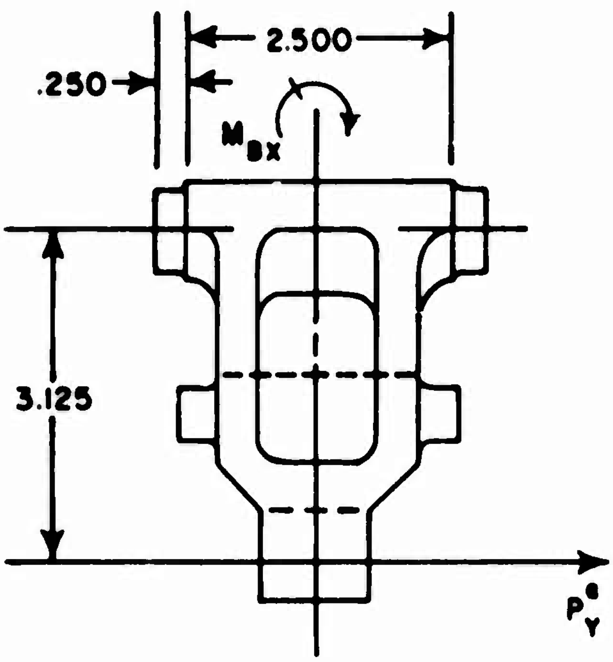
$$R_{cx} = P_{G'} - 0.976\ R_{H'}$$

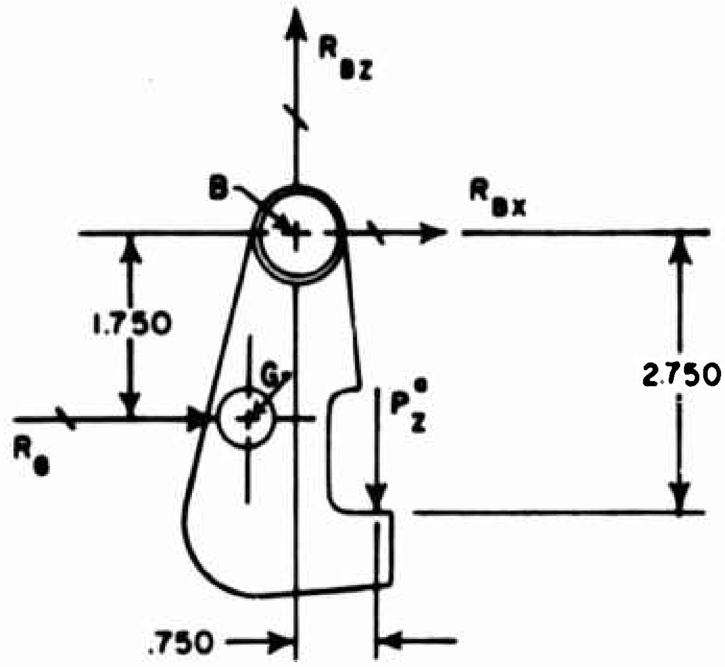
$$= P_{G'} - 0.976\ \left[0.980\ P_{G'}\right]$$ (Reference page 18)

$$= 0.044\ P_{G'} = 0.044\ \left[0.428\ P_z^f\right]$$ (Reference page 17)

$$= \underline{\underline{0.0188\ P_z^f}}$$

AFT 30-INCH SHACKLE REACTIONS
(Reference Drawing 60D46528)





Loads and reactions shown in Positive directions

General Equations for Reactions

$$\Sigma M_{By} = 0 \;:\; R_G(1.750) - P_z^a(0.750) = 0$$

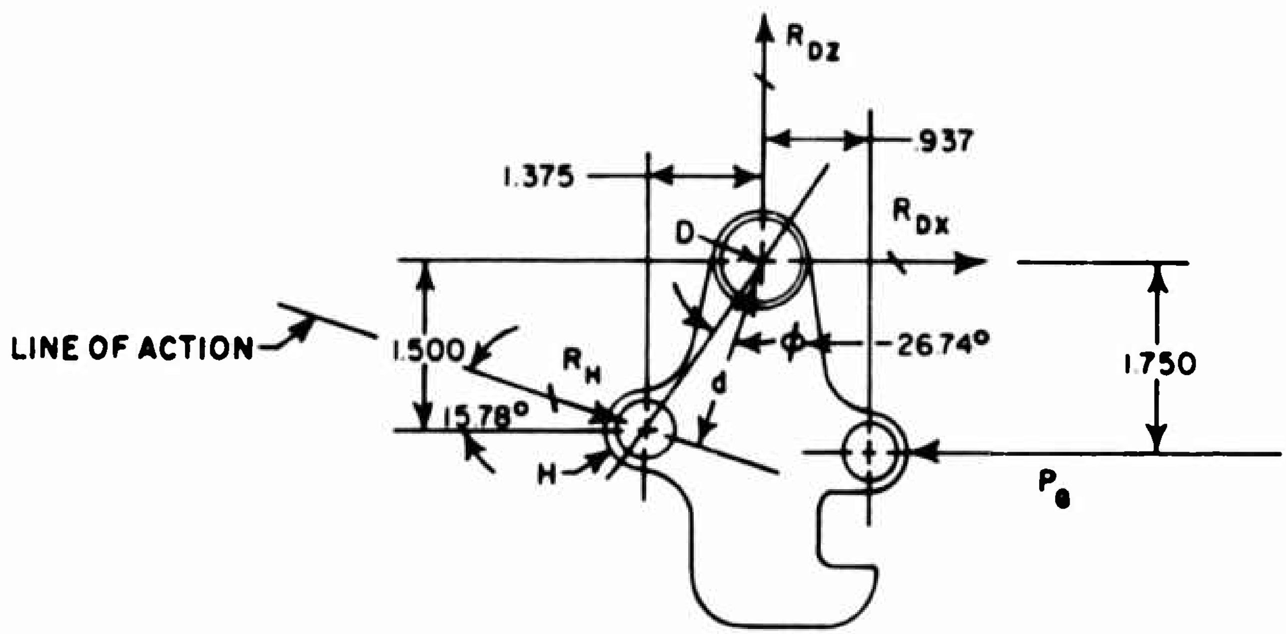
$$R_G = \frac{0.750}{1.750} P_z^a = 0.428\, P_z^a$$

$$\Sigma F_z = 0\uparrow^+ : \; R_{Bz} = P_z^a$$

$$\Sigma F_x = 0 \;(\rightarrow +) : \; R_{Bx} = -R_G = \underline{\underline{-0.428\, P_z^a}}$$

$$M_{Bx} = \underline{\underline{3.125\, P_y^a}}$$

AFT 14-INCH SHACKLE REACTIONS
(Reference Drawing 63J14363)



General Equations for Reactions

$$\overline{HD} = \sqrt{(1.375)^2 + (1.500)^2} = 2.07 \text{ in.}$$

$$\beta = 63.26^\circ \text{ (Reference page 14)}$$

$$\cos \varphi = \frac{d}{\overline{HD}}$$

$$\varphi = 90 - \beta = 90 - 63.26 = 26.74^\circ$$

$$\overline{HD} \cos 26.74^\circ = d$$

$$d = (2.07)(0.894) = 1.848 \text{ in.}$$

$$\overset{\curvearrowleft +}{\Sigma M_D} = 0$$

$$R_H d = 1.75\, P_G$$

$$R_H = \frac{1.75}{1.848} P_G = 0.948\, P_G$$

$$R_H = 0.948 \left[0.428\, P_z^a\right] \quad \text{(Reference page 20)}$$

$$= \underline{\underline{0.406\, P_z^a}}$$

$\Sigma F_z = 0 \uparrow^{+}$

$$R_{Dz} = R_H \sin 15.78^{\circ} = 0.2718\ R_H$$

$$= \underline{\underline{0.1103\ P_z^a}}$$

$\Sigma F_x = 0 \xrightarrow{} ^{+}$

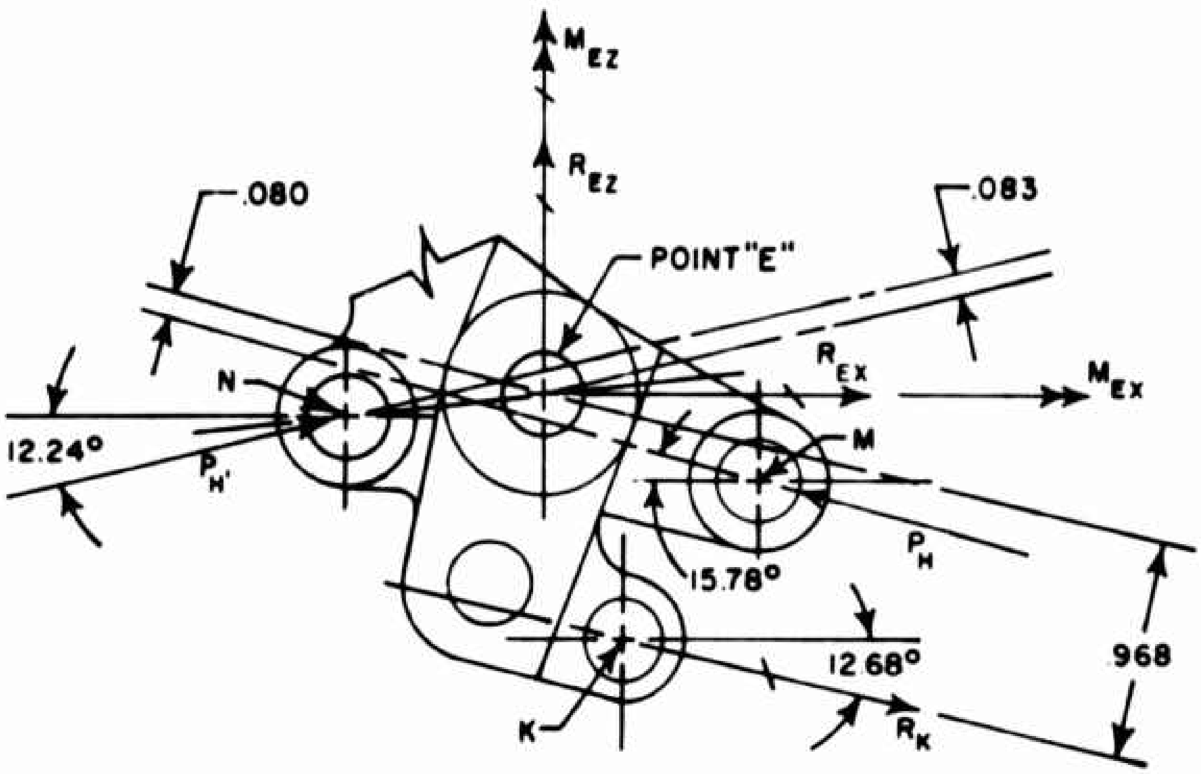
$$R_{Dx} + R_H \cos 15.78^{\circ} - P_G = 0$$

$$R_{Dx} = P_G - (0.962)\ R_H = P_G - (0.962)(0.948)\ P_G$$

$$\therefore R_{Dx} = 0.090\ P_G = 0.090\ \left[0.428\ P_z^a\right] = \underline{\underline{0.0386\ P_z^a}}$$

BELLCRANK REACTIONS

(Reference Drawing 63J14362)



General Equations (Reference pages 15, 16, 21, and 22 for dimensions)

$$\Sigma M_E = 0 \quad (+\curvearrowright)$$

$$(0.083)\ P_{H'} + (0.080)\ P_H - (0.968)\ R_K = 0$$

$$R_K = \left(\frac{0.083}{0.968}\right) P_{H'} + \left(\frac{0.080}{0.968}\right) P_H$$

$$= 0.0858\ P_{H'} + 0.0827\ P_H$$

$$= 0.0858\left[0.4195\ P_z^f\right] + 0.0827\left[0.406\ P_z^a\right]$$ (Reference pages 19 and 21)

$$= \underline{\underline{0.036\ P_z^f + 0.0336\ P_z^a}}$$

$$M_{Ex} = R_K \sin 12.68(0.875)$$ (Reference Drawing 63J14362 for dimensions)

$$= (0.875)(0.2195)\left[0.036\ P_z^f + 0.0336\ P_z^a\right]$$

$$= \underline{\underline{0.00692\ P_z^f + 0.00645\ P_z^a}}$$

$$M_{Ez} = R_K \cos 12.68\,(0.875)$$

$$= (0.875)(0.975)\left[0.036\,P_z^f + 0.0336\,P_z^a\right]$$

$$= \underline{\underline{0.0307\,P_z^f + 0.02865\,P_z^a}}$$

$\Sigma F_z = 0 \uparrow^{+}$

$$R_{Ez} + P_{H'} \sin 12.24^\circ + P_H \sin 15.78^\circ - R_K \sin 12.68^\circ = 0$$

$$R_{Ez} = 0.2195\,R_K - 0.212\,P_{H'} - 0.272\,P_H$$

$$P_{H'} = 0.4195\,P_z^f \quad \text{(Reference page 19)}$$

$$P_H = 0.406\,P_z^a \quad \text{(Reference page 21)}$$

$$R_K = 0.036\,P_z^f + 0.0336\,P_z^a \quad \text{(Reference page 23)}$$

$$R_{Ez} = 0.2195\left[0.036\,P_z^f + 0.0336\,P_z^a\right] - 0.212\left[0.4195\,P_z^f\right]$$

$$- 0.272\left[0.406\,P_z^a\right]$$

$$= 0.0079\,P_z^f + 0.00738\,P_z^a - 0.1105\,P_z^a - 0.0889\,P_z^f$$

$$= \underline{\underline{-0.081\,P_z^f - 0.103\,P_z^a}}$$

$\Sigma F_x = \overset{+}{\rightarrow} 0$

$$R_{Ex} + P_{H'} \cos 12.24 - P_H \cos 15.78 + R_K \cos 12.68 = 0$$

$$R_{Ex} = -0.976\,P_{H'} + 0.9625\,P_H - 0.975\,R_K$$

$$= -0.976\left[0.4195\,P_z^f\right] + 0.9625\left[0.406\,P_z^a\right]$$

$$-0.975\left[0.036\,P_z^f + 0.0336\,P_z^a\right]$$

$$= -0.410\,P_z^f + 0.3904\,P_z^a - 0.0351\,P_z^f - 0.0328\,P_z^a$$

$$= \underline{\underline{-0.4451\,P_z^f + 0.3576\,P_z^a}}$$

Table 3

CALCULATION OF LINKAGE MECHANISM REACTION

Applied and reacting loads are shown in pounds. Moments are

NOTES: 1 For constants and general equations, reference

(2) For l[illegible] source, reference page 7

ndition	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	P^f_y	P^f_z	F^a_y	P^a_z	0.036 P^f_z	0.00692 P^f_z	0.0307 P^f_z	0.081 P^f_z	0.4451 P^f_z
	← Ult applied loads to the 30-inch shackles			(2) →	0.036 (2)	0.00692 (2)	0.0307 (2)	0.081 (2)	0.4451 (2)
1	8,212	30,935	-8,212	17,198	1,114	214	950	2,506	13,769
2	-9,036	24,651	9,036	35,782	887	171	757	1,997	10,972
3	7,110	27,293	-7,110	16,141	983	189	838	2,211	12,148
4	9,076	31,244	-9,076	22,132	1,125	216	959	2,531	13,907
5	6,940	33,727	-6,940	12,432	1,214	233	1,035	2,732	15,012
6	5,340	45,744	-5,340	30,833	1,647	317	1,404	3,705	20,361
7	0	12,148	0	6,492	437	84	373	984	5,407
8	0	0	0	15,120	0	0	0	0	0

ndition	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
	M_{Ax}	$R_{H'}$	R_{cz}	R_{cx}	R_G	R_{Bx}	R_{Bz}	M_{Bx}	R_H
	3.125 (1)	0.4195 (2)	0.0889 (2)	0.0188 (2)	0.428 (4)	- (22)	(4)	3.125 (3)	0.406 (4)
1	25,663	12,977	2,750	582	7,361	-7,361	17,198	-25,663	6,982
2	-28,238	10,341	2,191	463	15,315	-15,315	35,782	+ 28,238	14,527
3	22,219	11,449	2,426	513	6,908	-6,908	16,141	-22,219	6,553
4	28,363	13,107	2,778	587	9,422	-9,422	22,132	-28,363	8,986
5	21,688	14,148	2,998	634	5,321	-5,321	12,432	-21,688	5,047
6	16,688	19,190	4,067	860	13,197	-13,197	30,833	-16,688	12,518
7	0	5,096	1,080	228	2,779	-2,779	6,492	0	2,636
8	0	0	0	0	6,471	-6,471	15,120	0	6,139

Table 3

ALCULATION OF LINKAGE MECHANISM REACTIONS (ULTIMATE)

nd reacting loads are shown in pounds. Moments are shown in inch-pounds.

S: 1 For constants and general equations, reference pages 17 through 24

[2] For load source, reference page 7

(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
7 P_z^f	0.081 P_z^f	0.4451 P_z^f	0.0336 P_z^a	0.00645 P_z^a	0.0287 P_z^a	0.1031 P_z^a	0.3576 P_z^a	$R_{G'}$	R_{Ax}
(2)	0.081 (2)	0.4451 (2)	0.0336 (4)	0.00645 (4)	0.0287 (4)	0.1031 (4)	0.3576 (4)	0.428 (2)	- (15)
950	2,506	13,769	578	111	493	1,773	6,150	13,240	-13,240
757	1,997	10,972	1,202	231	1,025	3,689	12,796	10,551	-10,551
838	2,211	12,148	542	104	462	1,664	5,772	11,681	-11,681
959	2,531	13,907	744	143	634	2,282	7,914	13,372	-13,372
035	2,732	15,012	418	80	356	1,282	4,446	14,435	-14,435
404	3,705	20,361	1,036	199	883	3,179	11,026	19,578	-19,578
373	984	5,407	218	42	186	669	2,322	5,199	-5,199
0	0	0	508	97	433	1,559	5,407	0	0

(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)
Bz	M_{Bx}	R_H	R_{Dz}	R_{Dx}	R_K	M_{Ex}	M_{Ez}	R_{Ez}	R_{Ex}
)	3.125 (3)	0.406 (4)	0.1103 (4)	0.0386 (4)	(5) + (10)	(6) + (11)	(7) + (12)	-(8) - (13)	-(9) + (14)
198	-25,663	6,982	1,897	664	1,692	325	1,443	-4,279	-7,619
782	+28,238	14,527	3,947	1,381	2,089	402	1,782	-5,686	1,824
141	-22,219	6,553	1,780	623	1,525	293	1,300	-3,875	-6,376
132	-28,363	8,986	2,441	854	1,869	359	1,593	-4,813	-5,993
432	-21,688	5,047	1,371	480	1,632	313	1,391	-4,014	-10,566
833	-16,688	12,518	3,401	1,190	2,683	516	2,287	-6,884	-9,335
492	0	2,636	716	251	655	126	559	-1,653	-3,085
120	0	6,139	1,668	584	508	97	433	-1,559	5,407

C

NISM REACTIONS (ULTIMATE)

s. Moments are shown in inch-pounds.

ations, reference pages 17 through 24

ge 7

(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
451 P_z^f	0.0336 P_z^a	0.00645 P_z^a	0.0287 P_z^a	0.1031 P_z^a	0.3576 P_z^a	$R_{G'}$	R_{Ax}	R_{Az}
451 (2)	0.0336 (4)	0.00645 (4)	0.0287 (4)	0.1031 (4)	0.3576 (4)	0.428 (2)	- (15)	(2)
13,769	578	111	493	1,773	6,150	13,240	-13,240	30,935
10,972	1,202	231	1,025	3,689	12,796	10,551	-10,551	24,651
12,148	542	104	462	1,664	5,772	11,681	-11,681	27,293
13,907	744	143	634	2,282	7,914	13,372	-13,372	31,244
15,012	418	80	356	1,282	4,446	14,435	-14,435	33,727
20,361	1,036	199	883	3,179	11,026	19,578	-19,578	45,744
5,407	218	42	186	669	2,322	5,199	-5,199	12,148
0	508	97	433	1,559	5,407	0	0	0

(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
R_H	R_{Dz}	R_{Dx}	R_K	M_{Ex}	M_{Ez}	R_{Ez}	R_{Ex}	
406 (4)	0.1103 (4)	0.0386 (4)	(5) + (10)	(6) + (11)	(7) + (12)	-(8) - (13)	-(9) + (14)	
6,982	1,897	664	1,692	325	1,443	-4,279	-7,619	
4,527	3,947	1,381	2,089	402	1,782	-5,686	1,824	
6,553	1,780	623	1,525	293	1,300	-3,875	-6,376	
8,986	2,441	854	1,869	359	1,593	-4,813	-5,993	
5,047	1,371	480	1,632	313	1,391	-4,014	-10,566	
2,518	3,401	1,190	2,683	516	2,287	-6,884	-9,335	
2,636	716	251	655	126	559	-1,653	-3,085	
6,139	1,668	584	508	97	433	-1,559	5,407	

4. STRUCTURAL STRESS ANALYSIS

The stress analysis for the MAU-12A/A Bomb Ejector Rack is presented in three sections: (a) body analysis (side plates and swaybraces); (b) linkage mechanism and drag fitting analysis; and (c) ballistic gas system analysis.

The body analysis is based upon the loads and moments produced by load condition No. 6 (reference tables 2 and 3) shown in figure 7. The components of these loads, in a vertical and horizontal plane, are shown in figure 8 with the shear and moment diagrams presented in figures 9 and 10.

Loads and moments produced by load condition No. 2 (reference tables 2 and 3) presented in figures 3, 4, 5, and 6 are for comparative purposes only.

The analysis of each component or assembly of the bomb rack was made using conservative methods as much as possible. However, the plastic bending methods were used in computing the ultimate bending allowability of the side plates and swaybraces. Static load tests to ultimate conditions 2, 4, 5, and 6 have verified the accuracy of these methods.

a. Body analysis

APPLIED LOADS AND AIRCRAFT REACTIONS

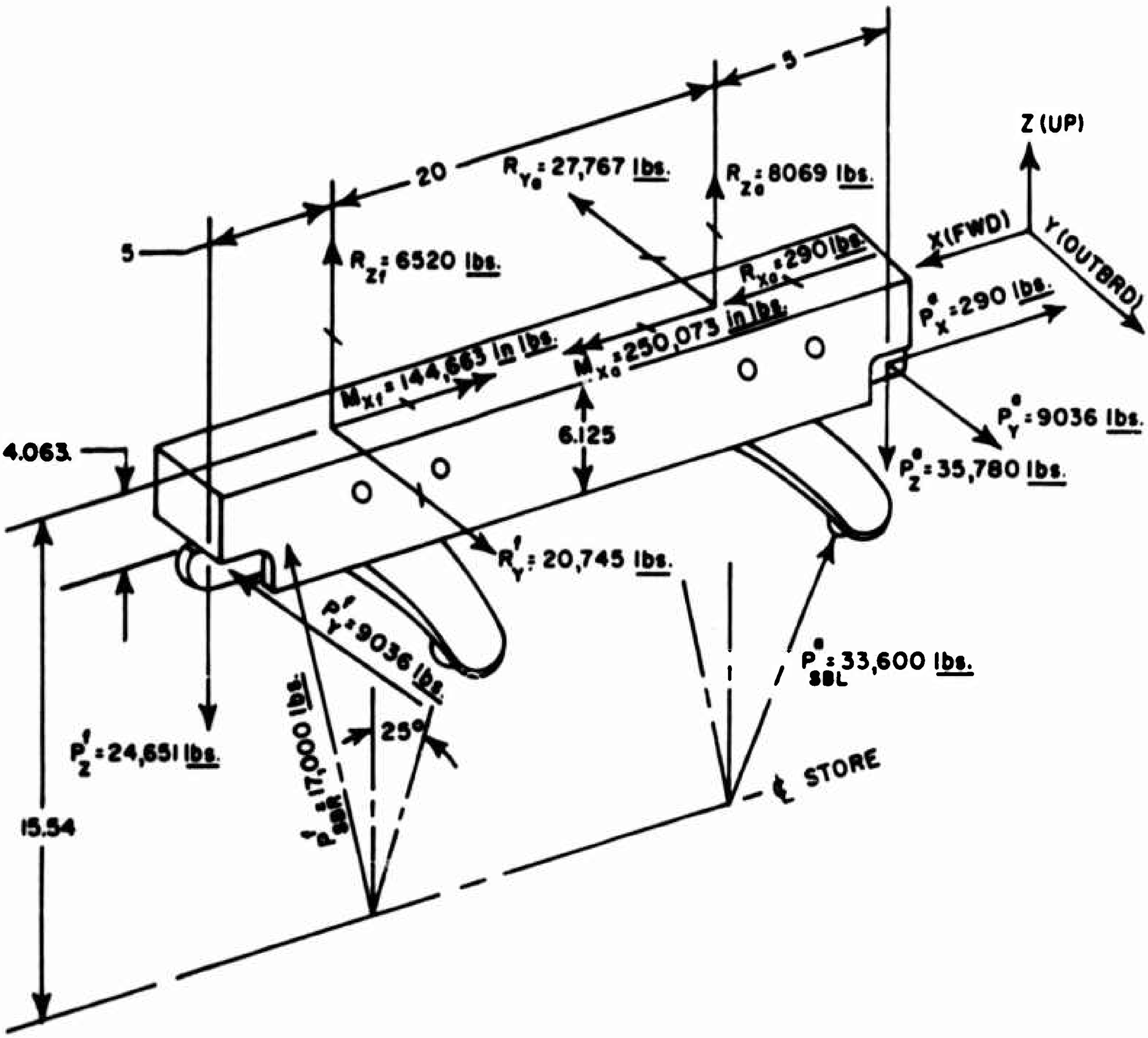


Figure 3. Static balance of rack for load condition No. 2

(Reference table 2)

(1) All loads and reactions are shown in proper direction

(2) Left-hand rule coordinates

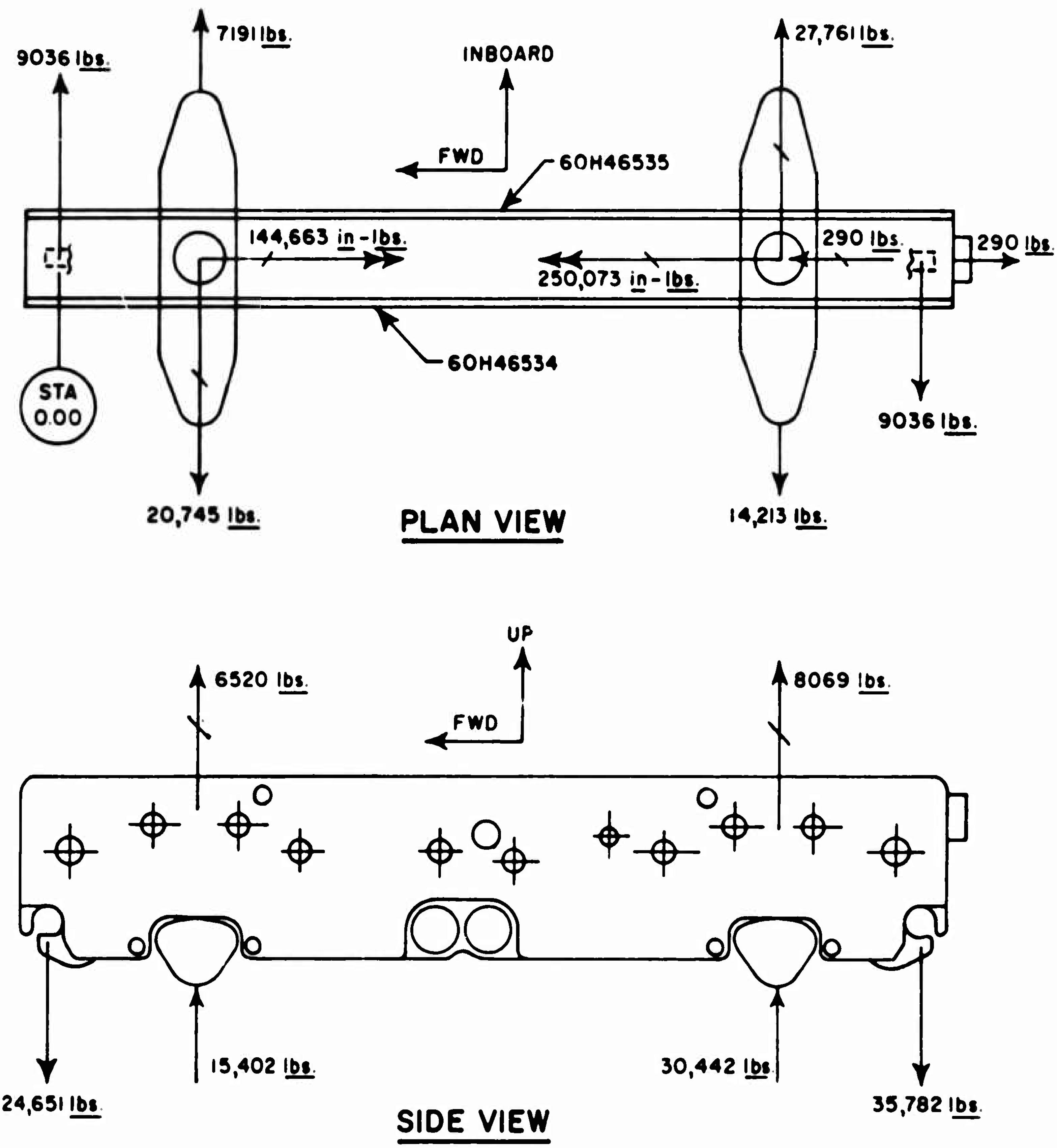


Figure 4. Body loads for load condition No. 2

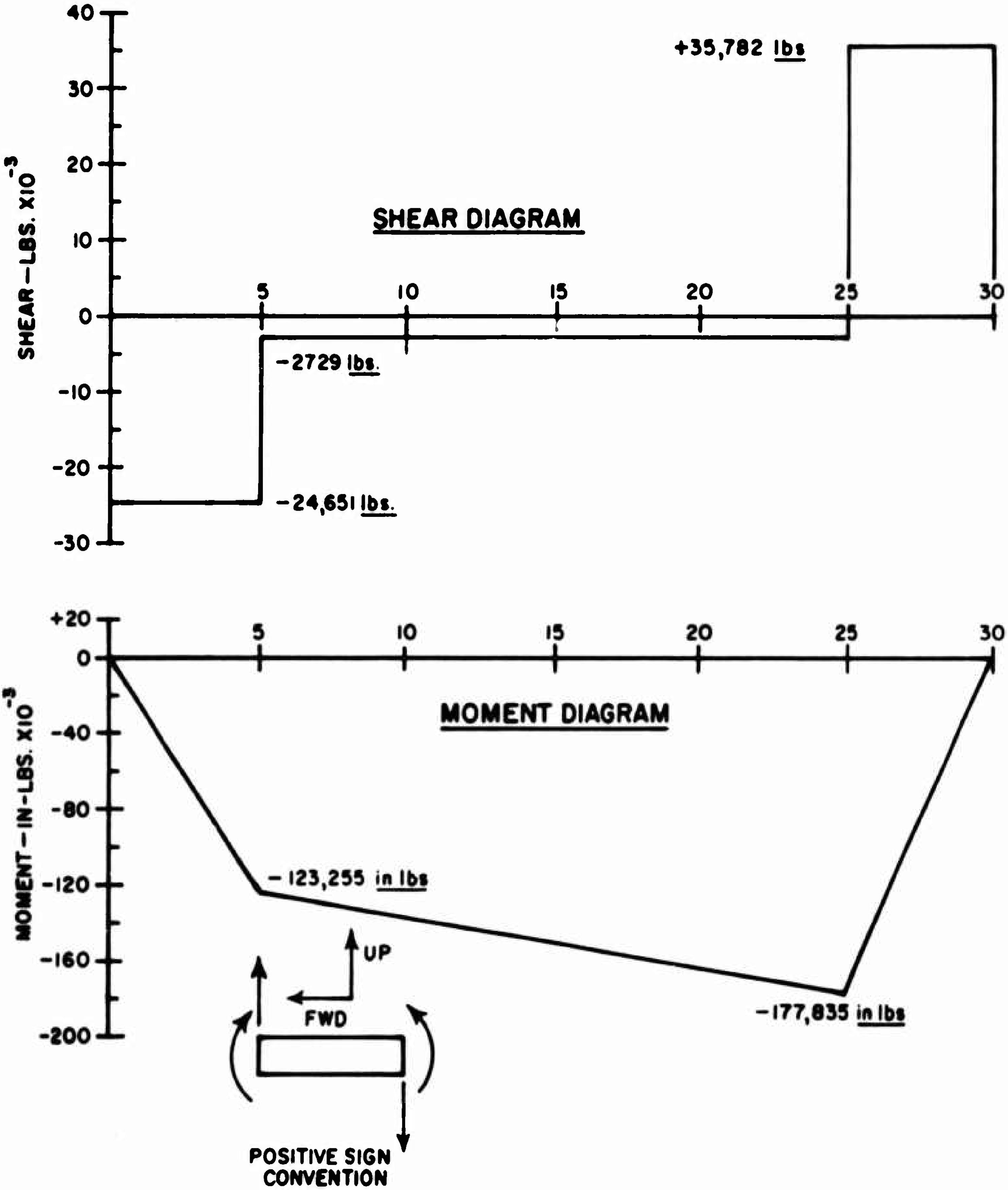


Figure 5. Shear and moment diagrams (vertical plane)

Load condition No. 2

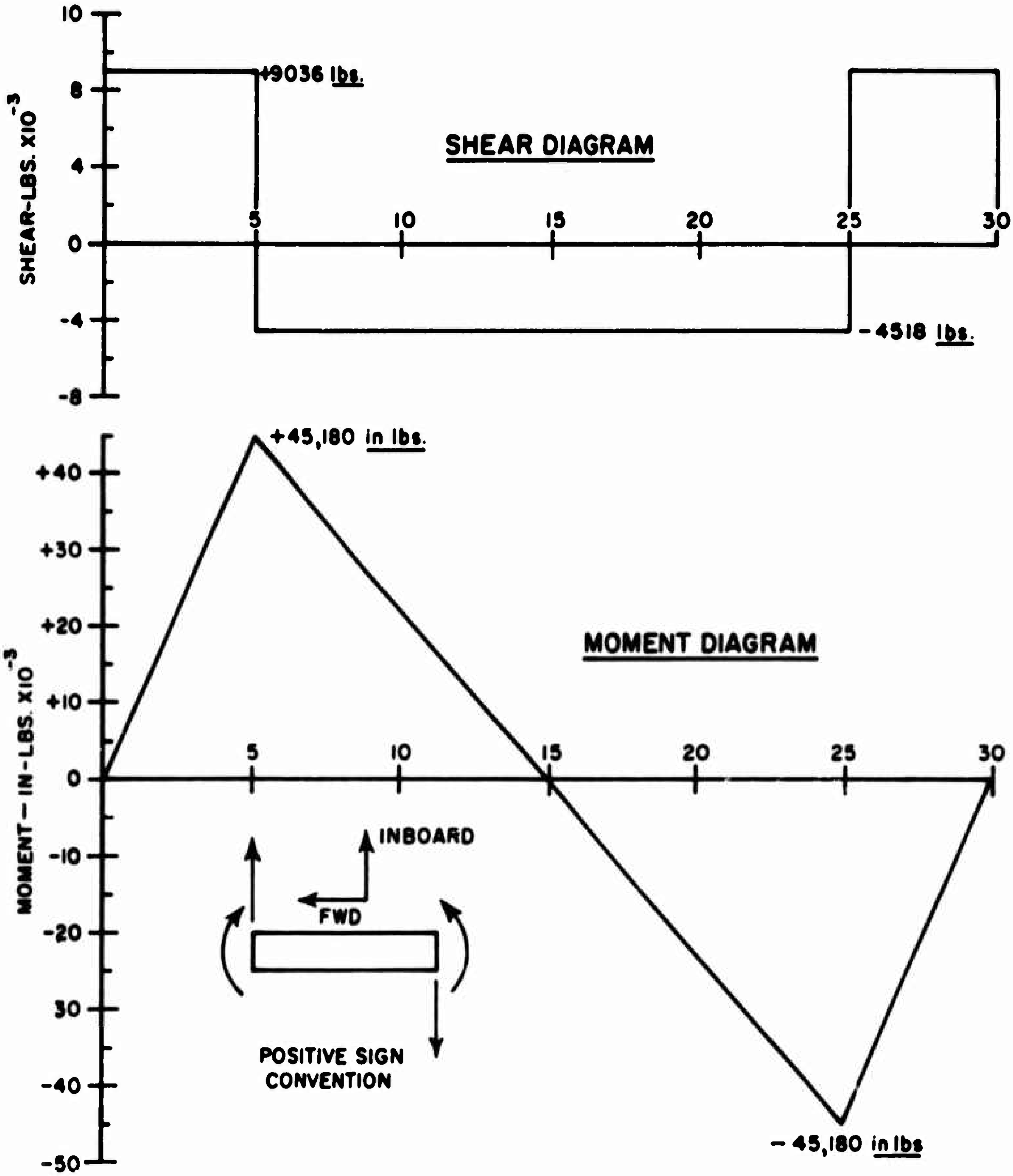


Figure 6. Shear and moment diagrams (horizontal plane)

Load condition No. 2

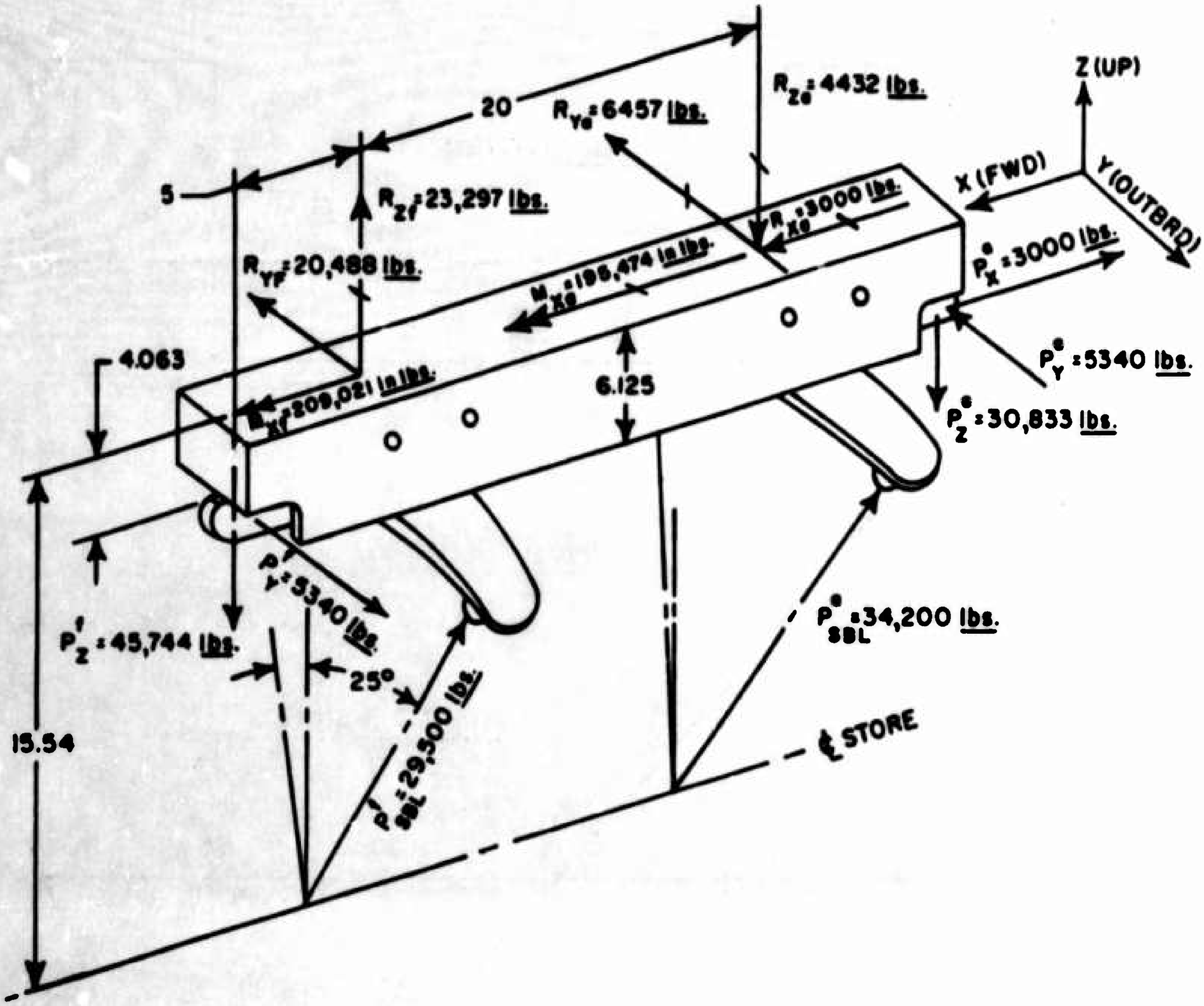
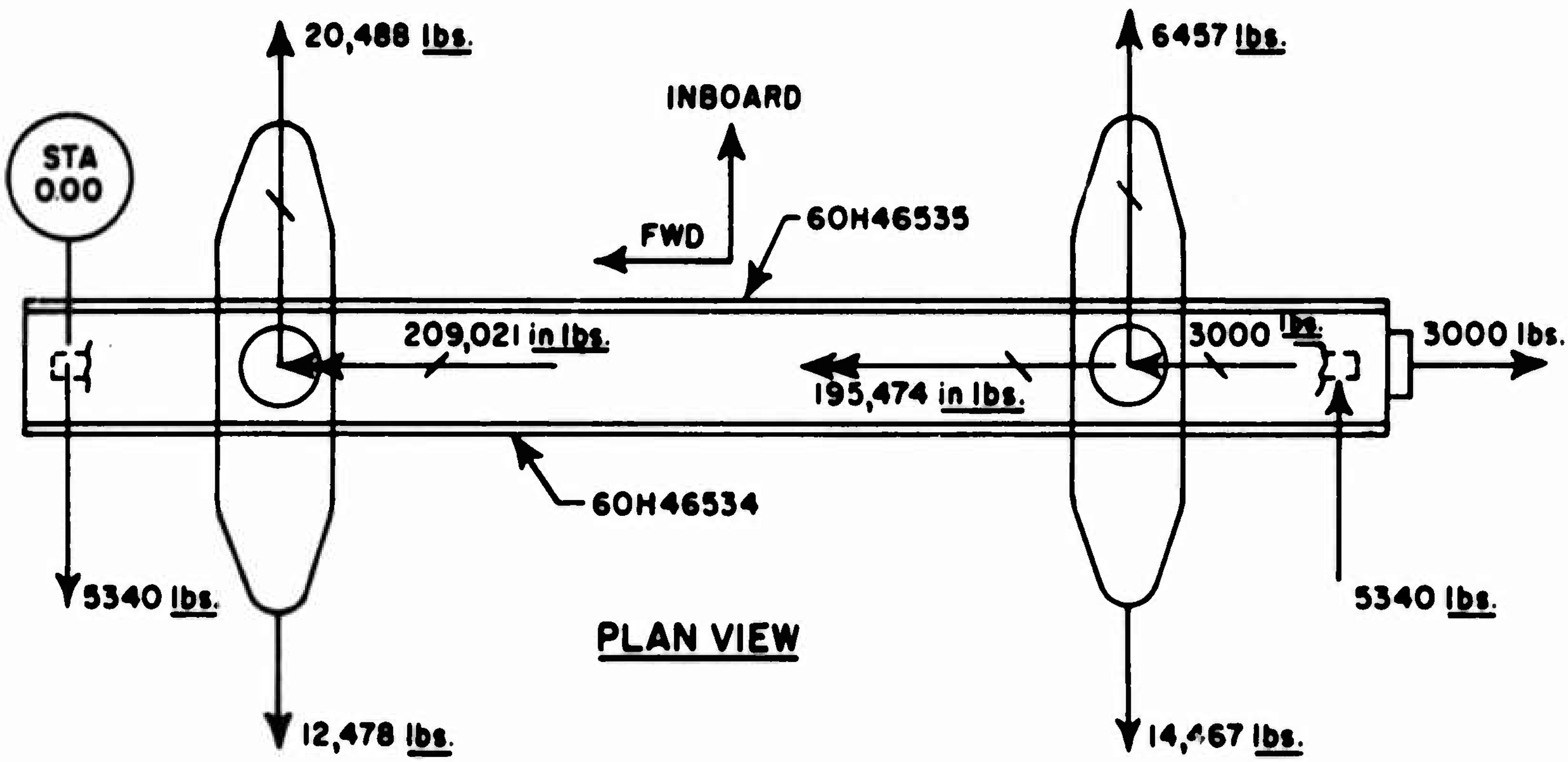


Figure 7. Static balance of rack for load condition No. 6

(Reference table 2)

(1) All loads and reactions are shown in proper direction

(2) Left-hand rule coordinates



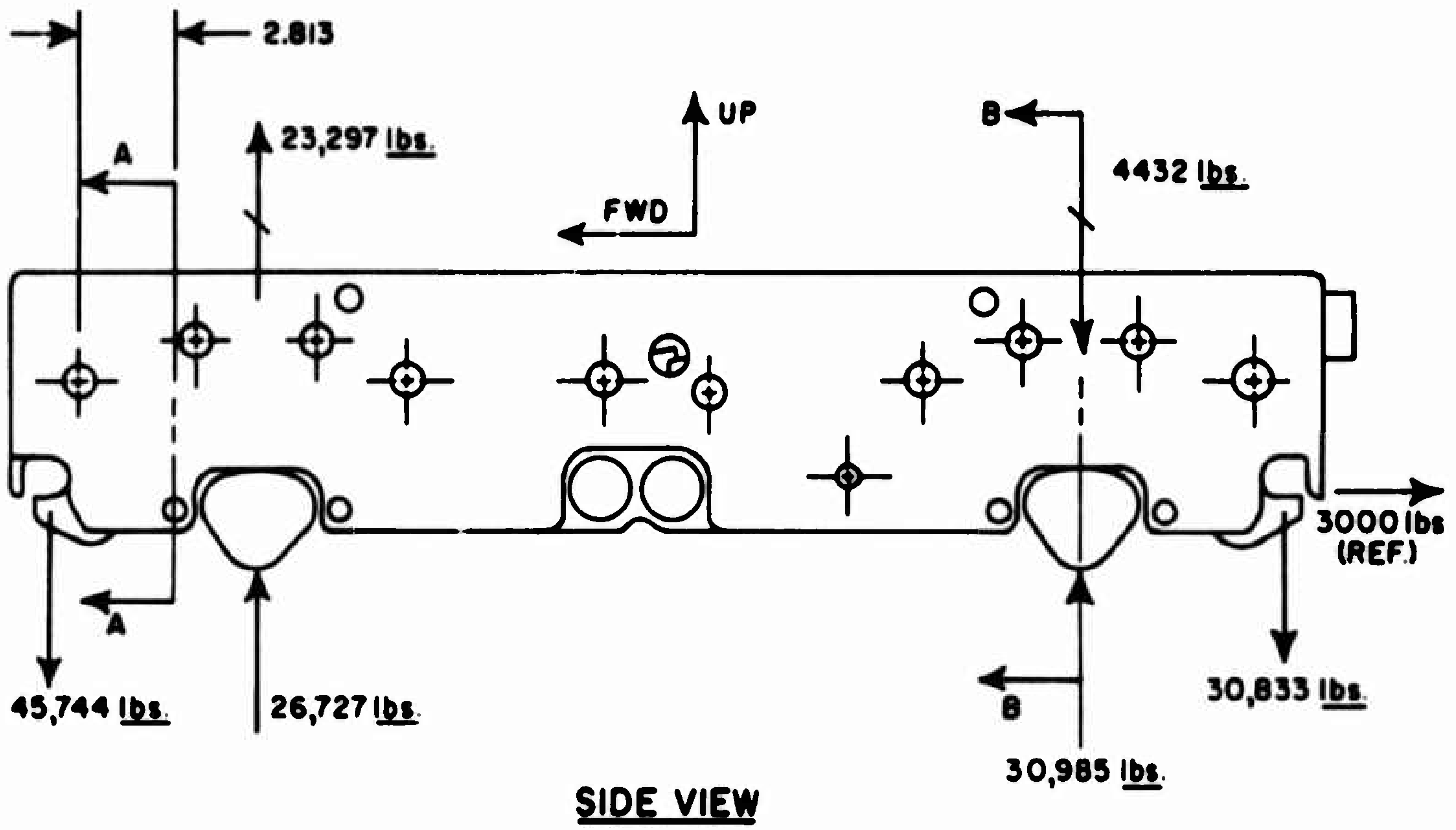


Figure 8. Body loads for load condition No. 6

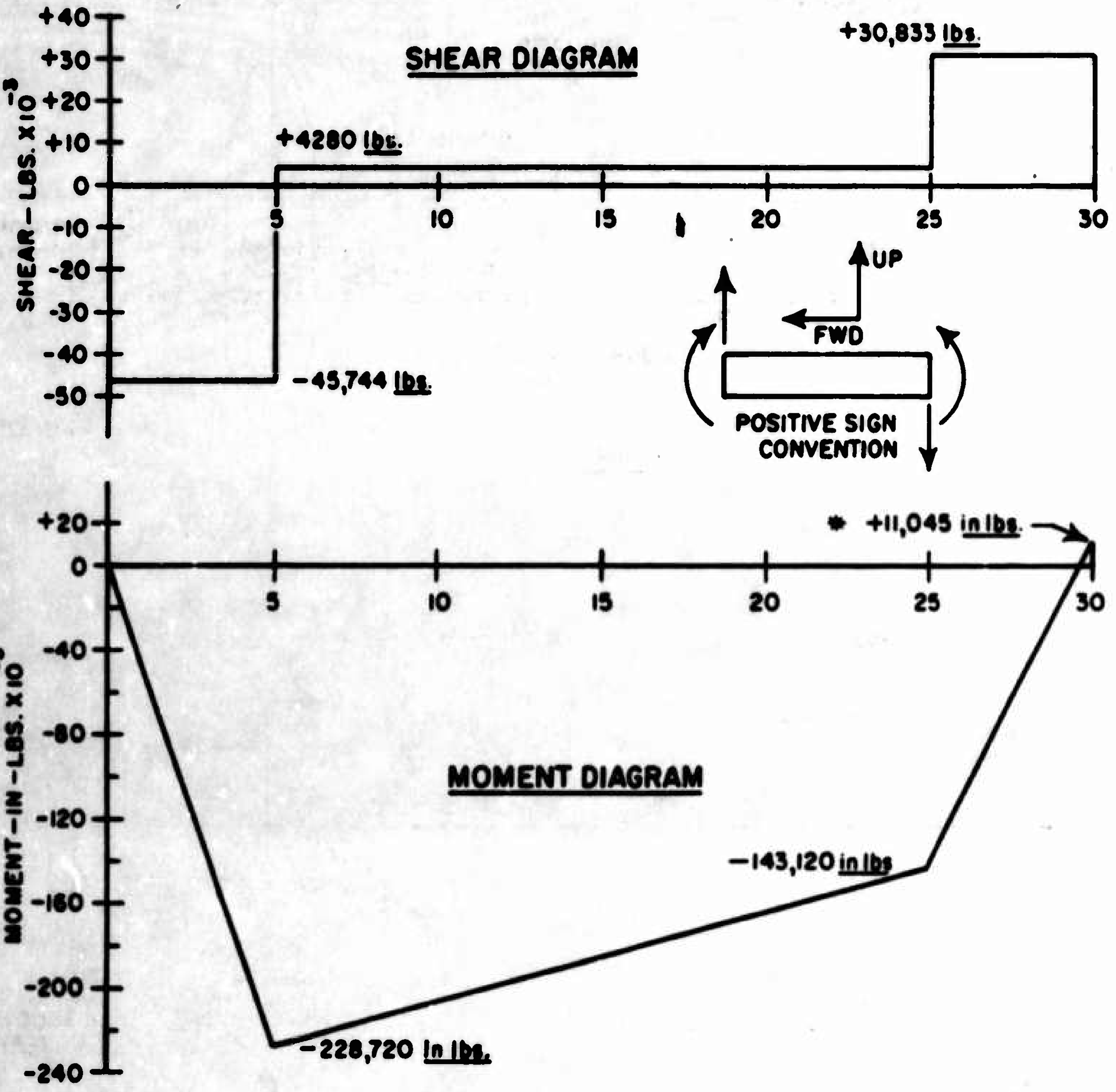


Figure 9. Shear and moment diagrams (vertical plane)

Load condition No. 6

*NOTE: The unbalanced moment (considering vertical loads) is balanced by the 3,000 lbs drag force (applied to the aft drag fitting) acting aft on a 3.688 in. moment arm.

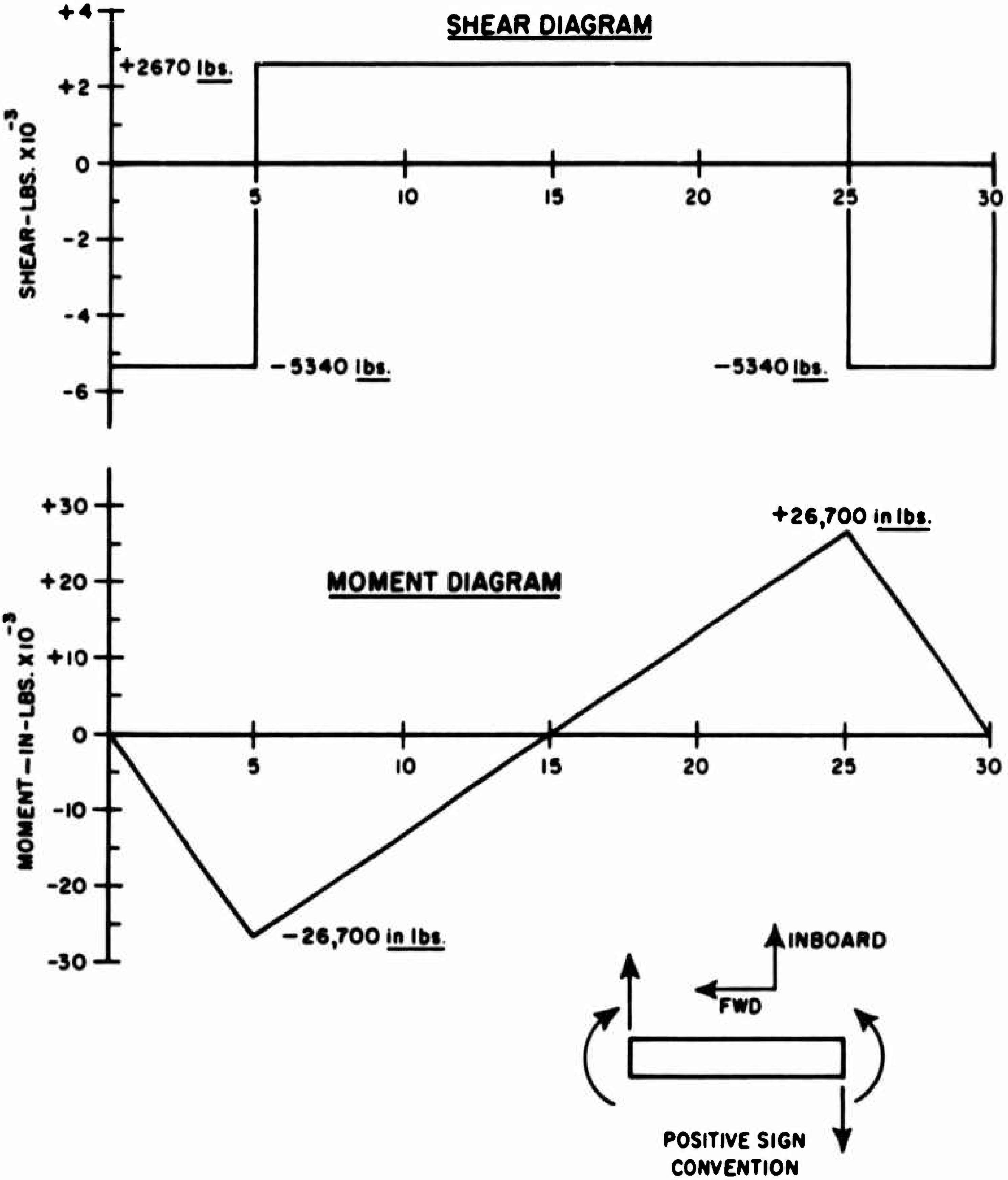
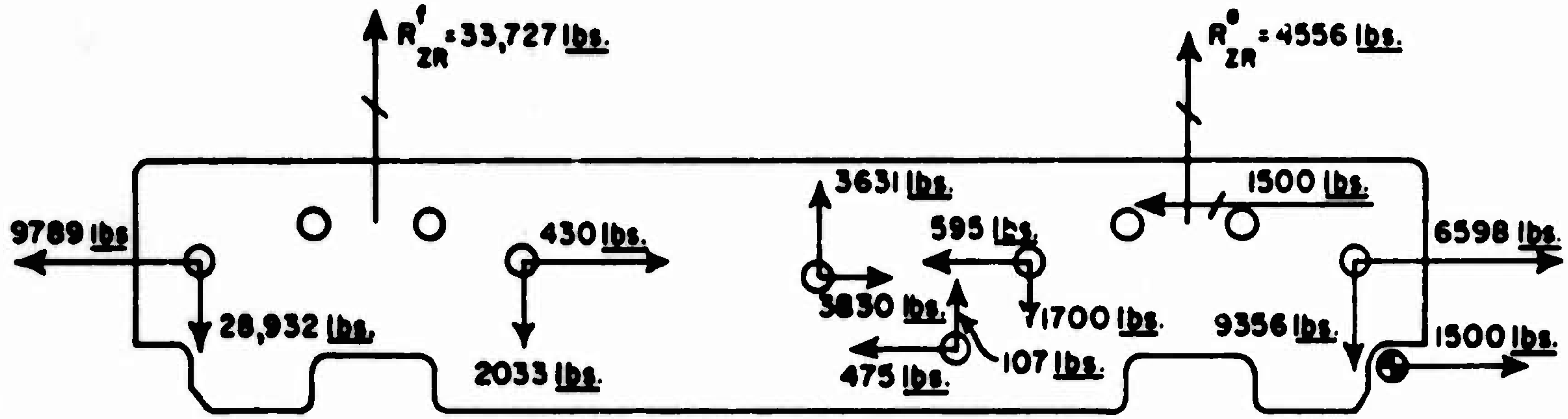
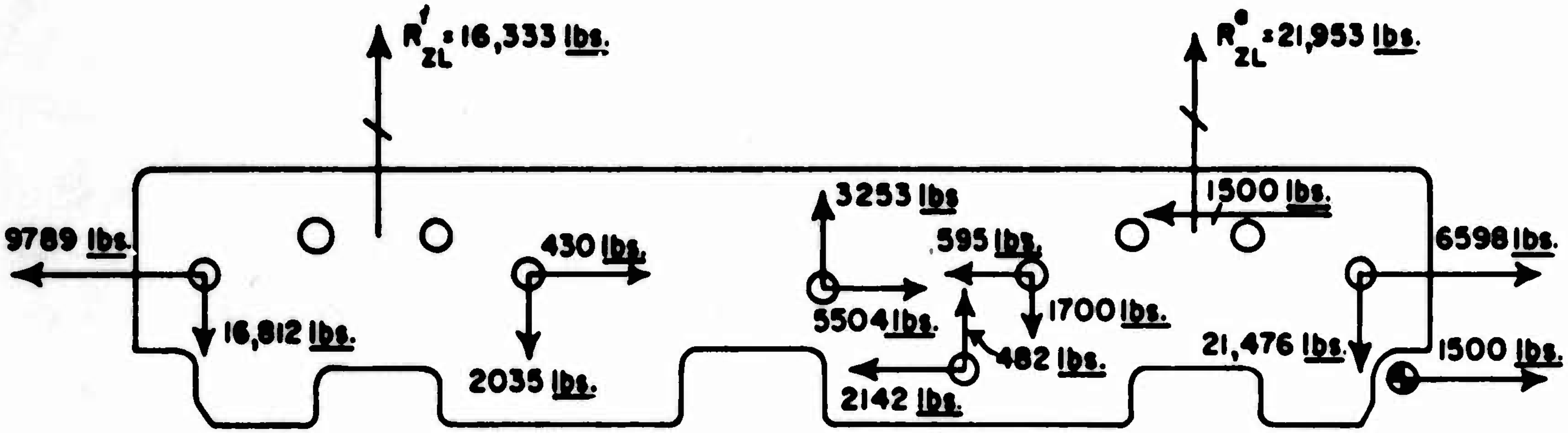


Figure 10. Shear and moment diagrams (horizontal plane)
Load condition No. 6



RIGHT-HAND SIDE PLATE (REF. DWG. 60H46535)



LEFT-HAND SIDE PLATE (REF. DWG. 60H46534)

SIDE PLATE LOADS AND REACTIONS

(1) Condition No. 6 (reference page 32)

(2) Assume side load torsion reacted by side plate differential bending

(3) Linkage pin joint loads are derived from loads shown in figure 11 and individual parts analyses, pages 48 through 86

SIDE PLATE REACTION CALCULATION

(Reference Drawings 60H46534 and 60H46535 for dimensions)

Right-hand Side Plate

$$\overset{\curvearrowleft +}{\Sigma M_A} = 0: \; [-9789+430-595+6598](0.938)-(9356)(4.25)+(1700)(3.75)$$
$$-(107)(6.19)-(475)(2.876)+3830(1.25)-3631(9.0)+2033(16.25)$$
$$+(28932)(24.25)+(1500)(3.688)-20R^f_{zR}=0$$

$$20R^f_{zR} = -3144-39800+6375-662-1365+4785-32680+33000+702500+5530=674539$$

$$R^f_{zR} = \frac{674539}{20} = 33727 \text{ lbs.}\uparrow$$

$$+\downarrow \; \Sigma F_z = 0: \; 28932-33727+2033-3631-107+1700-R^a_{zR}+9356=0$$

$$R^a_{zR} = 4556 \text{ lbs.}\uparrow$$

Left-hand Side Plate

$$\overset{\curvearrowleft +}{\Sigma M_A} = 0: \; [6598-595+430-9789](0.938)-(21476)(4.25)+1700(3.75)-482(6.19)$$
$$-(2142)(2.876)+5504(1.25)-3253(9.0)+(2033)(16.25)$$
$$+16812(24.25)+1500(3.688)-20R^f_{zL}=0$$

$$(20)R^f_{zL} = -3144-91100+6375-2980-6160+6875-29240+33000+407500+5530=326656$$

$$R^f_{zL} = \frac{326656}{20} = 16333 \text{ lbs.}\uparrow$$

$$+\downarrow \; \Sigma F_z = 0: \; 16812-16333+2033-3253-482+1700-R^a_{zL}+21476=0$$

$$R^a_{zL} = 21953 \text{ lbs.}\uparrow$$

SIDE PLATE, BENDING AND TENSION SECTION A-A

Side Plate Material

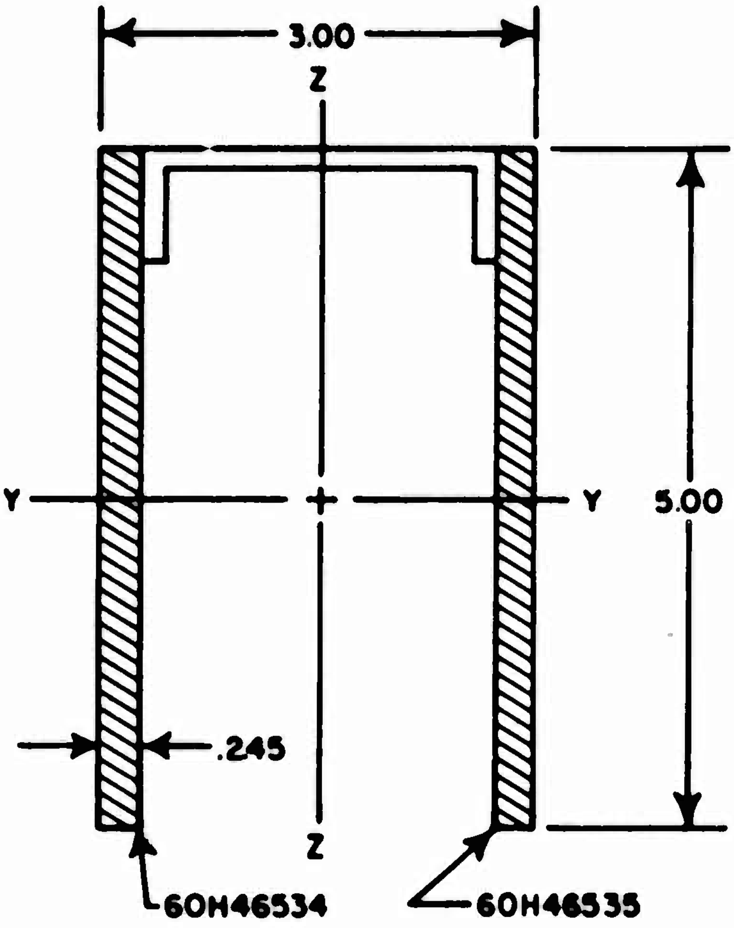
7075-T6 aluminum plate

Allowables (reference MIL-HNDBK-5)

$F_{tu} = 77000$ psi

$F_{ty} = 67000$ psi

$F_{su} = 46000$ psi



Section A-A (STA. 2.813)
(Reference page 33)

Section Properties

$$I_{y-y} = \frac{(0.245)(5)^3}{12}(2) = 5.11 \text{ in.}^4$$

$$A_{tot} = (5)(0.245)(2) = 2.45 \text{ in.}^2$$

$$I_{z-z} = Ad^2$$

$$= (2.45)(1.500-0.122)^2$$

$$= 4.65 \text{ in.}^4$$

Right-hand Side Plate Critical for Differential Bending
(Loads shown on pages 33 and 36)

$$M_{y-y(\text{side plate})} = 28932(2.813) + 9789(0.062) = 81900 \text{ in.-lbs.}$$

$$M_{z-z(\text{total})} = 5340(2.813) = 15000 \text{ in.-lbs.}; \quad I_y = \frac{I_{y-y}}{2} = \frac{5.11}{2} = 2.55$$

$$f_{by-y} = \frac{M_y c_z}{I_y} = \frac{(81900)(2.50)}{2.55}$$

$$= 80300 \text{ psi (right-hand side plate)}$$

$$f_{bz-z} = \frac{M_y c_z}{I_z} = \frac{(1500)(1.5)}{4.65}$$

$$= 4840 \text{ psi}$$

$$A = \frac{A_{(total)}}{2} = \frac{2.45}{2} = 1.225 \text{ in.}^2$$

$$f_t = \frac{P}{A} = \frac{9789}{1.225} = 7990 \text{ psi}$$

Bending Modulus of Rupture

$$F_{br} = 1.5\ F_{ty} = 1.5\,(67000) = 100500 \text{ psi}$$

$$R_{by} = \frac{80300}{100500} = 0.798$$

$$R_{bz} = \frac{4840}{100500} = 0.048$$

(Bend and tension $M.S. = \frac{1}{[0.798 + 0.048 + 0.104]} - 1 = \underline{+0.05}$

$$R_t = \frac{7990}{77000} = 0.104$$

$$f_s = \frac{P}{A} = \frac{28932}{1.225} = 23600 \text{ psi}$$

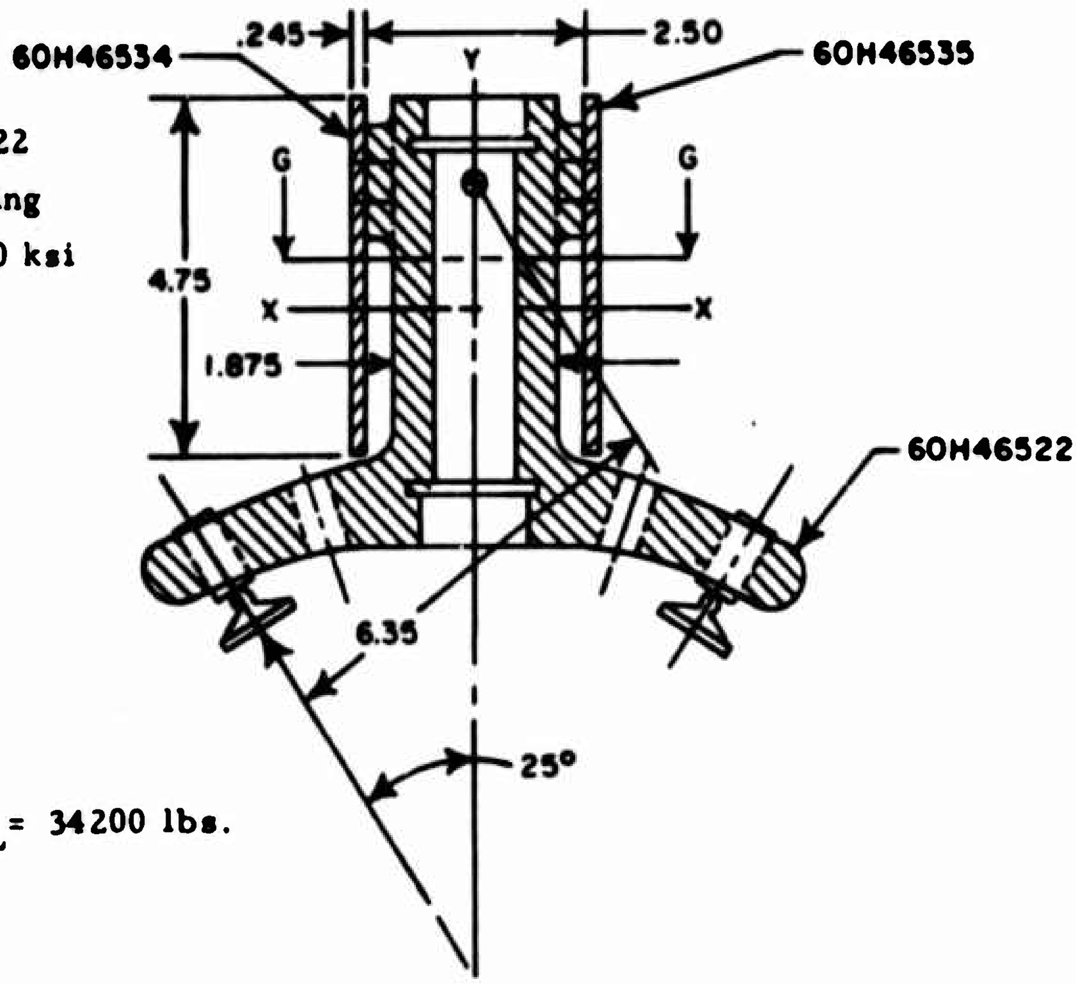
(Shear) $M.S. = \frac{46000}{23600} - 1 = \underline{+0.95}$

SWAYBRACE ANALYSIS

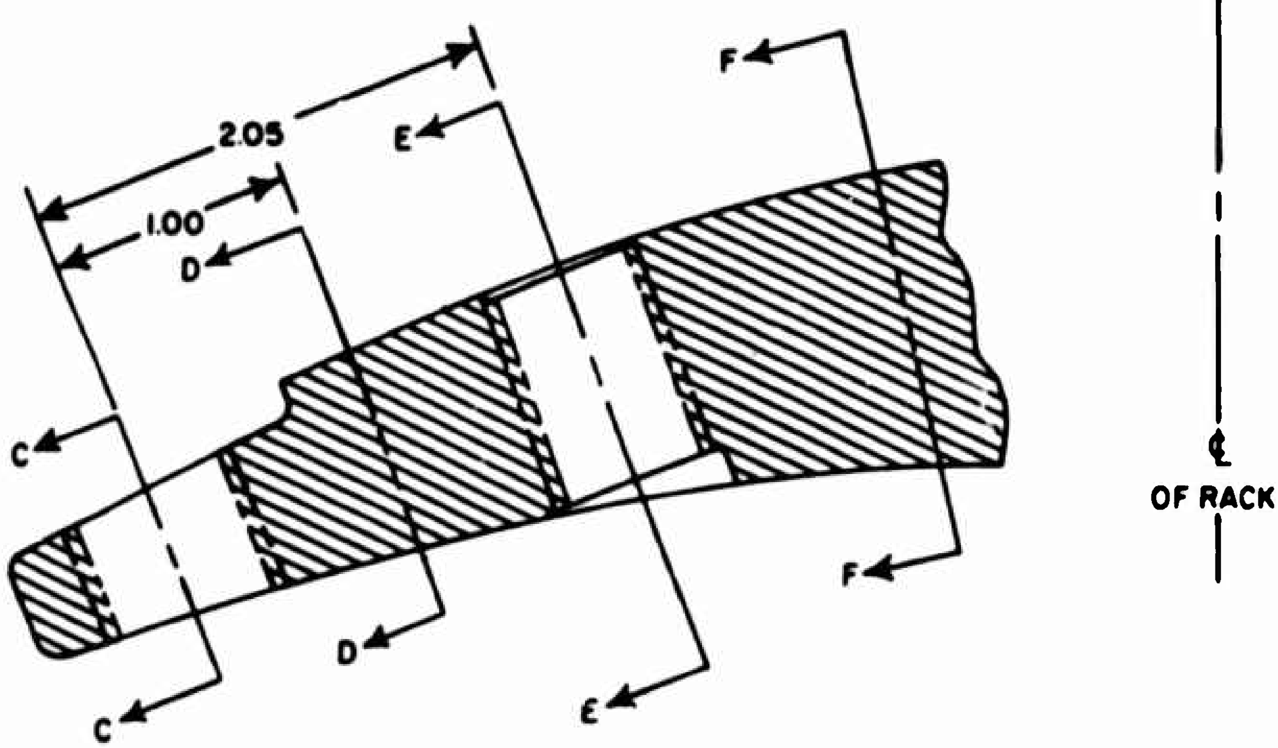
Bending and Shear Condition No. 6 (Reference figure 7)

Mat'l 60H46522
4340 Stl forging
H. T. 180-200 ksi

P^a_{SBL} = 34200 lbs.



SECTION B-B
(REF. PAGE 33)



Material 4340 Stl forging

H. T. 180-200 ksi

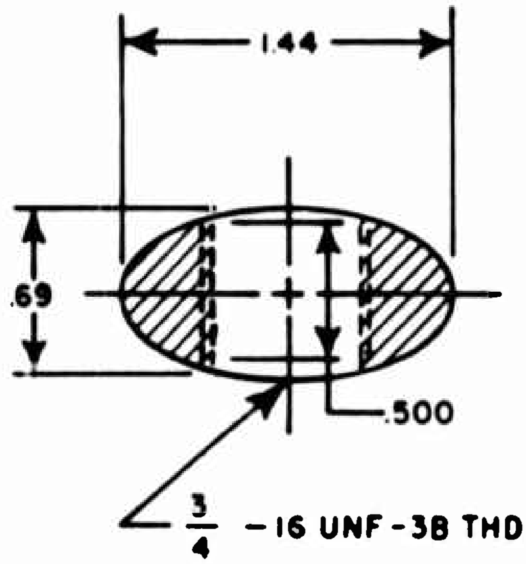
F_{tu} = 180000 psi

F_{ty} = 163000 psi

F_{su} = 109000 psi

P_s = 34200 lbs.

(Reference page 40)



Section C-C
(Reference page 40)

Thread Pitch diameter = 0.745 in.

$$A_s = \pi\,(P.D.)(L/2)$$

$$= 3.14(0.745)(0.5/2) = 0.585 \text{ in.}^2$$

$$f_s = \frac{P_s}{A_s} = \frac{34200}{0.585} = 58500 \text{ psi}$$

$$M.S. = \frac{109000}{58500} - 1 = \underline{+0.86}$$

Section D-D

Bending and Shear

P_s = 34200 lbs.

M_x = 34200 (1.0) = 34200 in.-lbs.

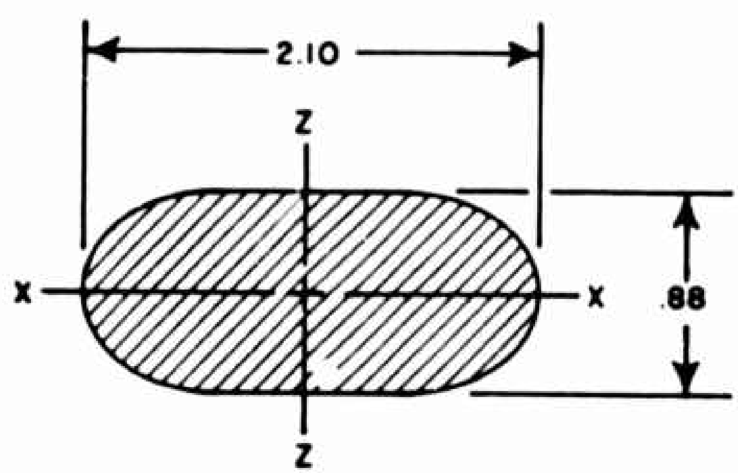
I_x = 0.091 in.^{4}

A_s = 1.62 in.^{2}

$$f_b = \frac{Mc}{I} = \frac{(34200)(0.44)}{0.091}$$

f_b = 165000 psi

$$f_s = \frac{P_s}{A_s} = \frac{34200}{1.62} = 21100 \text{ psi}$$



Section D-D
(Reference page 40)

$$\text{(Bending) } M.S. = \frac{180000}{165000} - 1 = \underline{+0.09}$$

$$\text{(Shear) } M.S. = \frac{109000}{21100} - 1 = \underline{+4.16}$$

Section E-E

Bending and Shear

P_s = 34200 lbs.
Moment arm = 2.05 in. } (Reference page 40)

$M_x = 34200(2.05) = 70000$ in.-lbs.

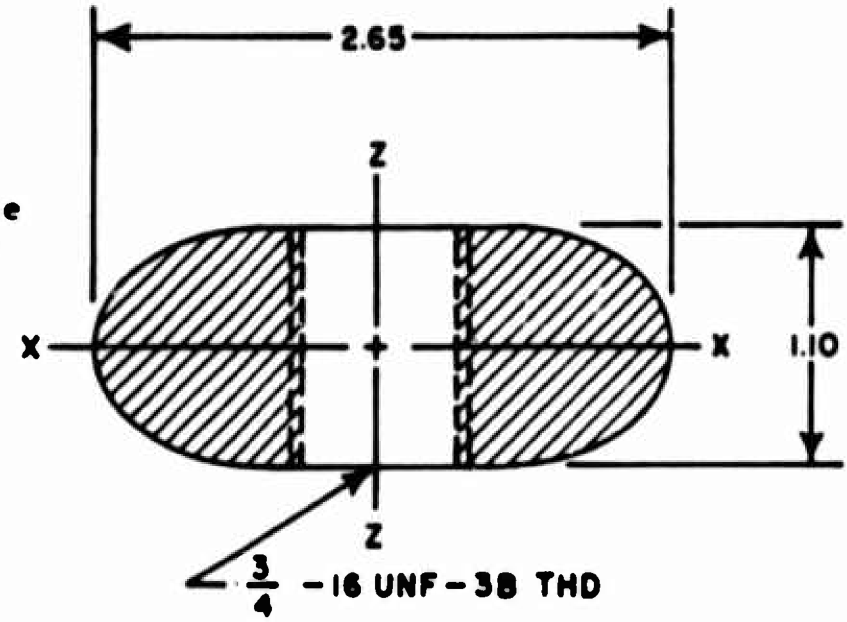
$A_s = 1.83$ in.^{2}

$Q = 0.252$ in.^{3}

$I_{x-x} = 0.1596$ in.^{4}

$$f_b = \frac{Mc}{I} = \frac{(70000)(0.55)}{0.1596}$$

$f_b = 241000$ psi



Section E-E
(Reference page 40)

Bending Modulus of Rupture

$$F_B = f_m + Kf_o$$

$$K = \frac{2Q}{I/c} - 1 = \frac{(2)(0.252)(0.55)}{0.1596} - 1 = 0.74$$

$$F_B = f_{ty} + 0.74\, f_{ty} = 1.74(163000) = 284000 \text{ psi}$$

(Bend, Ult) M.S. $= \frac{284000}{241000} - 1 = \underline{+0.18}$

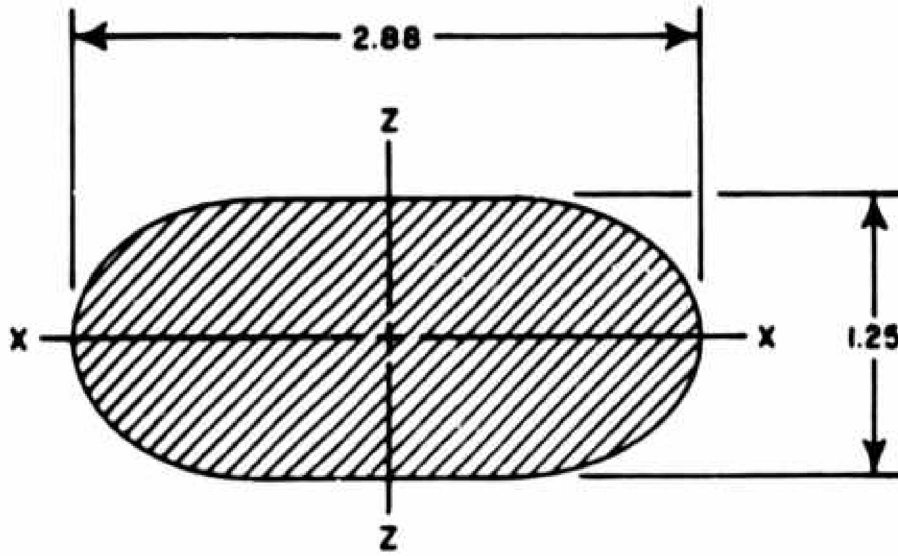
$$f_{b(yield)} = \frac{\left(\frac{70000}{1.5}\right)(0.55)}{0.1596} = 160000 \text{ psi (yield)}$$

(Bend, Yield) M.S. $= \frac{163000}{160000} - 1 = \underline{+0.02}$

$$f_s = \frac{34200}{1.83} = 18700 \text{ psi}$$

(Shear) M.S. $= \frac{109000}{18700} - 1 = \underline{+4.83}$

$F_{su} = 109000$ psi



Section F-F
(Reference page 40)

Section F-F

Bending and Shear

$P_s = 34200$ lbs.

$M_x = 34200\,(3.35)$

$= 114500$ in.-lbs.

$A_s = 3.173$ in.^{2}

$Q = 0.470$ in.^{3}

$I_{x-x} = 0.320$ in.^{4}

$$f_b = \frac{Mc}{I} = \frac{(114500)(0.625)}{0.320}$$

$f_b = 224000$ psi

Bending Modulus of Rupture

$$F_B = f_m + Kf_o$$

$$K = \frac{2Q}{I/c} - 1 = \frac{(2)(0.470)(0.625)}{(0.32)} - 1 = 0.835$$

$$F_B = f_{ty} + 0.835\, f_{ty} = 1.835\,(163000) = 299000 \text{ psi}$$

(Bend, Ult) $\text{M.S.} = \frac{299000}{224000} - 1 = \underline{+0.33}$

$$f_{b(yield)} = \frac{224000}{1.5} = 149300 \text{ psi}$$

(Bend, Yield) $\text{M.S.} = \frac{163000}{149300} - 1 = \underline{+0.09}$

$$f_s = \frac{P_s}{A_s} = \frac{34200}{3.173} = 10800 \text{ psi}$$

(Shear) $\text{M.S.} = \frac{109000}{10800} - 1 = \underline{+9.10}$

Section G-G

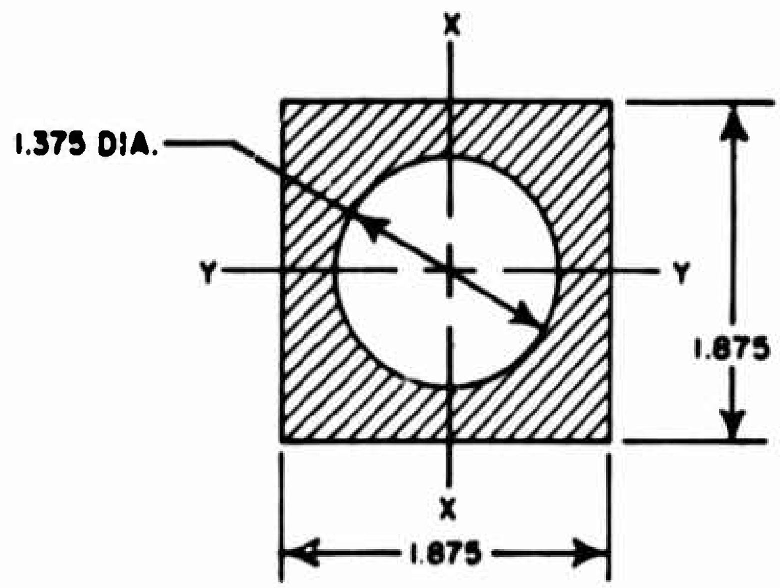
Bending and Compression

P_s = 34200 lbs.

(Reference page 40)

$M_x = (34200)(6.125)$

$= 209400$ in.-lbs.



Section G-G

(Reference page 40)

Compression Load

$P_z = P_s \cos 25^\circ$

$= 34200(0.906) = 31000$ lbs.

Shear Load

$P_y = P_s \sin 25^\circ = 34200\ (0.4225)$

$= 14450$ lbs.

$I = 0.855 \text{ in.}^4$

$A = 2.034 \text{ in.}^2$

$t = \dfrac{1.875 - 1.375}{2} = 0.25$

$D/_t = \dfrac{1.375}{0.25} = 5.5$

Bending Modulus of Rupture

F_{BR} = 270000 psi (reference MIL-HNDBK-

$f_b = \dfrac{Mc}{I} = \dfrac{(209400)(0.938)}{0.855} = 228400$ psi (ult)

$R_b = \dfrac{228400}{270000} = 0.847$

$f_c = \dfrac{P_z}{A} = \dfrac{31000}{2.034} = 15200$ psi (ult)

$R_c = \dfrac{15200}{179000} = 0.085$

(Ult) M.S. $= \dfrac{1}{[0.847 + 0.085]} - 1 = \underline{+0.07}$

AIRCRAFT ATTACHMENT CONDITION NO. 6

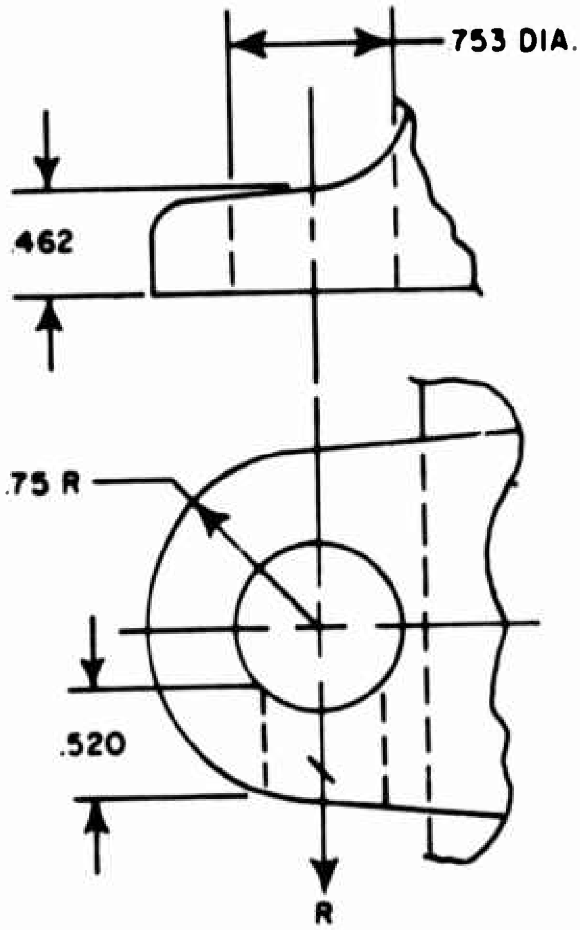
Maximum Reaction Load

(Reference page 40)

$$R = \frac{(34200)(6.35)}{(2.5)(2)} + \frac{34200 \cos 25^{\circ}}{4}$$

$$R = 43400 + 7750$$

$$R = 51150 \text{ lbs. (ult)}$$



Bearing and Shear-out Analysis

$$A_s = 2(0.520)(0.462) = 0.481 \text{ in.}^2$$

$$A_{br} = (0.753)(0.462) = 0.348 \text{ in.}^2$$

$$f_s = \frac{R}{A_s} = \frac{51150}{0.481} = 106500 \text{ psi}$$

$$f_{br} = \frac{R}{A_{br}} = \frac{51150}{0.348} = 147000 \text{ psi}$$

$$e/_D = 1.0$$

$\therefore$ use $F_{br} = 180000$ psi

$F_{su} = 109000$ psi

(Reference MIL-HNDBK-5)

$$\text{(Shear) M.S.} = \frac{109000}{106500} - 1 = \underline{+0.02}$$

$$\text{(Bearing) M.S.} = \frac{180000}{147000} - 1 = \underline{+0.22}$$

b. Linkage mechanism and drag fitting analysis

Loads applied at the 30-inch shackles have been resolved into the reaction loads and moments in planes of the linkage mechanism shown in table 3.

The individual parts of the linkage mechanism are analyzed according to the applicable combined stresses of shear, bending, compression, and tension of the critical local loads produced by load conditions No. 2 and No. 6. Also, the end fitting and attachment analysis based upon load condition No. 8 is included in this section.

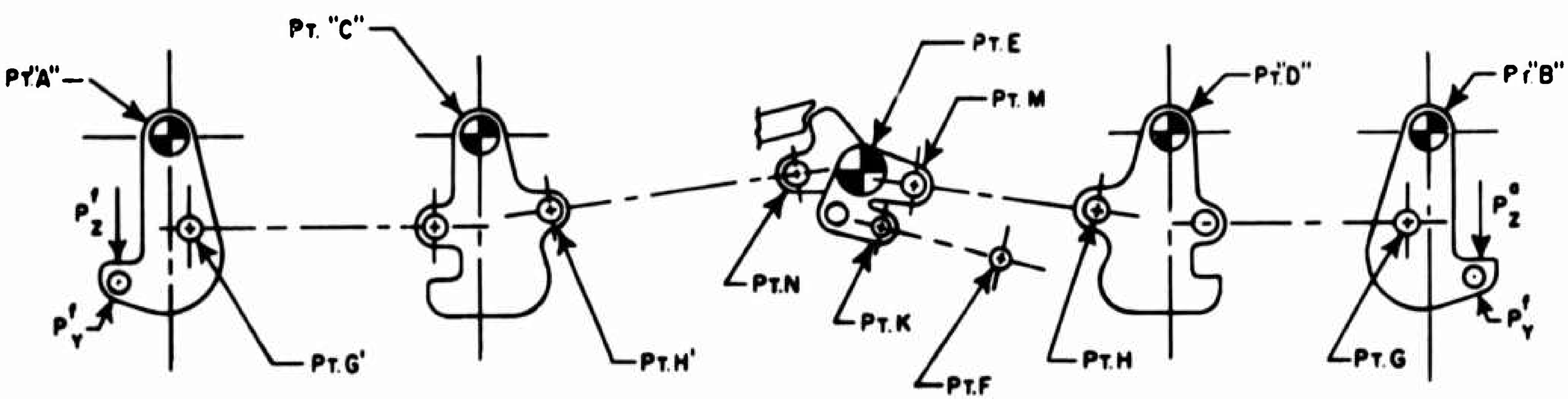


Figure 11. Linkage mechanism system

Condition	P_z^f	P_y^f *	P_z^a	P_y^a *	$P_{G'-G'}$	$P_{H'-N}$	P_{M-H}	P_{G-G}	P_{K-F}
2	-24,651	-9,036	-35,782	9,036	-10,551	-10,341	-14,527	-15,315	+2,089
6	-45,744	5,340	-30,833	-5,340	-19,578	-19,190	-12,518	-13,197	+2,683

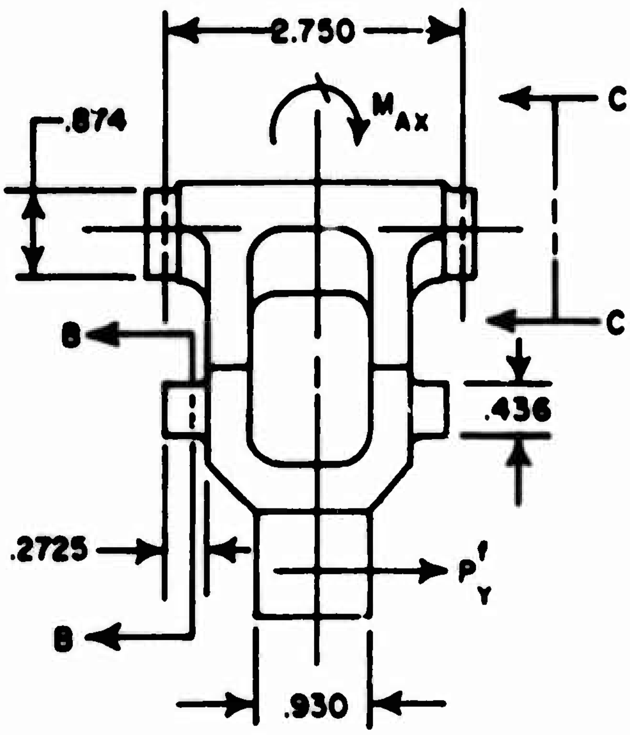
*Positive (+): Outboard

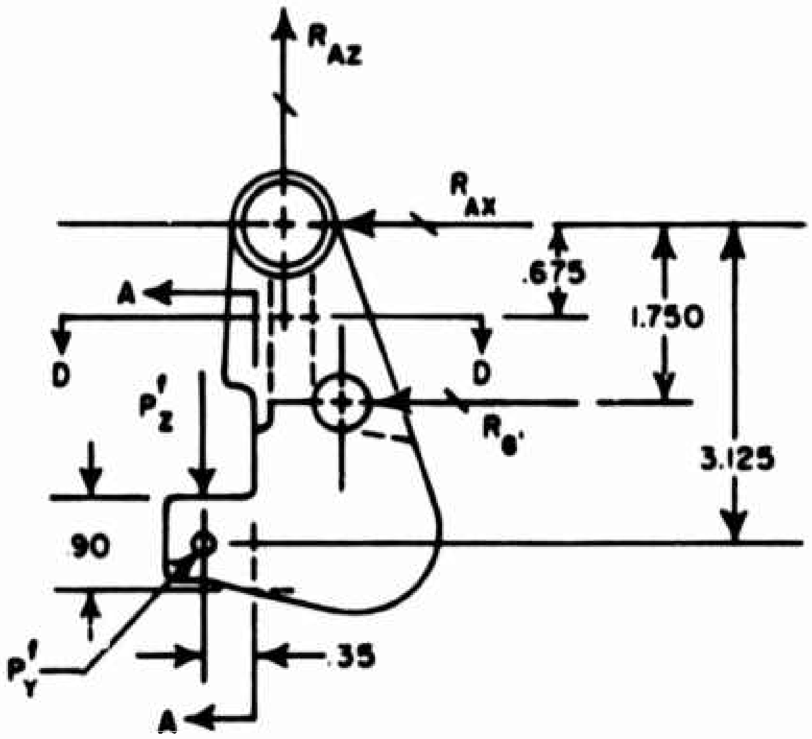
SIGN CONVENTION

(+) Tension and up

(-) Compression and down

FORWARD 30-INCH SHACKLE ANALYSIS
(Reference Drawing 60D46528)





Material 4340 Stl

H.T. 160-180 ksi

Allowables

(Reference MIL-HNDBK-5)

F_{tu} = 160000 psi

F_{ty} = 140000 psi

F_{su} = 100000 psi

F_{bu} = 219000 psi

$$A = (0.90)(0.93) = 0.837 \text{ in.}^2$$

$$I_x = \frac{(0.93)(0.9)^3}{12} = 0.0564 \text{ in.}^4$$

$$I_y = \frac{(0.90)(0.93)^3}{12} = 0.0603 \text{ in.}^4$$

P^f_z = 45744 lbs.

$R_{G'}$ = 19578 lbs.

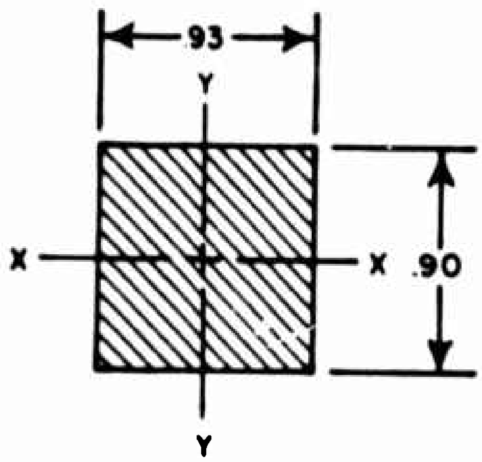
R_{Ax} = -19578 lbs.

R_{Az} = 45744 lbs.

P^f_y = 5340 lbs.

M_{Ax} = 16688 in.-lbs.

} Condition No. 6 ultimate loads and reactions (Reference page 25)



Section A-A

Bending and Shear at Section A-A

$$M_x = P_z^f (0.35)$$

$$= 45744\,(0.35) = 16000 \text{ in.-lbs. (Ult)}$$

$$f_{bx} = \frac{Mc_y}{I_x} = \frac{(16000)(0.45)}{0.0564} = 127500 \text{ psi}$$

$$M_y = P_y^f (0.35)$$

= [illegible] $(0.35) = 1870$ in.-lbs. (Ult)

$$f_{by} = \frac{M_y c_x}{I_y} = \frac{(1870)(0.465)}{0.0603} = 14400 \text{ psi}$$

$$f_{btotal} = f_{bx} + f_{by} = 127500 + 14400 = 141900 \text{ psi}$$

$$\text{M.S.} = \frac{160000}{141900} - 1 = \underline{+0.13}$$

$$P_{stotal} = \sqrt{P_y^2 + P_z^2} = \sqrt{(5340)^2 + (45744)^2}$$

$$= 46000 \text{ lbs.}$$

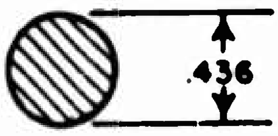
$$A_s = (0.90)(0.93) = 0.837 \text{ in.}^2$$

$$f_s = \frac{46000}{0.837} = 55000 \text{ psi}$$

$$\text{M.S.} = \frac{100000}{55000} - 1 = \underline{+0.82}$$

Bending and Shear at Section B-B

$R_{G'}$ = 19578 lbs (Reference page 48)



Section B-B (Reference page 49)

$$A = \frac{\pi}{4} D^2 = 0.785\,(0.436)^2 = 0.149 \text{ in.}^2$$

$$I = \frac{\pi}{64} D^4 = \frac{\pi}{64}(0.436)^4 = 0.001755 \text{ in.}^4$$

$$M = \frac{R_{G'}L}{2} = \frac{19578}{2}(0.136) = 1330 \text{ in.-lbs.}$$

$$f_s = \frac{R_{G'}}{2A} = \frac{19578}{2(0.149)} = 65600 \text{ psi}$$

$$\text{(Shear) M.S.} = \frac{100000}{65600} - 1 = \underline{+0.52}$$

$$f_b = \frac{Mc}{I} = \frac{1330(0.218)}{0.001755} = 165000 \text{ psi}$$

Bending Modulus of Rupture

F_B = 265000 psi (Reference MIL-HDBK-5)

$$\text{M.S.} = \frac{265000}{165000} - 1 = \underline{+0.60}$$

SIDE PLATE ATTACHMENT REACTIONS
SECTION C-C

Left-hand Side Plate

$$R^L_{Az} = \frac{R_{Az}}{2} - \frac{M_{Ax}}{2.75}$$

$$= \frac{45744}{2} - \frac{16688}{2.75}$$

$$= 16812 \text{ lbs. (Ult)}$$

$$R^L_{Ax} = \frac{R_{Ax}}{2} = \frac{-19578}{2} = -9789 \text{ lbs.}$$

Right-hand Side Plate

$$R^R_{Az} = \frac{R_{Az}}{2} + \frac{M_{Ax}}{2.75} = \frac{45744}{2} + \frac{16688}{2.75}$$

$$= 22872 + 6060 = 28932 \text{ lbs.}$$

$$R^L_{Ax} = \frac{R_{Ax}}{2} = \frac{-19578}{2} = -9789 \text{ lbs.}$$

Maximum Load

$$R = \sqrt{\left(R^L_{Az}\right)^2 + \left(R^L_{Ax}\right)^2} = \sqrt{(28932)^2 + (9789)^2}$$

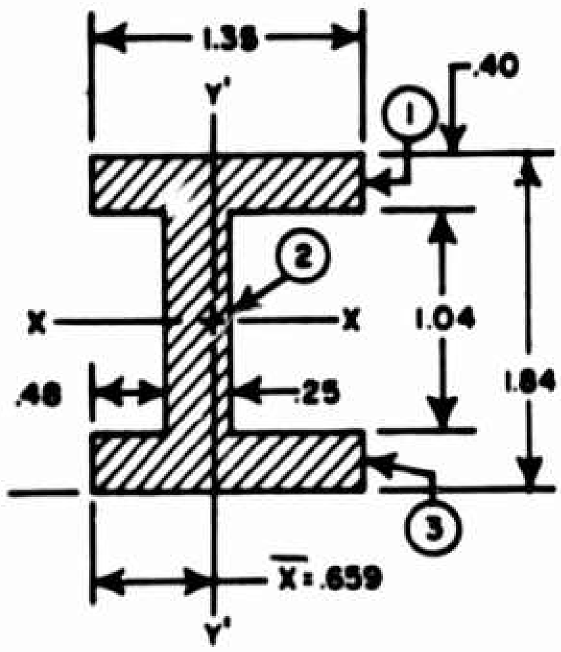
$$R = 30500 \text{ lbs. (Ult)}$$

$$A_{c-c} = \frac{\pi}{4}D^2 = 0.785(0.874)^2 = 0.596 \text{ in}^2$$

$$f_s = \frac{P}{A} = \frac{30500}{0.596} = 51200 \text{ psi}$$

$$\text{(Shear) M.S.} = \frac{100000}{51200} - 1 = \underline{+0.96}$$

Combined Bending, Tension and Shear, Section D-D
(Reference page 48 for applied loads and reactions)



ELEM NO.	A	X	AX	AX^2	I_o
1	0.540	0.675	0.364	0.246	0.082
2	0.260	0.605	0.157	0.095	0.003
3	0.540	0.675	0.364	0.246	0.082
Σ	1.340		0.885	0.587	0.167

$$\bar{X} = \frac{0.885}{1.340} = 0.659 \text{ in.}$$

$$I_{y-y} = 0.587 + 0.167 = 0.754$$

$$\bar{I}_{y'-y'} = 0.754 - 1.340(0.659)^2 = 0.172 \text{ in.}^4$$

$$\bar{I}_{x-x} = \frac{(1.35)(1.84)^3}{12} - \frac{(1.10)(1.04)^3}{12} = 0.597 \text{ in.}^4$$

$$M_{x-x} = P_y^f (2.450) = (5340)(2.450) = 13080 \text{ in.-lbs.}$$

$$M_{y'-y'} = P_z^f (0.90) - R_G (1.075) = 45744 (0.90) - 19578 (1.075) = 20150 \text{ in.-lbs.}$$

$$f_{bx-x} = \frac{M_x c_y}{I_x} = \frac{(13080)(0.92)}{0.597} = 20140 \text{ psi}$$

$$f_{by-y} = \frac{M_y c_x}{I_y} = \frac{(20150)(0.691)}{0.172} = 81000 \text{ psi}$$

$$f_t = \frac{P_z^f}{A} = \frac{45744}{1.340} = 34100 \text{ psi}$$

Torsion Shear

$$\tau = P_y^f (0.90) = 5340 (0.90) = 4800 \text{ in.-lbs.}$$

$$f_s = \frac{3\tau}{at_1^2 + 2bt_2^2}$$

$$= \frac{(3)(4800)}{(1.08)(0.25)^2 + 2(1.35)(0.38)^2}$$

$$= \frac{(3)(4800)}{0.4565} = 32200 \text{ psi}$$

$$f_{tmax} = f_{bx-x} + f_{by-y} + f_t$$

$$= 20140 + 81000 + 34100$$

$$= 135240 \text{ psi}$$

$$R_t = \frac{135240}{160000} = 0.844$$

$$R_s = \frac{32200}{100000} = 0.322$$

$$M.S. = \frac{1}{\left[(0.844)^2 + (0.322)^2\right]^{1/2}} - 1 = \underline{+0.11}$$

AFT 30-INCH SHACKLE ANALYSIS

(Reference Drawing 60D46528)

Shear and Bending Analysis

Reference pages 20 and 48 for shackle sketch and page 25 for applied loads and reactions.

Loading Condition No. 2

$$\left.\begin{aligned} P_z^a &= 35782 \text{ lbs.} \\ P_y^a &= 9036 \text{ lbs.} \\ R_G &= 15315 \text{ lbs.} \\ R_{Bx} &= -15315 \text{ lbs.} \\ R_{Bz} &= 35782 \text{ lbs.} \\ M_{Bx} &= 28238 \text{ lbs.} \end{aligned}\right\} \text{(Ult)}$$

Section A-A (Reference page 48 for sketch and properties)

$$A = 0.837 \text{ in.}^2;\ c_y = 0.45 \text{ in.};\ I_x = 0.0564 \text{ in.}^4$$

$$I_y = 0.0603 \text{ in.}^4;\ c_x = 0.465 \text{ in.}$$

$$M_x = P_z^a(0.35) = (35782)(0.35) = 12500 \text{ in.-lbs.}$$

$$M_y = P_y^a(0.35) = (9036)(0.35) = 3160 \text{ in.-lbs.}$$

$$f_{btotal} = \frac{(12500)(0.45)}{0.0564} + \frac{(3160)(0.465)}{0.0603} =$$

$$f_{btotal} = 99700 + 24600 = 124300 \text{ psi}$$

$$M.S. = \frac{160000}{124300} - 1 = \underline{+0.28}$$

$$P_{smax} = \sqrt{P_y^2 + P_z^2} = \sqrt{(9036)^2 + (35782)^2}$$

$$P_{smax} = 36900 \text{ lbs.}$$

$$f_s = \frac{P}{A} = \frac{36900}{0.837} = 44100 \text{ psi}$$

$$\text{(Shear) M.S.} = \frac{100000}{44100} - 1 = \underline{1.27}$$

Shear and Bending, Section B-B

(Reference pages 48 and 50 for sketch and properties)

$$A = 0.149 \text{ in.}^2$$

$$I = 0.001755 \text{ in.}^4$$

$$M = \frac{R_G}{2} L = \frac{15315}{2}(0.136) = 1042 \text{ in.-lbs.}$$

$$f_s = \frac{R_G}{2A} = \frac{15315}{2(0.149)} = 51400 \text{ psi}$$

$$\text{Shear (ult) M.S.} = \frac{100000}{51400} - 1 = \underline{+0.95}$$

$$f_b = \frac{Mc}{I} = \frac{(1042)(0.218)}{0.001755} = 129400 \text{ psi}$$

$$\text{Bending M.S.} = \frac{160000}{129400} - 1 = \underline{+0.24}$$

Section C-C (Reference pages 48 and 51 for sketch and properties)

Side Plate Attachment Reactions

Left-hand Side Plate

$$R^L_{Bz} = \frac{R_{Bz}}{2} - \frac{M_{Bx}}{2.75}$$

$$= \frac{35782}{2} - \frac{28238}{2.75} = 17891 - 10270$$

$$= 7621 \text{ lbs. (Ult)}$$

$$R^L_{Bx} = \frac{R_{Bx}}{2} = -\frac{15315}{2} = -7658 \text{ lbs. (Ult)}$$

Right-hand Side Plate

$$R^R_{Bz} = \frac{R_{Bz}}{2} + \frac{M_{Bx}}{2.75} = \frac{35782}{2} + \frac{28238}{2.75} = 17891 + 10270$$

$$R^R_{Bz} = 28161 \text{ lbs. (Ult)}$$

$$R^R_{Bx} = \frac{R_{Bx}}{2} = \frac{-15315}{2} = -7658 \text{ lbs. (Ult)}$$

Maximum Load

$$R = \sqrt{\left(R^R_{Bz}\right)^2 + \left(R^R_{Bx}\right)^2} = \sqrt{(28161)^2 + (7658)^2}$$

$$= 29150 \text{ lbs. (Ult)}$$

$$A_{c-c} = 0.596 \text{ in.}^2 \text{ (Reference page 51)}$$

$$f_s = \frac{R}{A} = \frac{29150}{0.596} = 48900 \text{ psi (Ult)}$$

$$\text{Shear (Ult)} \quad M.S. = \frac{100000}{48900} - 1 = \underline{+1.04}$$

Combined Bending, Tension and Shear, Section D-D

(Reference pages 48 and 52 for section sketch and properties)

$\bar{I}_{y-y} = 0.191 \text{ in.}^4;\ \bar{I}_{x-x} = 0.597 \text{ in.}^4;\ A = 1.340 \text{ in.}^2$

$M_{x-x} = P_y^a (2.450) = 9036\ (2.45) = 22100 \text{ in.-lbs.}$

$M_y = 35782\,(0.90) - 15315\,(1.075) = 15700 \text{ in.-lbs. (Ult)}$

$$f_{by} = \frac{M_y c_x}{I_y} = \frac{(15700)(0.691)}{0.191} = 56800 \text{ psi}$$

$$f_{bx} = \frac{M_x c_y}{I_x} = \frac{(22100)(0.92)}{0.597} = 34100 \text{ psi}$$

$$f_t = \frac{P_z^a}{A} = \frac{35782}{1.340} = 26700 \text{ psi}$$

Torque: $\tau = P_y^a (0.90) = 9036\ (0.90) = 8120 \text{ in.-lbs.}$

$$f_{storque} = \frac{3(8120)}{(0.4565)^*} = 53450 \text{ psi}$$

*Reference page 53

$f_{tmax} = f_{bx} + f_{by} + f_t = 34100 + 56800 + 26700 = 117600 \text{ psi}$

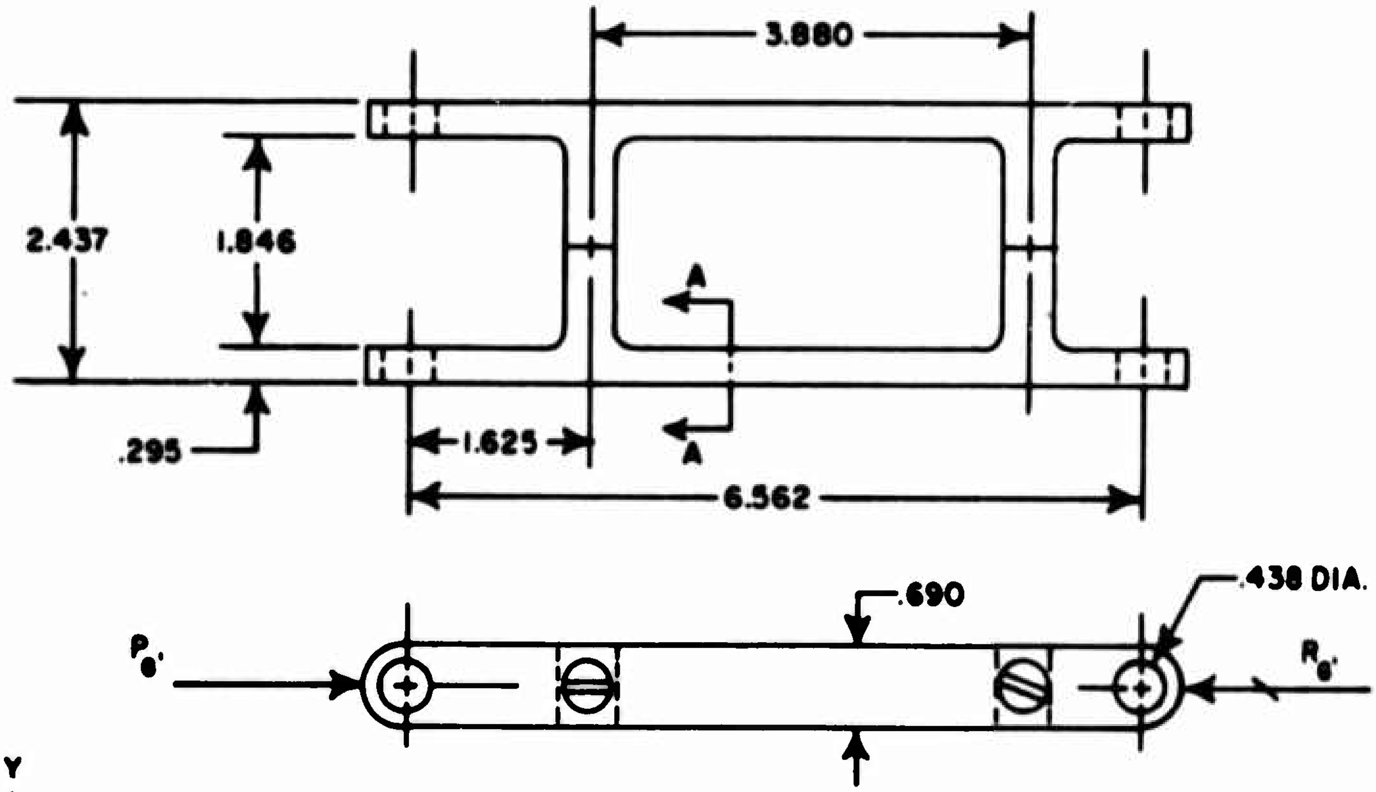
$$R_t = \frac{117600}{160000} = 0.735$$

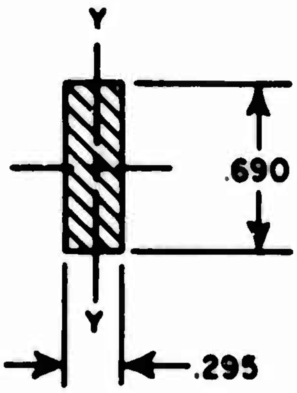
$$R_s = \frac{53450}{100000} = 0.535$$

$$M.S. = \frac{1}{\left[(0.735)^2 + (0.535)^2\right]^{1/2}} - 1 = \underline{+0.10}$$

FORWARD LINK CONNECTING ANALYSIS

(Reference Drawing 60C46530)





SECTION A-A

Stl material 4340 forging

H. T. 160-180 ksi

$P_{G'}$ = 19578 lbs. (Ult)

(Reference pages 25 and 47)

$$A = 0.295(0.690) = 0.203 \text{ in.}^2$$

$$I_{y-y} = \frac{bh^3}{12} = \frac{(0.690)(0.295)^3}{12} = 0.00147 \text{ in.}^4$$

$$\rho = \sqrt{I/A} = \sqrt{0.00147/0.203} = 0.085 \text{ in.}$$

$$L' = \frac{L}{\sqrt{c}} = \frac{3.88}{\sqrt{4}} = 1.94 \text{ in.}$$

$$L'/\rho = \frac{1.94}{0.085} = 22.8 \qquad \therefore F_c = 160000 \text{ psi (crippling)}$$

Stress Allowables

$$\left.\begin{aligned} F_{tu} &= 160000 \text{ psi} \\ F_{ty} &= 140000 \text{ psi} \\ F_{bru} &= 219000 \text{ psi} \\ F_{bry} &= 189000 \text{ psi} \end{aligned}\right\} \text{(Reference MIL-HDBK-5)}$$

Applied load $P_{G'}$ (Ult) = 19578 lbs. (Total) (Reference page 58)

Compression, Section A-A

$$\text{Load} = \frac{P_{G'}}{2} = \frac{19578}{2} = 9789 \text{ lbs.}$$

$$\text{Area} = 0.295\,(0.690) = 0.203 \text{ in.}^2$$

$$f_c = \frac{P}{A} = \frac{9789}{0.203} = 48200 \text{ psi}$$

$$\text{(Ult) M.S.} = \frac{160000}{48200} - 1 = \underline{+2.32}$$

Bearing Stress

$$A_{bru} = (\text{Dia.})(\text{Thick})$$

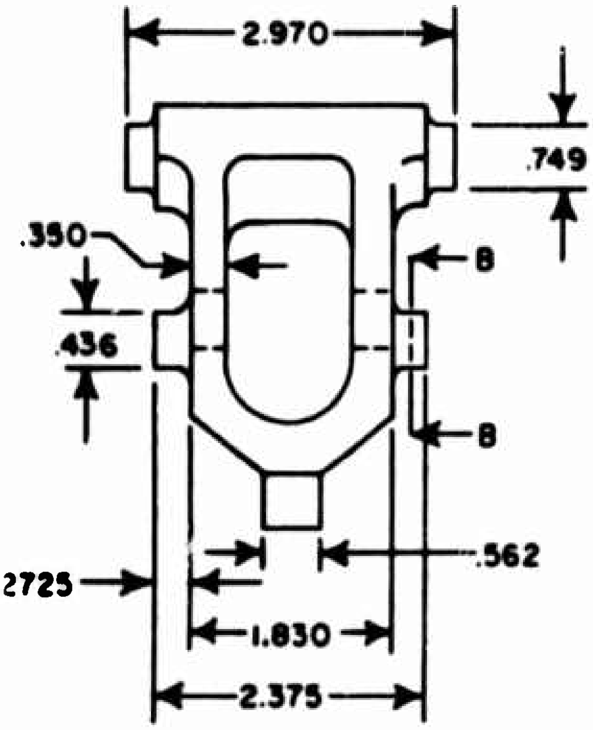
$$= (0.438)(0.295) = 0.129 \text{ in.}^2$$

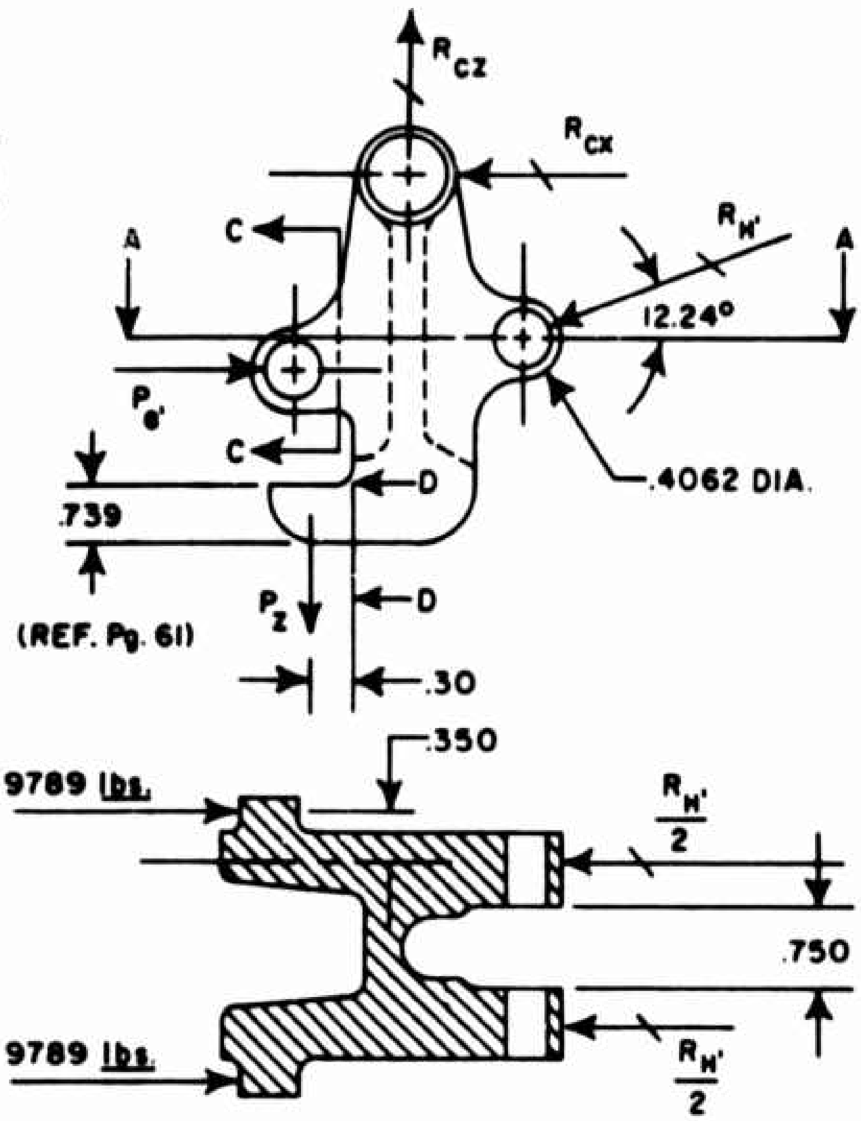
$$f_{bru} = \frac{P_{G'}}{2A_{br}} = \frac{19578}{2(0.129)} = 75800 \text{ psi}$$

$$\text{(Ult) M.S.} = \frac{219000}{75800} - 1 = \underline{+1.89}$$

FORWARD 14-INCH SHACKLE ANALYSIS

(Reference Drawing 63J14363)





SECTION A-A

Reference Drawing 63J14363

Material ~ 4340 Stl forging

H. T. ~ 180-200 ksi

Stress Allowables

Reference MIL-HNDBK-5)

F_{tu} = 180000 psi

F_{ty} = 163000 psi

F_{cy} = 179000 psi

F_{bru} = 250000 psi

F_{su} = 109000 psi

R_{cz} = 4067 lbs.

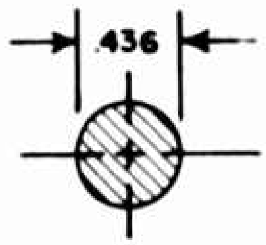
R_{cx} = 860 lbs.

$R_{H'}$ = 19190 lbs.

$P_{G'}$, $R_{G'}$ = 19578 lbs.

} Condition No. 6 Ult loads and reactions, ref. pages 25 and 47

Shear and Bending, Section B-B



Section B-B
(Reference page 60)

$$A = \frac{\pi}{4}D^2 = 0.785(0.436)^2 = 0.149 \text{ in.}^2 \qquad P_{G'} = 19578 \text{ lbs.}$$

(Reference page 60)

$$f_{su} = \frac{P_{G'}}{2A} = \frac{19578}{2(0.149)} = 65700 \text{ psi}$$

$$\text{Ult shear M.S.} = \frac{109000}{65700} - 1 = \underline{+0.66}$$

$$I = \frac{\pi}{64}D^4 = \frac{\pi}{64}(0.436)^4 = 0.001765 \text{ in.}^4$$

$$M = \frac{P_{G'}}{2} L = \frac{19578}{2}(0.136) = 1330 \text{ in.-lbs.}$$

$$f_b = \frac{Mc}{I} = \frac{(1330)(0.218)}{0.001765} = 164000 \text{ psi (Ult)}$$

$$\text{Ult bending M.S.} = \frac{180000}{164000} - 1 = \underline{+0.10}$$

Determination for the Ult Vertical Load P_z (Reference page 60)

$$F_{tu} = 180000 \text{ psi}$$

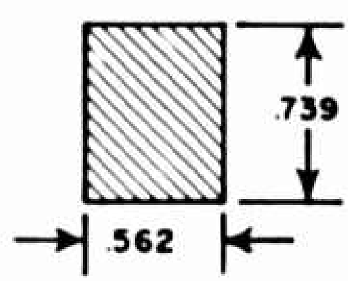
$$F_{tu} = \frac{Mc}{I} = \frac{6M}{bh^2} = \frac{6M}{(0.562)(0.739)^2} = 19.5M$$

$$M = \frac{180000}{19.5} = 9240 \text{ in.-lbs.}$$

$$M = P_z L = P_z(0.30) = 9240$$

$$P_z = \frac{9240}{0.30} = 30800 \text{ lbs. (Ult) Allowable}$$

$$R_{H'} = \frac{30800(0.68)}{1.788} = 11700 \text{ lbs. (Not critical)}$$



Section D-D

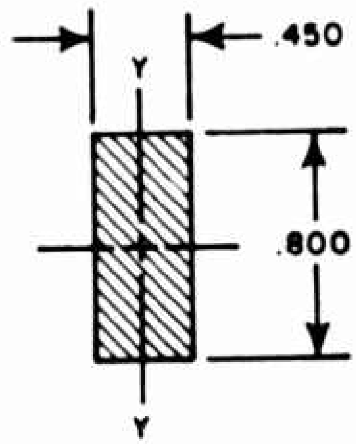
Bending and Compression, Section C-C

Applied load, $R_1 = \frac{P_{G'}}{2} = 9789$ lbs. (Ult)

(Reference page 60)

Moment arm, L = 0.350 in.

(Reference page 60)



Section C-C

(Reference page 60, assumed effective area)

$$I_{y-y} = \frac{bh^3}{12} = \frac{(0.800)(0.450)^3}{12}$$

$$I_{y-y} = 0.006 \text{ in.}^4$$

$$A = bh = (0.80)(0.45) = 0.360 \text{ in.}^2$$

$$f_c = \frac{R_1}{A} = \frac{9789}{0.360} = 27200 \text{ psi (Ult)}$$

$$M = R_1 L = 9789(0.35) = 3420 \text{ in.-lbs. (Ult)}$$

$$f_b = \frac{Mc}{I} = \frac{(3420)(0.225)}{0.006} = 128000 \text{ psi (Ult)}$$

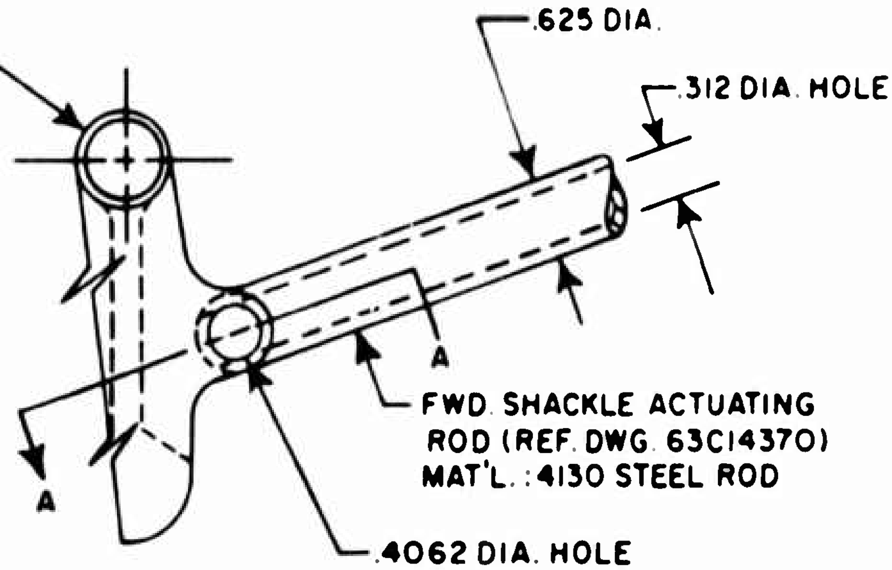
$$f_{cmax} = f_c + f_b$$

$$= 27200 + 128000$$

$$= 155200 \text{ psi (Ult)}$$

$$M.S. = \frac{179000}{155200} - 1 = \underline{+0.15}$$

Lug and Pin Analysis; Bearing



Loading Condition No. 6

Axial load, $R_{H'}$ = 19190 lbs (Ult)

(Reference page 60)

Bearing Area

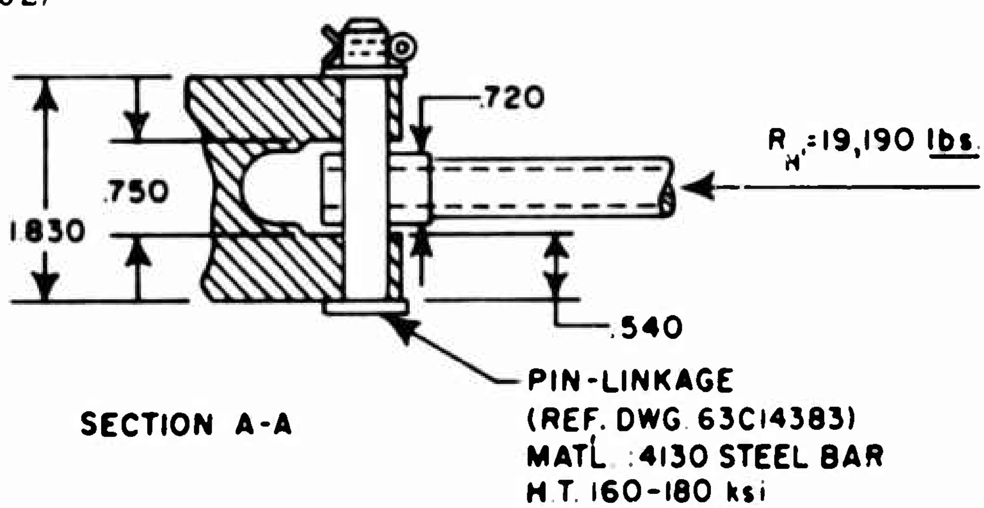
$$A_{(shk)} = (1.83-0.75)(0.4062)$$

$$= 0.439 \text{ in.}^2$$

$$A_{(rod)} = (0.720)(0.4062) - \frac{\pi}{4}(0.312)^2$$

$$= 0.292 - 0.076$$

$$= 0.216 \text{ in.}^2$$



SECTION A-A

$$f_{br(shk)} = \frac{R_{H'}}{A} = \frac{19190}{0.439} = 43700 \text{ psi (Ult)}$$

$$f_{br(rod)} = \frac{R_{H'}}{A_{ROD}} = \frac{19190}{0.216} = 88800 \text{ psi (Ult)}$$

F_{tu} = 160000 psi
F_{ty} = 140000 psi
F_{bru} = 219000 psi
(Reference page 60)

$$\text{Ult bearing M.S.} = \frac{219000}{88800} - 1 = \underline{+1.47}$$

Shear Stress

$$A_{pin} = 0.785\, D^2 = 0.785\,(0.404)^2 = 0.128 \text{ in.}^2$$

Allowable shear load = 160000 (0.128)(2)(0.7) = 28700 lbs.

$$\text{Ult shear M.S.} = \frac{28700}{19190} - 1 = \underline{+0.49}$$

AFT LINK CONNECTING ANALYSIS

(Reference Drawing 60C46530)

Compression and Bearing Analysis

Reference page 58 for sketch of aft connecting link and page 59 for stress allowables.

Condition No. 2

Applied load, R_G = 15315 lbs. (Ult) (Reference pages 25 and 47)

$$f_c = \frac{R_G}{2A} = \frac{15315}{2(0.203)} = 37800 \text{ psi}$$

$$(\text{Ult comp}) \text{ M.S.} = \frac{160000}{37800} - 1 = \underline{+3.23}$$

A_{bru} = 0.129 in.^{2} (Reference page 59)

$$f_{bru} = \frac{R_G}{2A_{bru}} = \frac{15315}{2\ (0.129)} = 59400 \text{ psi}$$

$$\text{Bearing M.S.} = \frac{219000}{59400} - 1 = \underline{+2.69}$$

AFT 14-INCH SHACKLE ANALYSIS
(Reference Drawing 63J14363)

Reference pages 21 and 60 for shackle sketch and page 25 for applied loads and reactions.

Loading Condition No. 2

$$\left.\begin{aligned} P_G &= 15315 \text{ lbs.} \\ R_H &= 14527 \text{ lbs.} \\ R_{Dx} &= 1381 \text{ lbs.} \\ R_{Dz} &= 3947 \text{ lbs.} \end{aligned}\right\} \text{(Ult)}$$

Shear and Bending, Section B-B
(Reference pages 60 and 61 for sketch and properties)

$$\left.\begin{aligned} A &= 0.149 \text{ in.}^2 \qquad c = 0.218 \text{ in.} \\ I &= 0.001765 \text{ in.}^4 \end{aligned}\right\} \text{Reference page 61}$$

$$M = (P_G/2)(0.136) = \frac{(15315)(0.136)}{2} = 1042 \text{ in.-lbs.}$$

$$f_s = \frac{P_G}{2A} = \frac{15315}{2(0.149)} = 51400 \text{ psi}$$

$$\text{Shear M.S.} = \frac{109000}{51400} - 1 = \underline{1.12}$$

$$f_b = \frac{Mc}{I} = \frac{(1042)(0.218)}{0.001765} = 128800 \text{ psi}$$

$$\text{Bending (Ult) M.S.} = \frac{180000}{128800} - 1 = \underline{+0.40}$$

Bending and Compression, Section C-C
(Reference pages 60 and 62 for sketch and properties)

Applied load, $R_1 = \frac{P_G}{2} = \frac{15315}{2} = 7658$ lbs. (Ult) (Reference page 65)

$I_{y-y} = 0.006$ in.^{4}, $c = 0.225$ in.
$A = 0.360$ in.^{2}, Moment arm, $L = 0.350$ in.
(Reference page 62)

$$f_c = \frac{R_1}{A} = \frac{7658}{0.360} = 21300 \text{ psi (Ult)}$$

$$M = R_1 L = 7658(0.350) = 2680 \text{ in.-lbs.}$$

$$f_b = \frac{Mc}{I} = \frac{(2680)(0.225)}{0.006} = 100800 \text{ psi (Ult)}$$

$$f_{cmax} = f_b + f_c$$

$$= 100800 + 21300$$

$$= 122100 \text{ psi}$$

$$M.S. = \frac{179000}{122100} - 1 = \underline{+0.46}$$

Lug and Pin Analysis; Bearing

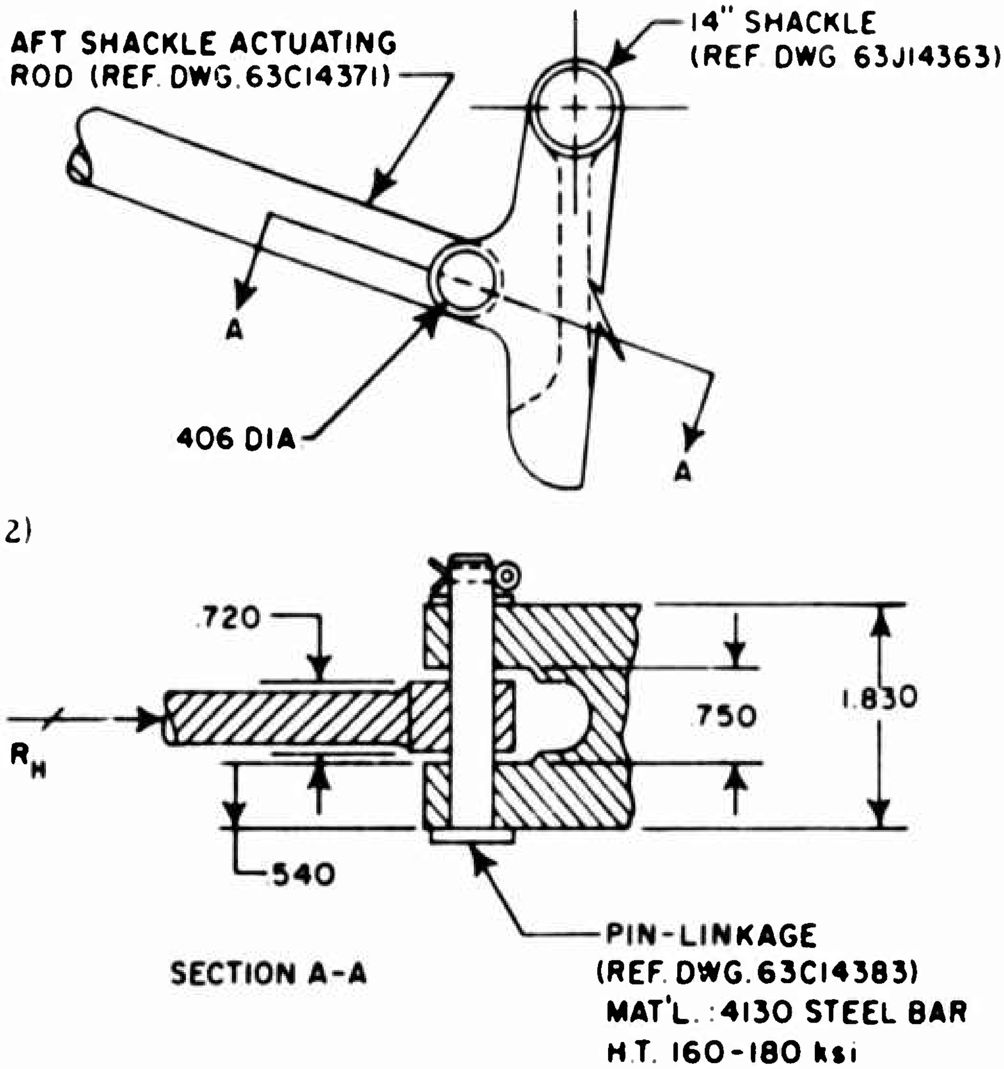
Loading condition No. 2

Axial load

R_H = 14527 lbs. (Ult)

(Reference page 25)

Bearing Area



$A_{(shk)} = (1.83-0.75)(0.4062)$

$= 0.439 \text{ in.}^2$

$A_{(rod)} = (0.720)(0.4062)$

$= 0.292 \text{ in.}^2$

$f_{br(shk)} = \frac{R_H}{A} = \frac{14527}{0.439} = 33100$ psi

$f_{br(rod)} = \frac{R_H}{A} = \frac{14527}{0.292} = 49800$ psi

Ult bearing M.S. $= \frac{219000}{49800} - 1 = \underline{+3.40}$

Shear allowable

P'_s = 28700 lbs. (Reference page 63)

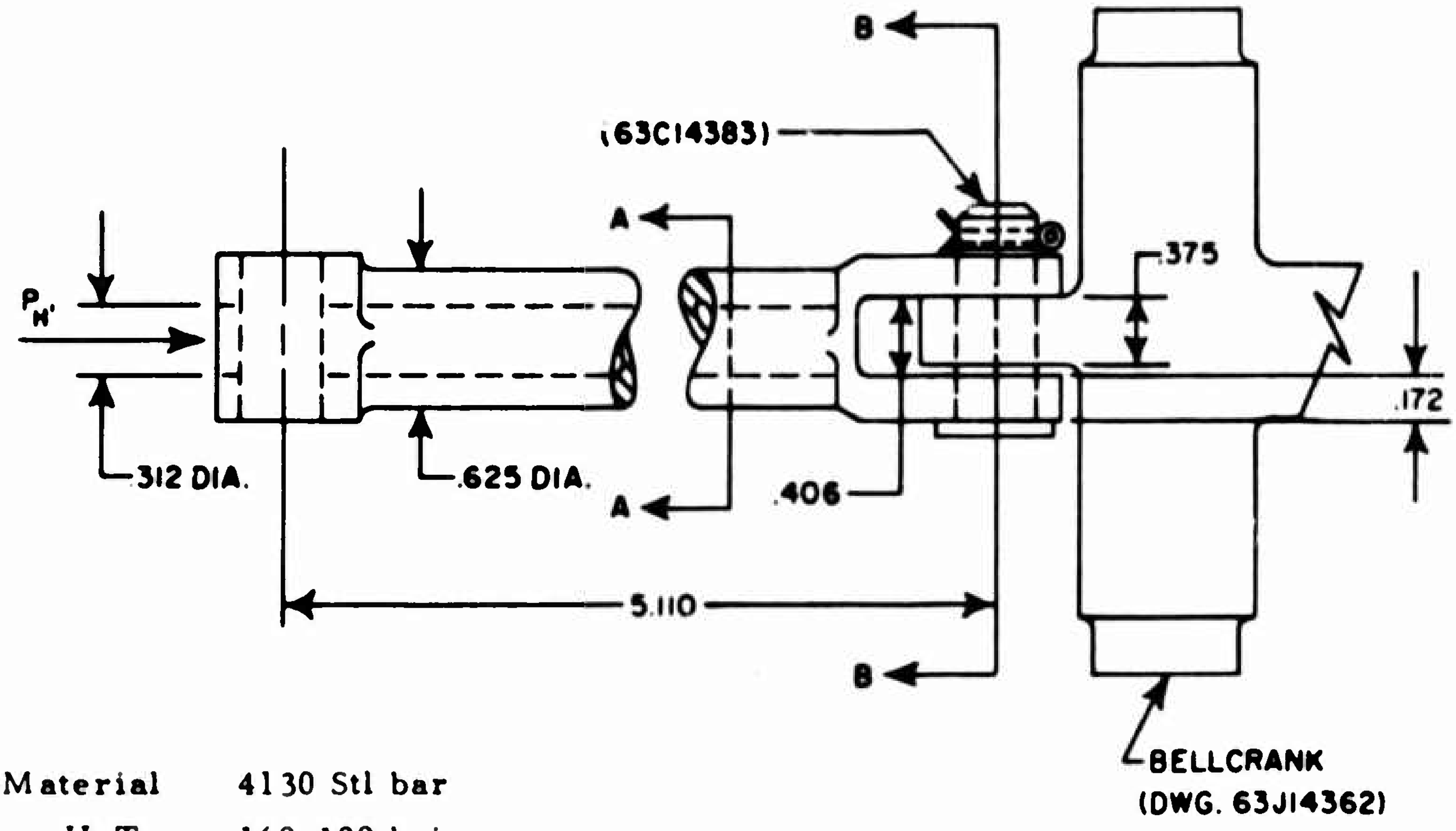
(Pin) Ult shear M.S. $= \frac{28700}{14527} - 1 = \underline{+0.97}$

FORWARD SHACKLE ACTUATING ROD ANALYSIS

(Reference Drawing 63C14370)

Compression Stress

Condition No. 6; $P_{H'}$ = 19190 lbs. (Ult) (Reference pages 25 and 47)

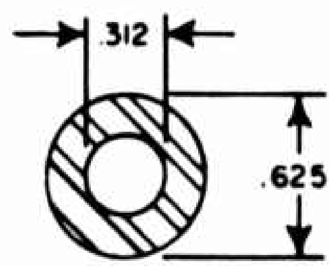


Material 4130 Stl bar

H. T. 160-180 ksi

$$A = \frac{\pi}{4}\left[D_o^2 - D_i^2\right] = 0.785\left[(0.625)^2 - (0.312)^2\right]$$

$$= 0.230 \text{ in.}^2$$



SECTION A-A

$$I = \frac{\pi}{64}\left[D_o^4 - D_i^4\right] = 0.0491\left[(0.625)^4 - (0.312)^4\right]$$

$$I = 0.00717 \text{ in.}^4$$

$$L' = \frac{L}{\sqrt{C}} = \frac{5.110}{1} = 5.110$$

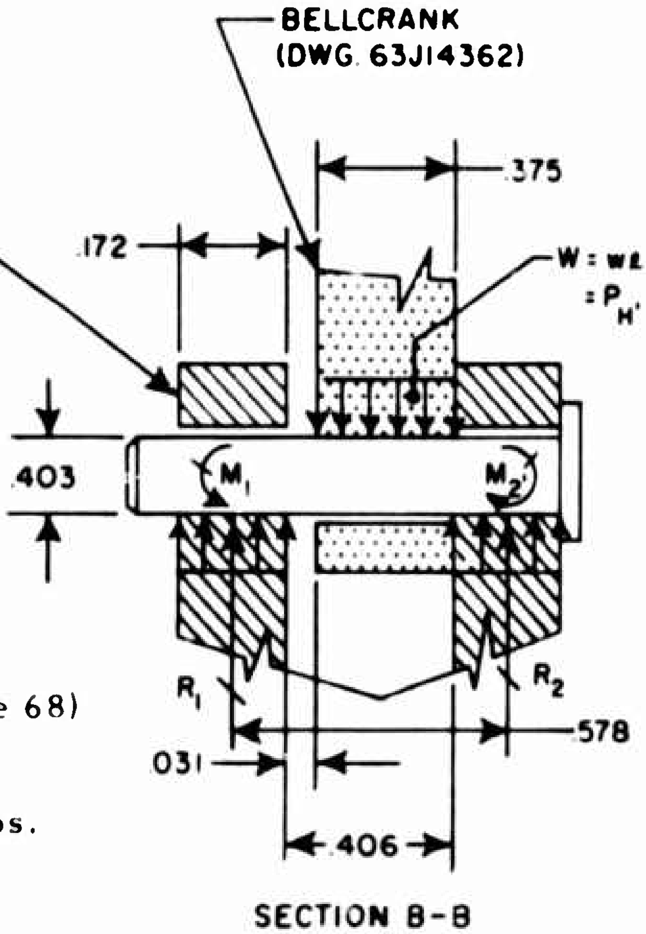
$$\rho = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.00717}{0.230}} = 0.177 \text{ in.}$$

$$\frac{L'}{\rho} = \frac{5.110}{0.177} = 28.8$$

$$F_c = 156000\left[1 - \frac{156000(28.8)^2}{4\pi^2(29)10^6}\right] = 138500 \text{ psi (Allowable)}$$

$$f_c = \frac{19190}{0.230} = 83400 \text{ psi} \qquad M.S. = \frac{138500}{83400} - 1 = \underline{+0.67}$$

Lug and Pin Analysis



Maximum hole diameter = 0.4067 in.

Minimum pin diameter = 0.402 in.

Difference 0.0037 in.

Assume pin to act as "fixed end" beam, uniform loaded.

$P_{H'}$ = 19190 lbs. (Ult) (Reference page 68)

$$R_1 = R_2 = \frac{W}{2} = \frac{P_{H'}}{2} = \frac{19190}{2} = 9595 \text{ lbs.}$$

$$M_1 = \frac{WL}{12} = \frac{(19190)(0.578)}{12} = 925 \text{ in.-lbs.}$$

$$I_{PIN} = \frac{\pi}{64} D^4 = \frac{\pi}{64}(0.404)^4 = 0.0013 \text{ in.}^4$$

$$f_b = \frac{Mc}{I} = \frac{(925)(0.202)}{0.0013} = 143500 \text{ psi (Ult)}$$

$$\text{Pin bending M.S.} = \frac{160000}{143500} - 1 = \underline{+0.11}$$

Shear stress

Allowable P_s = 28700 lbs. (Reference page 63)

$$\text{M.S.} = \frac{28700}{19190} - 1 = \underline{+0.49}$$

CENTER BELLCRANK ANALYSIS

(Reference Drawing 63J14362)

Lug and Pin Analysis

(Reference pages 25 and 47)

Loading condition No. 6

$P_{H'}$ = 19190 lbs.

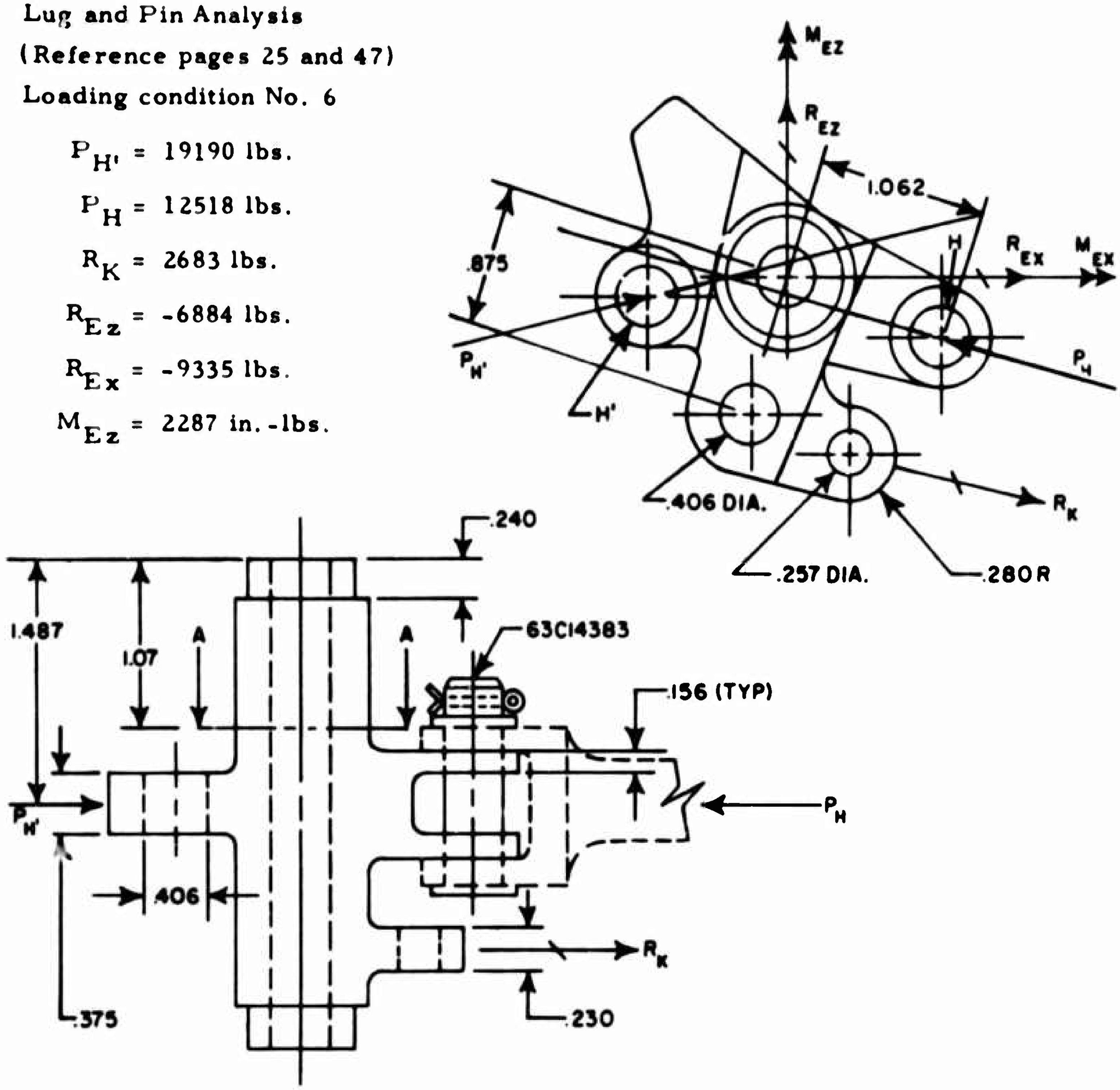
P_H = 12518 lbs.

R_K = 2683 lbs.

R_{Ez} = -6884 lbs.

R_{Ex} = -9335 lbs.

M_{Ez} = 2287 in.-lbs.



Material 4130 Stl forging

H. T. 160-180000 psi

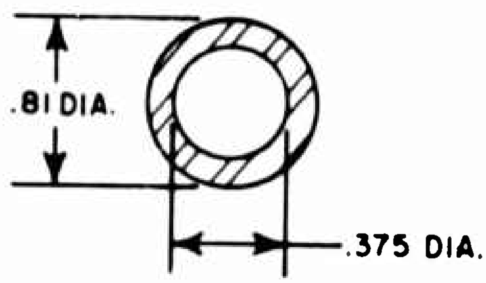
Allowables

F_{tu} = 160000 psi

F_{su} = 100000 psi (Reference MIL-HNDBK-5)

F_{bru} = 287000 psi

Bending and Shear Check at Section A-A
(Reference page 70)



Section A-A

Left-hand Reaction

$$R'_{Ez} = \frac{R_{Ez}}{2} = \frac{6884}{2} = 3442 \text{ lbs. (Down)}$$

$$R'_{Ex} = \frac{R_{Ex}}{2} + \frac{M_{Ez}}{2.254} = \frac{9335}{2} + \frac{2287}{2.254} = 5683 \text{ lbs. (Forward)}$$

$$M = \left[(3442)^2 + (5683)^2\right]^{1/2} (1.07 - 0.120)$$

$$= (6640)(0.95) = 6300 \text{ in.-lbs. (Ult)}$$

$$I = \frac{\pi}{64}\left[D_o^{\,4} - D_i^{\,4}\right] = \frac{\pi}{64}\left[(0.81)^4 - (0.375)^4\right] = 0.020 \text{ in.}^4$$

$$A = \frac{\pi}{4}\left[D_o^{\,2} - D_i^{\,2}\right] = \frac{\pi}{4}\left[(0.81)^2 - (0.375)^2\right] = 0.405 \text{ in.}^2$$

$$f_b = \frac{Mc}{I} = \frac{(6300)(0.405)}{0.020} = 127600 \text{ psi}$$

$$R_b = \frac{127600}{160000} = 0.797$$

$$f_s = \frac{P}{A} = \frac{6640}{0.405} = 16400 \text{ psi}$$

$$R_s = \frac{16400}{100000} = 0.164$$

$$M.S. = \frac{1}{\left[(0.797)^2 + (0.164)^2\right]^{1/2}} - 1 = \underline{+0.23}$$

Safety Pin Hole

M_E (Due to pinned shut firing)

$p = 70000$ psi (burst pressure)

$A_{slavepiston} = 0.785(0.327)^2 = 0.084 \text{ in.}^2$

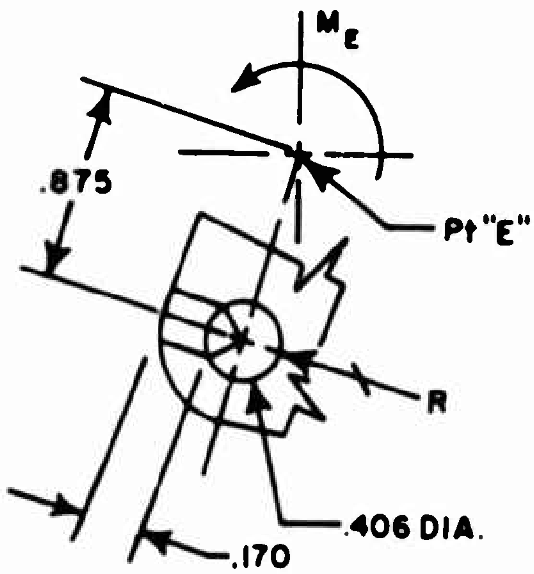
$L_1 = 1.062$ in.; $L_2 = 0.875$ in.

$M_E = pA\ L_1$

$= 70000\ (0.084)(1.062)$

$= 6250$ in.-lbs.

$R = \frac{M}{L_2} = \frac{6250}{0.875} = 7140$ lbs.



Shear-out Check

$A_s = 2L_3t = 2(0.170)(0.23) = 0.078 \text{ in.}^2$

$f_s = \frac{R}{A_s} = \frac{7140}{0.078} = 91500$ psi

$F_s = 100000$ psi (Reference page 70)

$M.S. = \frac{100000}{91500} - 1 = \underline{+0.10}$

Bearing at Point H'
(Reference page 70)

$$A_{bru} = 0.375(0.406) = 0.152 \text{ in.}^2$$

$$P_{H'} = 19190 \text{ lbs. (Ult) (Reference page 70)}$$

$$f_{bru} = \frac{P}{A} = \frac{19190}{0.152} = 126000 \text{ psi}$$

$$\text{Ult bearing M.S.} = \frac{^{*}287000}{126000} - 1 = \underline{+1.28}$$

Bearing at Point H
(Reference page 70)

$$A_{bru} = (0.156)(0.406)(2) = 0.128 \text{ in.}^2$$

$$P_H = 12518 \text{ lbs. (Reference page 70)}$$

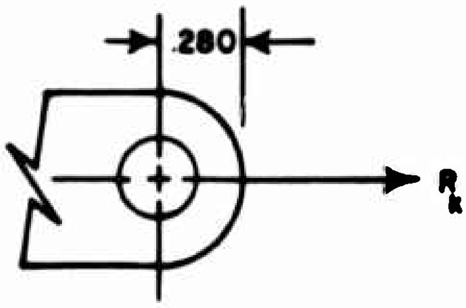
$$f_{bru} = \frac{P}{A} = \frac{12518}{0.128} = 98000 \text{ psi}$$

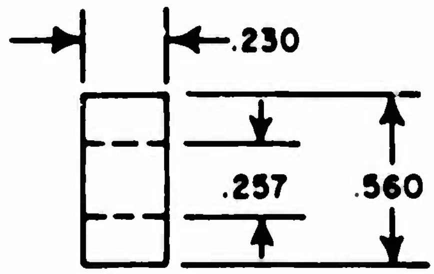
$$\text{(Bearing) M.S.} = \frac{^{*}287000}{98000} - 1 = \underline{+1.93}$$

*Ult allowables, reference page 70

Tension at Point "K"; R_K = 2683 lbs. (Ult) (Reference page 70)

Lug Check (Analysis per Reference 3)





$$\left.\frac{W}{D} = \frac{0.560}{0.257} = 2.18\right\} K_t = 0.97$$

$$\left.\begin{array}{l}\frac{D}{t} = \frac{0.257}{0.230} = 1.12 \\ \frac{a}{D} = \frac{0.280}{0.257} = 1.09\end{array}\right\} K_{br} = 0.975$$

$$A_{br} = (0.257)(0.230) = 0.059 \text{ in.}^2$$

$$A_t = (0.560-0.257)(0.230) = 0.0697 \text{ in.}^2$$

Shear-Bearing Allowable

$$P'_{br} = K_{br} A_{br} F_{tu}$$

$$= (0.975)(0.059)(160000)$$

$$= 9200 \text{ lbs.}$$

Tension Allowable

$$P'_t = K_t A_t F_{tu}$$

$$= 0.97(0.0697)(160000)$$

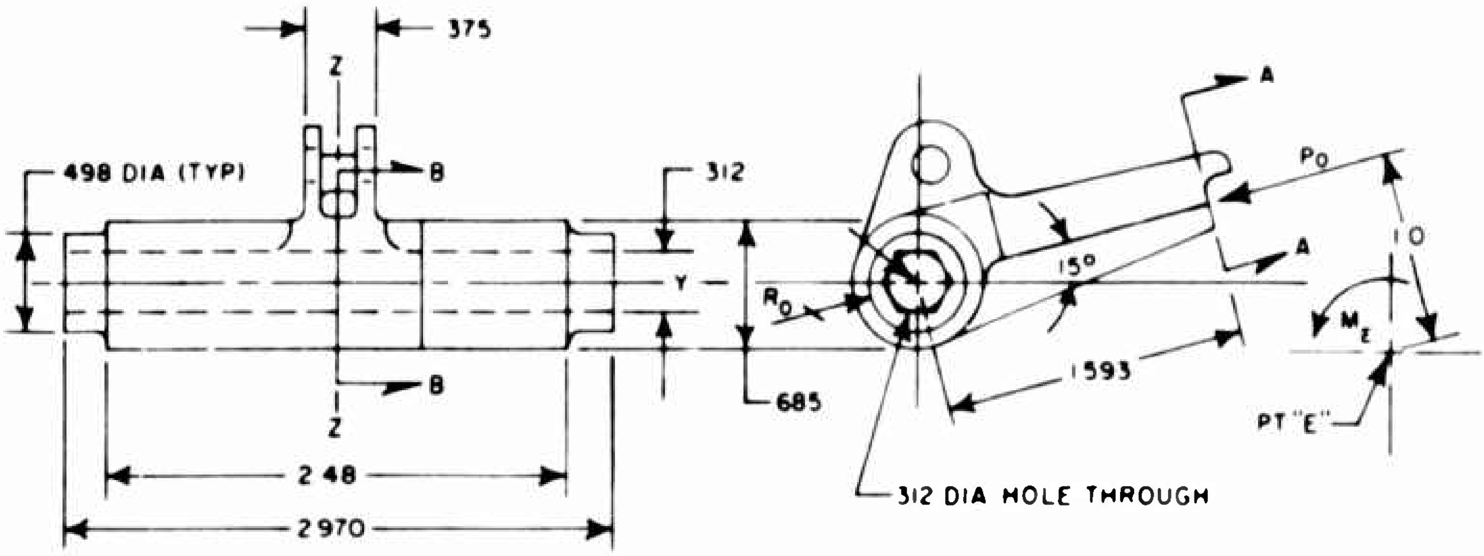
$$= 10800 \text{ lbs.}$$

$$M.S. = \frac{9200}{2683} - 1 = \underline{+2.42}$$

SAFETY LOCK BELLCRANK ANALYSIS

(Reference Drawing 60C46541)

$P_o = \frac{M_E}{1.0}$ M_E = 6250 in.-lbs. (Due to inadvertent firing, reference page 72)



Material 4130 Stl forging

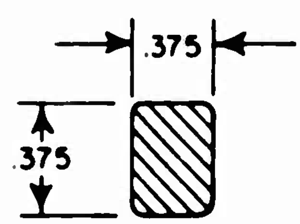
H.T. 160-180000 psi

Compression Check at Section A-A

$$P_o = \frac{M_E}{1.0} = \frac{6250}{1.0} = 6250 \text{ lbs. (Ult)}$$

$$A_c = (0.375)^2 = 0.141 \text{ in.}^2$$

$$f_c = \frac{6250}{0.141} = 44300 \text{ psi}$$



SECTION A-A

$$M.S. = \frac{160000}{44300} - 1 = \underline{+2.62}$$

Shear Check at 0.498 diameter shoulder

$$P_s = \frac{P_o}{2} = \frac{6250}{2} = 3125 \text{ lbs. (Ult)}$$

$$A_s = 0.785 \left[(0.498)^2 - (0.312)^2\right] = 0.1185 \text{ in.}^2$$

$$f_s = \frac{3125}{0.1185} = 26400 \text{ psi} \qquad M.S. = \frac{95000}{26400} - 1 = \underline{+2.60}$$

Bending and Shear Analysis, Section B-B

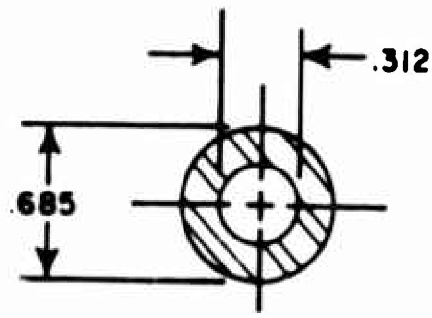
$$M = \frac{P_o}{2} L$$

$$= \frac{(6250)(1.365)}{2} = 4270 \text{ in.-lbs.}$$

$$I = \frac{\pi}{64}\left[D_o^4 - D_i^4\right]$$

$$= \frac{\pi}{64}\left[(0.685)^4 - (0.312)^4\right]$$

$$= 0.0103 \text{ in.}^4$$



Section B-B

$$A_s = \frac{\pi}{4}\left[D_o^2 - D_i^2\right]$$

$$= 0.785\left[(0.685)^2 - (0.312)^2\right]$$

$$= 0.293 \text{ in.}^2$$

$$f_b = \frac{Mc}{I} = \frac{(4270)(0.3425)}{0.0103} = 142000 \text{ psi}$$

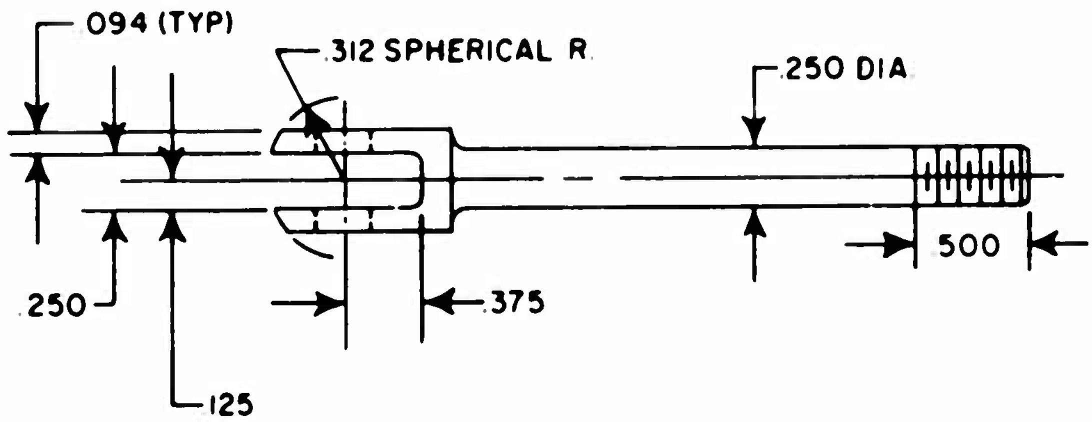
$$M.S. = \frac{160000}{142000} - 1 = \underline{+0.13}$$

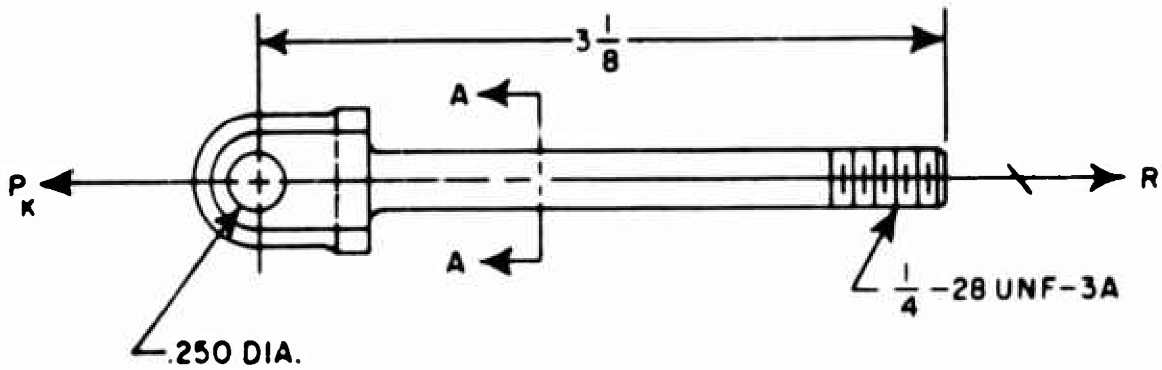
$$f_s = \frac{P_o}{2A_s} = \frac{(6250)}{2(0.293)} = 10700 \text{ psi}$$

$$M.S. = \frac{95000}{10700} - 1 = \underline{+7.87}$$

OVER-CENTER GUIDE CLEVIS ANALYSIS

(Reference Drawing 60C46538)





Loading condition No. 6

Ult tension load

P_K = 2683 lbs.

(Reference pages 25 and 47)

Material 4130 Stl bar

H.T. 125000 psi

Stress Allowables

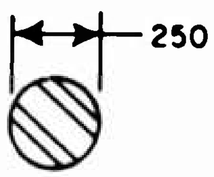
F_{tu} = 125000 psi

F_{ty} = 103000 psi

F_{su} = 82000 psi

F_{bru} = 194000 psi

(Reference MIL-HNDBK-5)

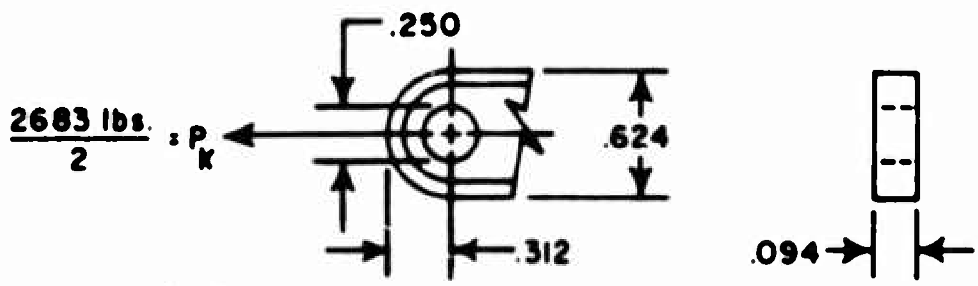


$$A_t = \frac{\pi}{4} D^2 = 0.785\,(0.25)^2 = 0.049 \text{ in.}^2$$

$$f_t = \frac{P_K}{A} = \frac{2683}{0.049} = 54800 \text{ psi}$$

$$\text{M.S.} = \frac{125000}{54800} - 1 = \underline{+1.28}$$

Lug and Pin Analysis (Analysis per Reference 3)



$$\frac{W}{D} = \frac{0.624}{0.250} = 2.49 \Big\} K_t = 0.95$$

$$\left.\begin{array}{l} \frac{D}{t} = \frac{0.250}{0.094} = 2.60 \\ \frac{a}{D} = \frac{0.312}{0.250} = 1.25 \end{array}\right\} K_{br} = 1.10$$

$$A_{br} = (0.250)(0.094) = 0.0235 \text{ in.}^2$$

$$A_t = (0.624-0.25)(0.094)$$

$$= 0.0351 \text{ in.}^2$$

Shear-Bearing Allowable

$$P'_{br} = K_{br} A_{br} F_{tu}$$

$$= (1.1)(0.0235)(125000)$$

$$= 3230 \text{ lbs.}$$

Tension Allowable

$$P'_t = K_t A_t F_{tu}$$

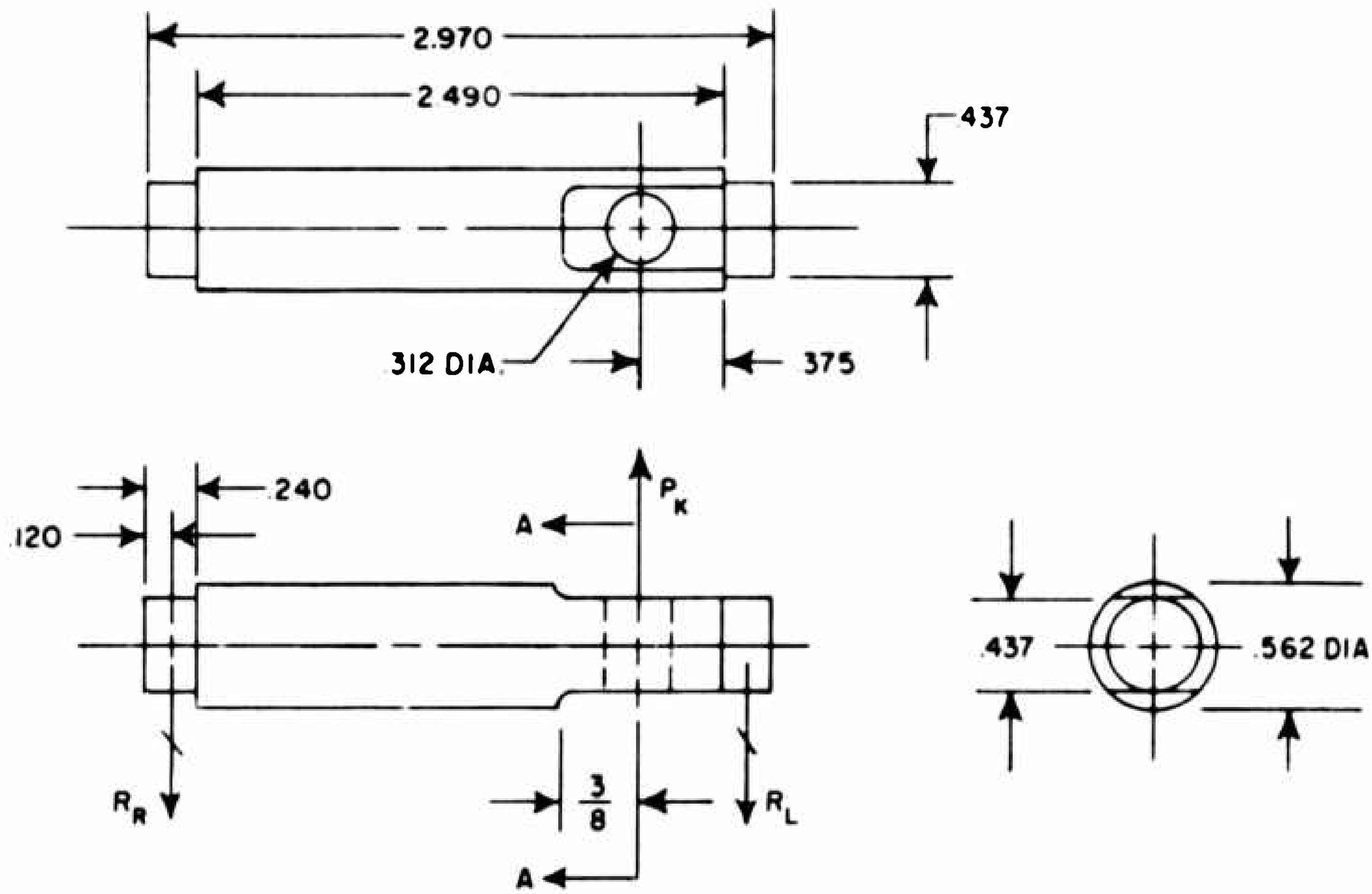
$$= (0.95)(0.0351)(125000)$$

$$= 4160 \text{ lbs.}$$

Applied load $= \frac{2683}{2} = 1342$ lbs.

Ult M.S. $= \frac{3230}{1342} - 1 = \underline{+1.40}$

CLEVIS TRUNNION ANALYSIS
(Reference Drawing 60C46540)



Loading condition No. 6 — Material 4130 Stl bar

Ult tension load — H. T. 160-180000 psi

P_K = 2683 lbs. (Reference page 77)

Static Balance of Clevis Trunnion

$$\Sigma M_L = 0 \qquad P_K(0.375 + 0.120) - R_R(2.490 + 0.240) = 0$$

$$R_R = \frac{0.495\, P_K}{2.730} = \frac{(0.495)(2683)}{2.730} = 487 \text{ lbs.}$$

$$\Sigma F_v = 0 \qquad P_K - R_L - R_R = 0$$

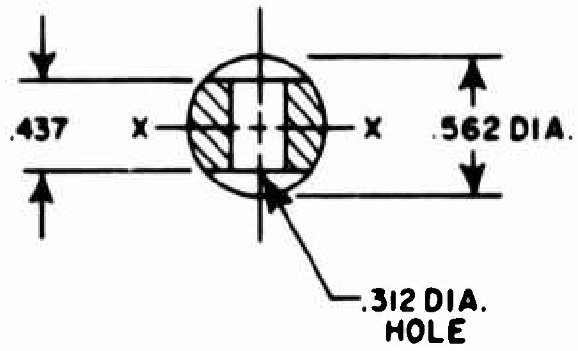
$$R_L = P_K - R_R = 2683 - 487 = 2196 \text{ lbs.}$$

Bending and Shear Analysis

Maximum bending moment

$$M_x = R_L (0.495)$$

$$= 2196 (0.495) = 1088 \text{ in.-lbs.}$$



Section A-A
(Reference page 79)

Maximum shear load

$$R_L = 2196 \text{ lbs.}$$

$$I_x = 0.003 \text{ in.}^4$$

$$A_s = 0.100 \text{ in.}^2$$

$$f_b = \frac{Mc}{I} = \frac{(1088)(0.218)}{0.003} = 79000 \text{ psi}$$

$$f_s = \frac{R_L}{A} = \frac{2196}{0.100} = 21960 \text{ psi}$$

$$F_{tu} = 160000 \text{ psi}$$

$$F_{su} = 100000 \text{ psi}$$

$$R_b = \frac{79000}{160000} = 0.493$$

$$R_s = \frac{21960}{100000} = 0.2196$$

$$M.S. = \frac{1}{\left[R_b^2 + R_s^2\right]^{1/2}} - 1$$

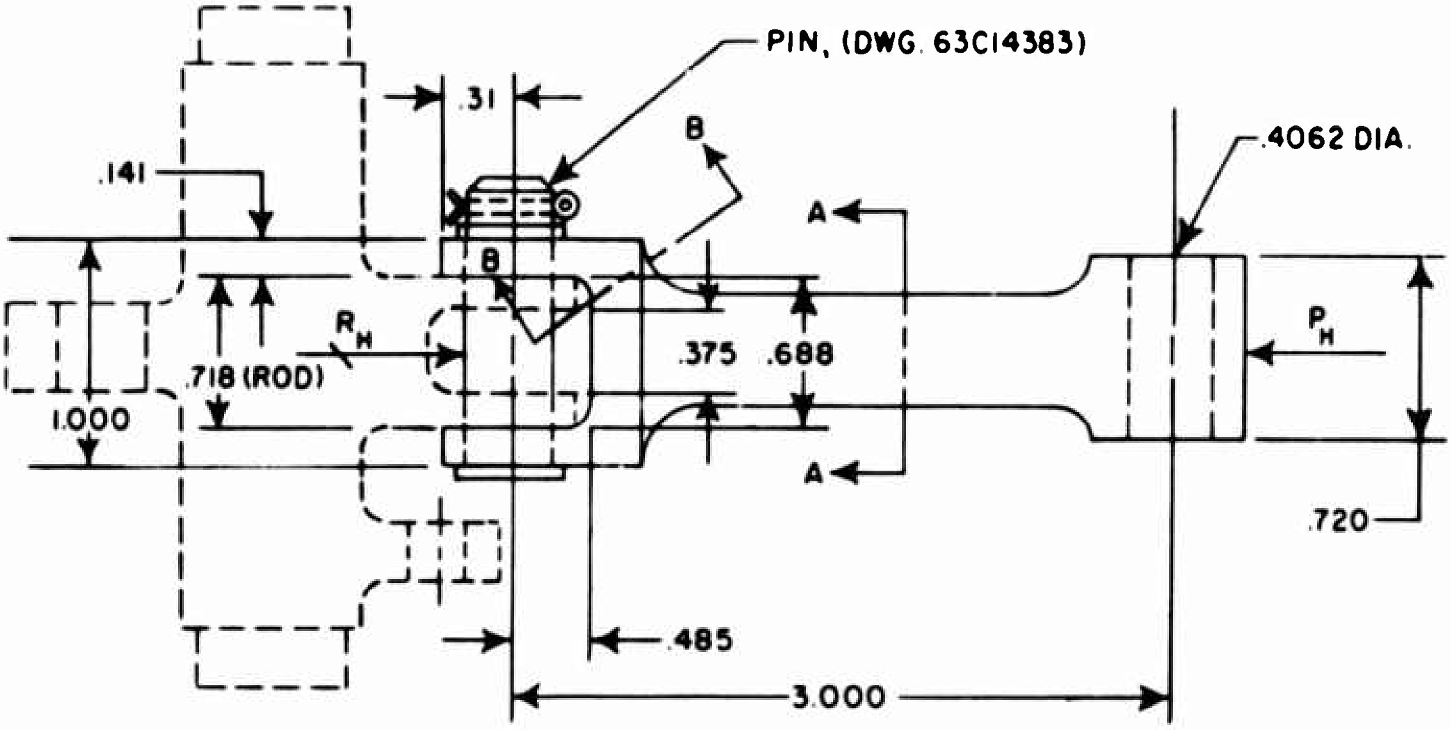
$$= \frac{1}{\left[(0.493)^2 + (0.220)^2\right]^{1/2}} - 1 = \underline{+0.85}$$

AFT SHACKLE ACTUATING ROD ANALYSIS

(Reference Drawing 63C14371)

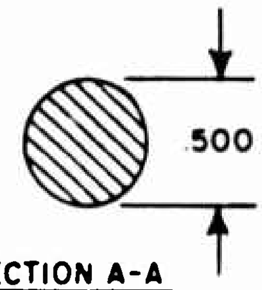
Compression Stress

Condition No. 2 $\quad R_H = 14527$ lbs. (Reference page 25)



Material $\quad$ 4130 Stl bar

H. T. $\quad$ 160-180 ksi



SECTION A-A

Allowables

$F_{tu} = 160000$ psi

$F_{su} = 100000$ psi $\Big\}$ (Reference MIL-HNDBK-5)

$F_{bru} = 287000$ psi

$A = \frac{\pi}{4} D^2 = 0.785(0.5)^2 = 0.196 \text{ in.}^2$

$I = 0.00306 \text{ in.}^4$

$L = 3,000$ in.; $c = 1$

$L' = \frac{L}{\sqrt{c}} = \frac{3.00}{\sqrt{1}} = 3.00$ in.

$\rho = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.00306}{0.196}}$

$\rho = 0.125$ in.

$\frac{L'}{\rho} = \frac{3.00}{0.125} = 24.00; \quad F_{c(allow)} = 156000 \left[1 - \frac{156000(24)^2}{4(\pi^2)(29)10^6} \right]$

$F_c = 141000$ psi

$f_c = \frac{P_H}{A} = \frac{14527}{0.196} = 74200$ psi $\qquad$ M.S. $= \frac{141000}{74200} - 1 = \underline{+0.90}$

Compression and Bending

R_H = 14527 lbs. (Ult) (Reference page 81)

$A = (0.250)(0.625) = 0.156 \text{ in.}^2$

$I_{y-y} = \frac{bh^3}{12} = \frac{(0.625)(0.23)^3}{12} = 0.000834 \text{ in.}^4$

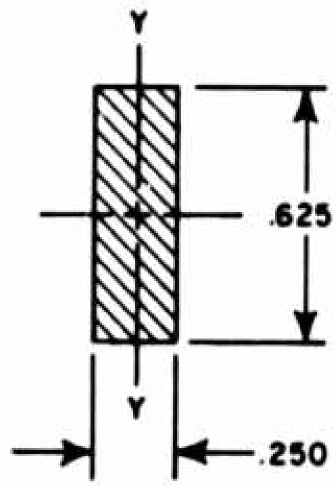
$M_y = \frac{R_H}{2}(0.06) = \frac{14527}{2}(0.06)$

M_y = 436 in.-lbs. (Ult)

$f_b = \frac{Mc}{I} = \frac{(436)(0.125)}{0.000834}$

f_b = 65500 psi

$f_c = \frac{R_H}{2A} = \frac{14527}{2.(0.156)} = 46600$ psi



Section B-B

$f_{cmax} = f_c + f_b$

= 46600 + 65500

= 112100 psi

$M.S. = \frac{160000}{112100} - 1 = \underline{+0.43}$

Lug and Pin Analysis, Bearing and Shear

Loading condition No. 2

Axial load, R_H = 14527 lbs. (Ult)

(Reference page 25)

Bearing area

$$A_{rod} = (1.00 - 0.718)(0.406)$$

$$= 0.1145 \text{ in.}^2$$

$$A_{bell} = (0.688 - 0.375)(0.406)$$

$$= 0.127 \text{ in.}^2$$

$$f_{bru} = \frac{R_H}{A} = \frac{14527}{0.1145} = 127000 \text{ psi (Rod)}$$

$$f_{bru} = \frac{R_H}{A} = \frac{14527}{0.127} = 114300 \text{ psi (Bellcrank)}$$

$$F_{bru} = 287000 \text{ psi}$$ (Reference page 81)

$$M.S. = \frac{287000}{127000} - 1 = \underline{+1.26}$$

Allowable Shear Load per Pin

$$P_s = 28700 \text{ lbs.}$$ (Reference page 63)

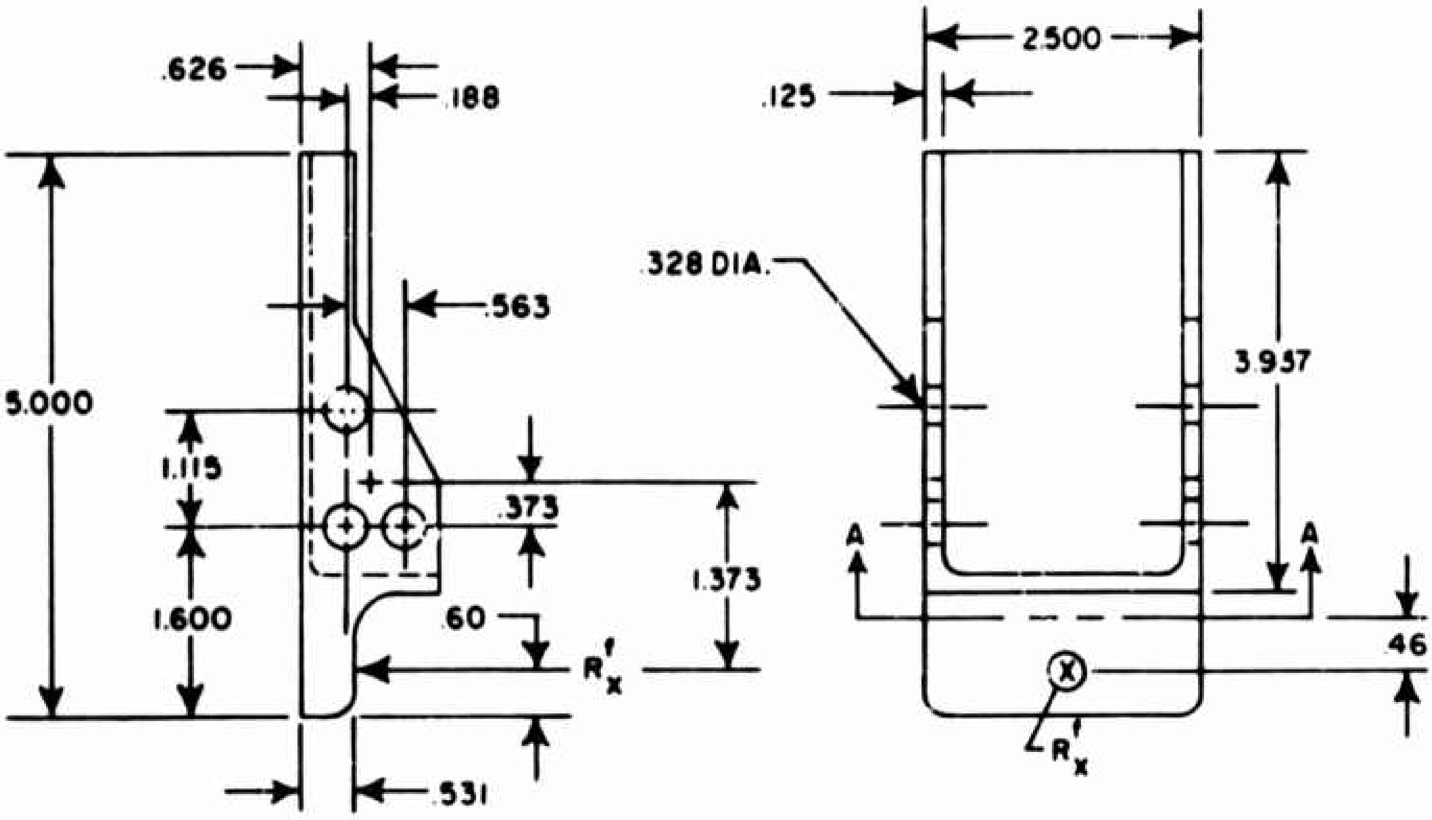
$$M.S. = \frac{28700}{14527} - 1 = \underline{+0.97}$$

VERTICAL DRAG-FITTING ANALYSIS

(Reference Drawing 63D14369)

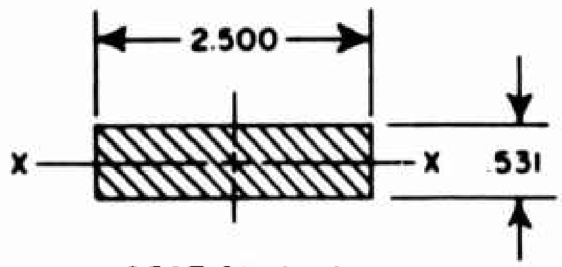
Condition No. 8

Applied drag load R_x^f = 15000 lbs. (Ult) (Reference page 7)



Material 4340 Stl casting

H. T. 160-180000 psi



SECTION A—A

(ASSUMED EFF. AREA)

Bending, Section A-A

$$M_{x-x} = R_x^f (0.46)$$

$$= 15000\,(0.46) = 6900 \text{ in.-lbs. (Ult)}$$

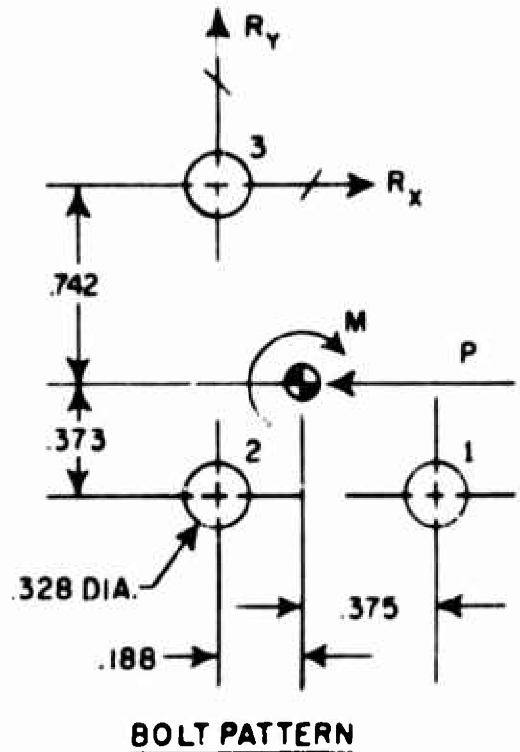
$$f_b = \frac{6M}{bh^2} = \frac{(6)(6900)}{(2.50)(0.531)^2} = 59000 \text{ psi}$$

$$\text{Bending M.S.} = \frac{160000}{59000} - 1 = \underline{1.71}$$

Side Plate Attachments

Fastener Check

$\frac{5}{16}$ diameter bolt (Reference Drawing 62B13022)



Material 4130 Stl bar

H. T. 160-180000 psi

Ult shear allowable $F_s = 7300$ lbs.

(Reference MIL-HNDBK-5)

$$R_{cx} = \frac{P}{n} = \frac{P}{3}$$

$$R_{Mx} = \frac{-My}{\Sigma x^2 + \Sigma y^2}$$

$$R_{My} = \frac{Mx}{\Sigma x^2 + \Sigma y^2}$$

$$R_{total} = \sqrt{(R_{cx} + R_{Mx})^2 + R_y^2}$$

P = 15000 lbs. (Ult) (Reference page 84)

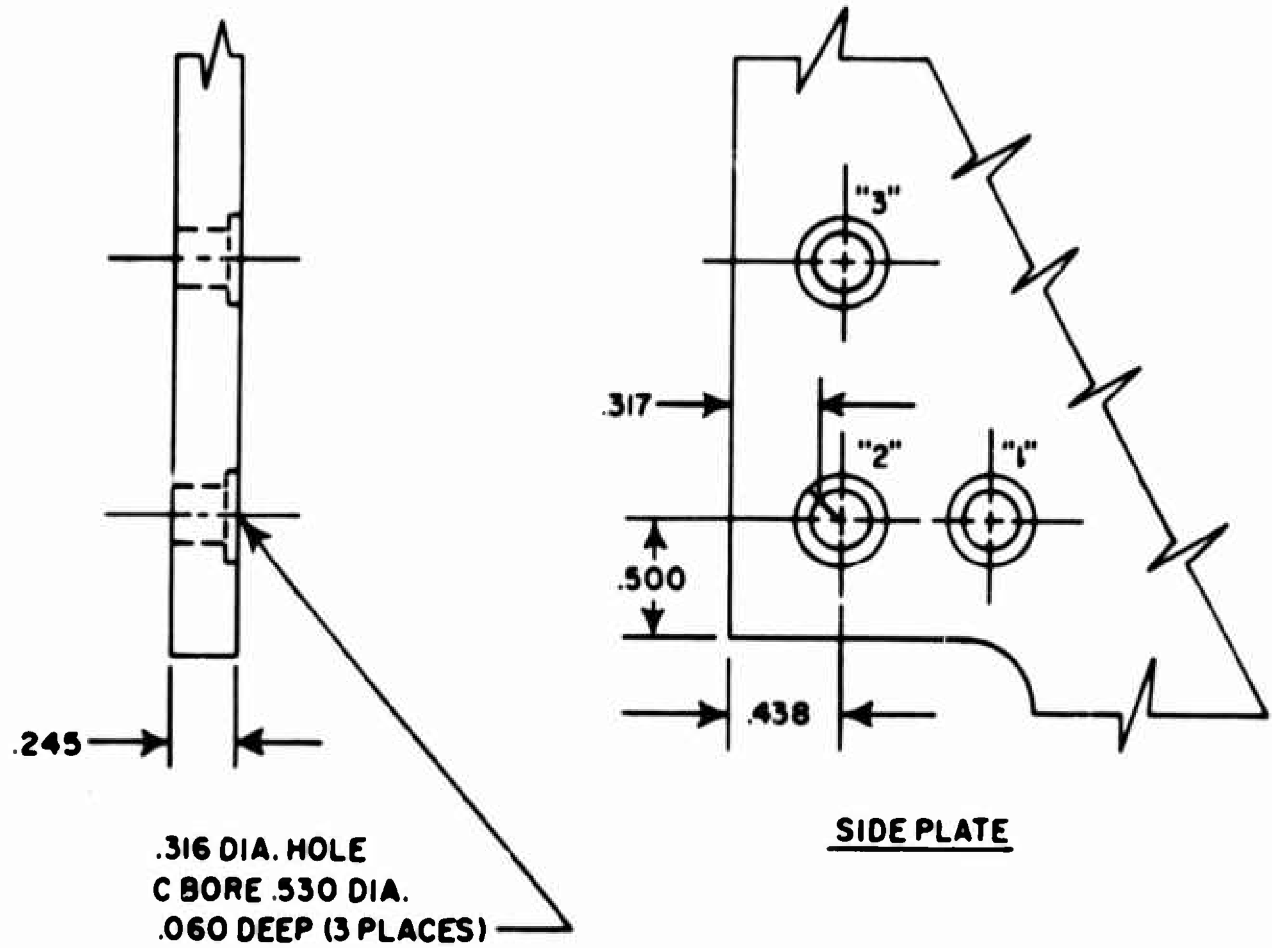
M = 15000 (1.373) = 20600 in.-lbs.

ELEM	x	y	x^2	y^2	Mx	My	R_{cx}	R_{Mx}	R_{My}
1	0.375	-0.373	0.140	0.139	7725	-7675	5000	+ 7400	+ 7440
2	-0.188	-0.373	0.035	0.139	- 3870	-7675	5000	+ 7400	- 3730
3	-0.188	0.742	0.035	0.550	- 3870	15300	5000	- 14750	- 3730
Σ			0.210	0.828					

ELEM	$(R_{cx} + R_{Mx})^2$	R_{My}^2	R_{total}	$R_{L.H.}$	$R_{R.H.}$
1	154×10^6	55.0×10^6	14480 lbs.	7240	7240
2	154×10^6	13.9×10^6	12980 lbs.	6490	6490
3	95×10^6	13.9×10^6	10440 lbs.	5220	5220

(Bolt) M.S. $= \frac{7300}{7240} - 1 = \underline{+0.01}$

Side Plate Attachment



Minimum shear-out area

$$A_s = 2(0.317)(0.245) = 0.1553 \text{ in.}^2$$

$$P_2 = 6490 \text{ lbs.} \quad \text{(Reference page 85)}$$

$$f_s = \frac{P}{A_s} = \frac{6490}{0.1553} = 41700 \text{ psi}$$

Reference 60H46534 and 60H46535

Material: 7075-T6 Al aly plate

$$F_{tu} = 77000 \text{ psi}$$

$$F_{ty} = 67000 \text{ psi}$$

$$F_{su} = 46000 \text{ psi}$$

$$F_{bru} = 146000 \text{ psi}$$

(Reference MIL-HNDBK-5)

$$\text{(Shear) M.S.} = \frac{46000}{41700} - 1 = \underline{+0.10}$$

$$A_{br} = (0.316)(0.245-0.06) = 0.0585 \text{ in.}^2$$

$$P_1 = 7240 \text{ lbs.} \quad \text{(Reference page 85)}$$

$$f_{bru} = \frac{7240}{0.0585} = 123800 \text{ psi}$$

$$\text{(Bearing) M.S.} = \frac{146000}{123800} - 1 = \underline{+0.18}$$

c. Ballistic gas system analysis

The analysis of each component or assembly of the ballistic gas system is based upon the 70,000-psi burst pressure. This pressure includes the ultimate factor of safety of 2.5. The analysis of each component was made using conservative methods. The sketch of the ballistic gas system assembly is shown in figure 12.

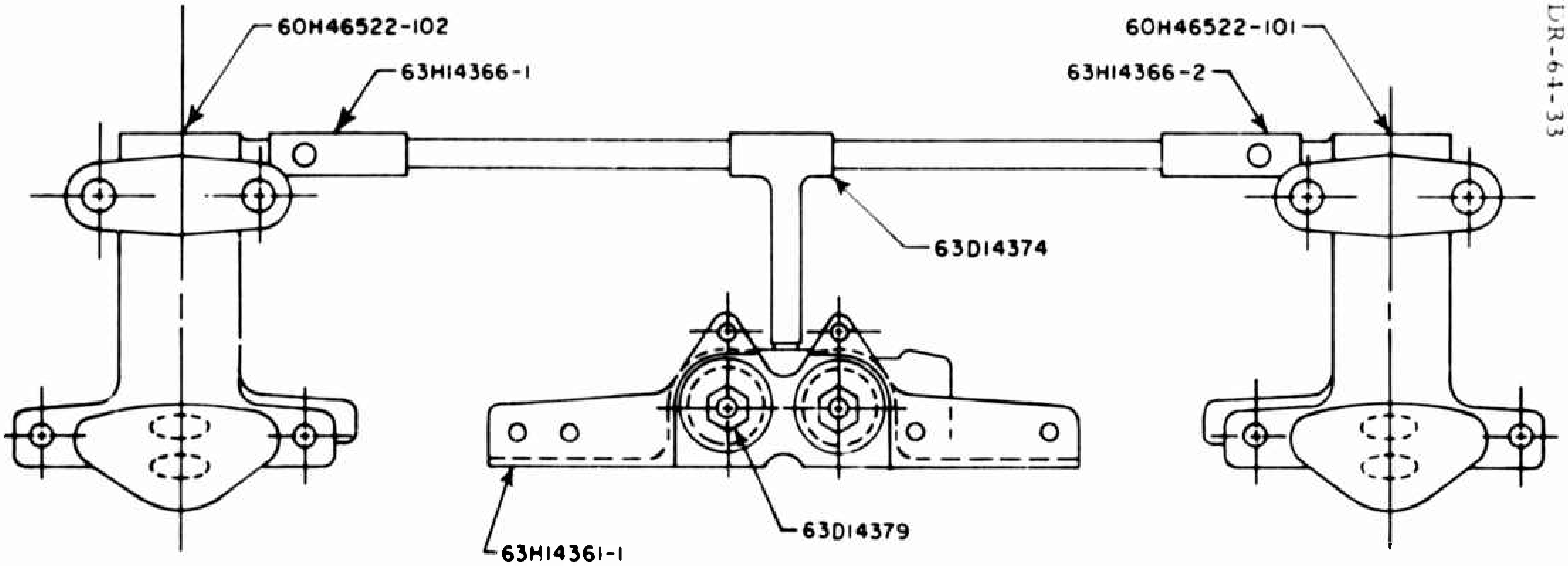


Figure 12. Ballistic gas system

$p = 70000$ psi (burst)
For breech, tubes and orifice block
(Reference MIL-R-27587)

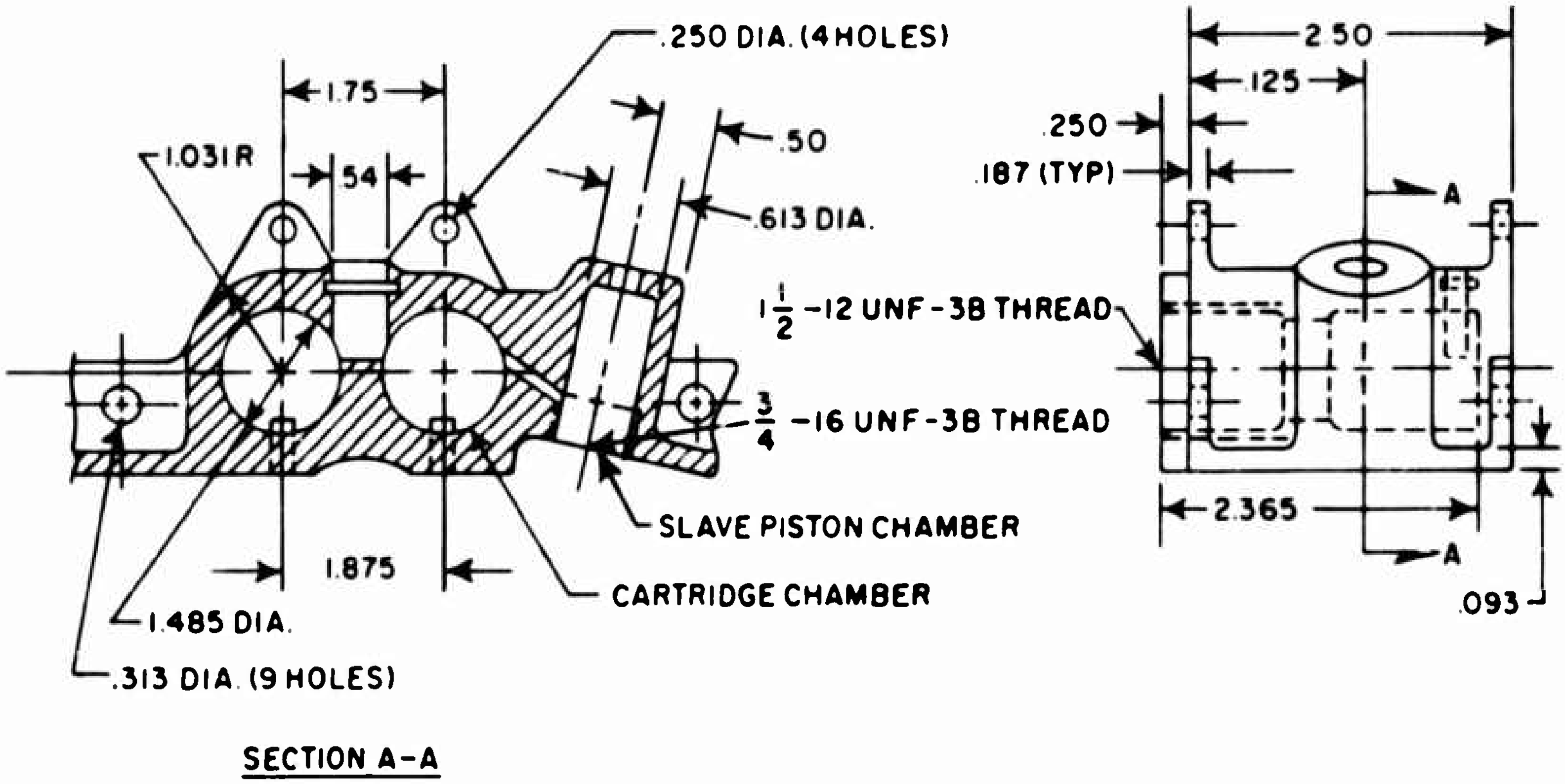
The ultimate factor of safety is 2.5 times the gas pressure limit load for all ballistic system components.

BREECH ANALYSIS

(Reference Drawing 63H14361)

Critical Pressure

p = 70000 psi (burst)



Material 4340 Stl forging

H. T. 180-200 ksi

Hoop tension check through cartridge chamber

$$f_t = p\frac{R_i}{t} = 70000\left(\frac{0.742}{0.289}\right)$$

$$= 178000 \text{ psi}$$

Stress Allowables

F_{tu} = 180000 psi

F_{ty} = 160000 psi

F_{su} = 109000 psi

$$M.S. = \frac{180000}{178000} - 1 = \underline{+0.01}$$

Hoop tension check through slave piston chamber

$$f_t = p\frac{R_i}{t} = 70000\frac{(0.307)}{0.193} = 111400 \text{ psi}$$

$$M.S. = \frac{180000}{111400} - 1 = \underline{+0.61}$$

Thread analysis

(Reference page 90)

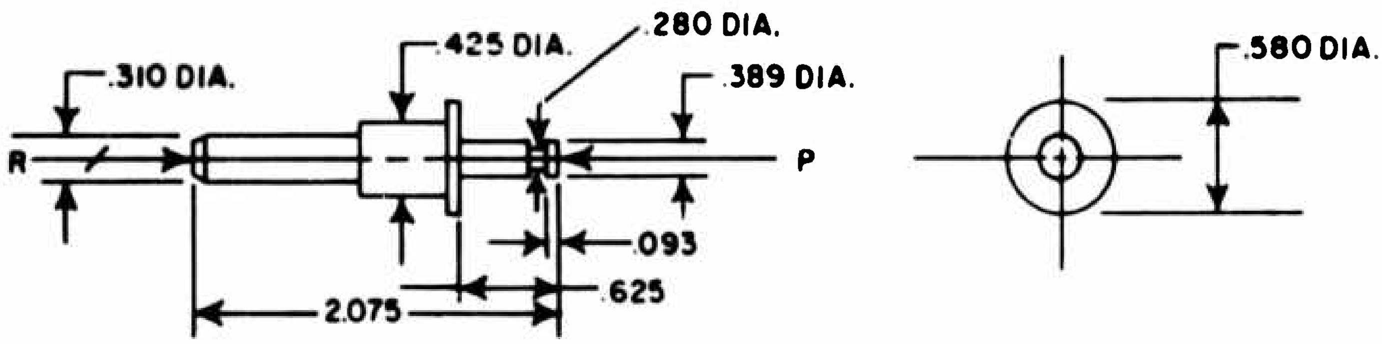
SLAVE PISTON ANALYSIS

(Reference Drawing 64C13032)

p = 70000 psi (burst)

Material 17-4 ph cres bar

H. T. 180-215 ksi



Compression

$P = pA = 70000\,(0.785)(0.389)^2 = 8300$ lbs.

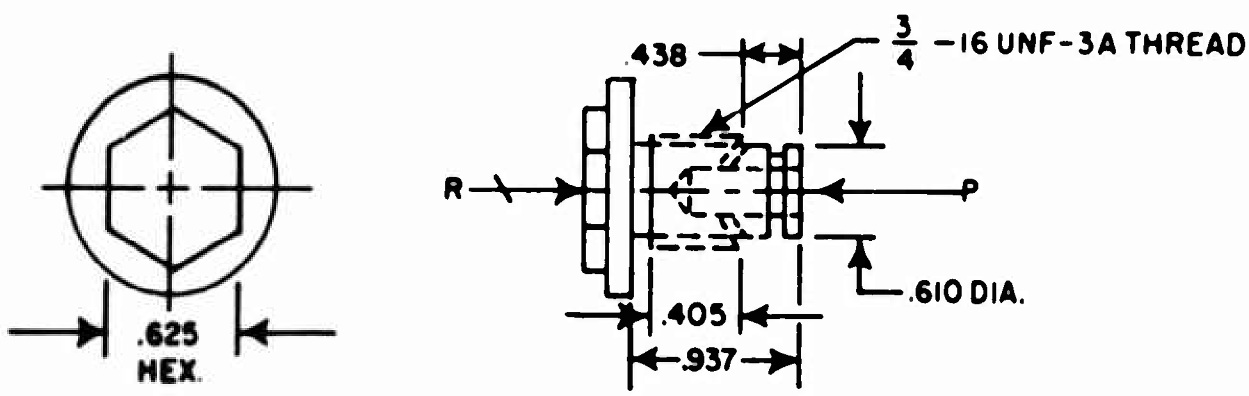
$A'_c = (0.785)(0.280)^2 = 0.061$ in.^{2} $\quad F_{cy} = 180000$ psi

$A''_c = (0.785)(0.310)^2 = 0.075$ in.^{2}

$f_c = \frac{P}{A} = \frac{8300}{0.061} = 136000$ psi $\quad$ M.S. $= \frac{180000}{136000} - 1 = \underline{+0.32}$

SLAVE PISTON PLUG ANALYSIS

(Reference Drawing 64D13082)



Thread shear check

Material 17-4 ph cres bar

H. T. 180-215 ksi

$P = 70000\,(0.785)(0.610)^2 = 20500$ lbs.

Length of engaged thread = 0.405 in.

Pitch diameter = 0.745 in.

$A_s = \pi\,(\text{P.D.})\,\frac{L}{2} = (3.14)(0.745)\left(\frac{0.405}{2}\right) = 0.475$ in.^{2}

$f_s = \frac{P}{A} = \frac{20500}{0.475} = 43200$ psi

M.S. $= \frac{123000}{43200} - 1 = \underline{+1.84}$

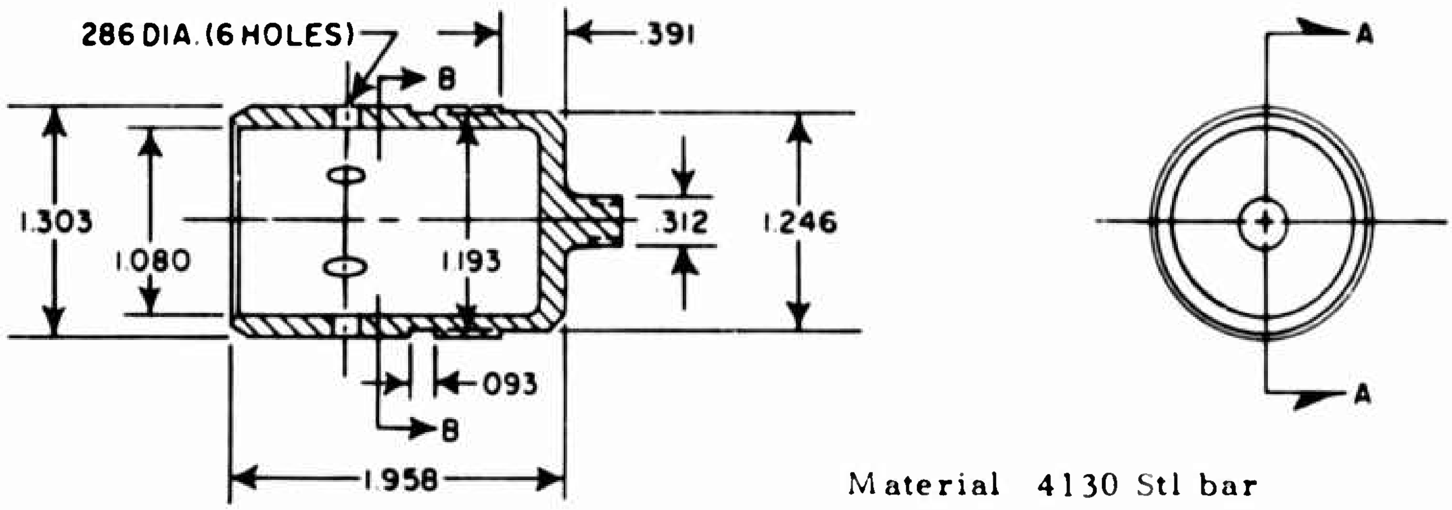
$F_s = 123000$ psi

CARTRIDGE B[illegible] [illegible]ETAINER ANALYSIS

(Reference Drawing 63D14368)

Maximum pressure $p = 70000$ psi (burst)*

* Breech burst pressure



SECTION A-A

Material 4130 Stl bar

H.T. 160-180 ksi

Hoop tension check at Section B-B

$p' = 25000$ psi (Cartridge case burst pressure)

$$f_t = \frac{pD_i}{2t} = \frac{(25000)(1.080)}{2(0.112)} = 121000 \text{ psi}$$

$$M.S. = \frac{160000}{121000} - 1 = \underline{+0.32}$$

Compression check at "O" ring groove

$$P_c = p\left(\frac{\pi}{4}\right)\left(D_o^2 - D_i^2\right)$$

$p = 70000$ psi (After rupture of cartridge case)

$$= 70000\,(0.785)\left[(1.303)^2 - (1.080)^2\right] = 29200 \text{ lbs.}$$

$$A_c = 0.785\left[(1.303)^2 - (1.193)^2\right] = 0.214 \text{ in.}^2$$

$$f_c = \frac{29200}{0.214} = 136000 \text{ psi}$$

$$F_c = 156000 \text{ psi}$$

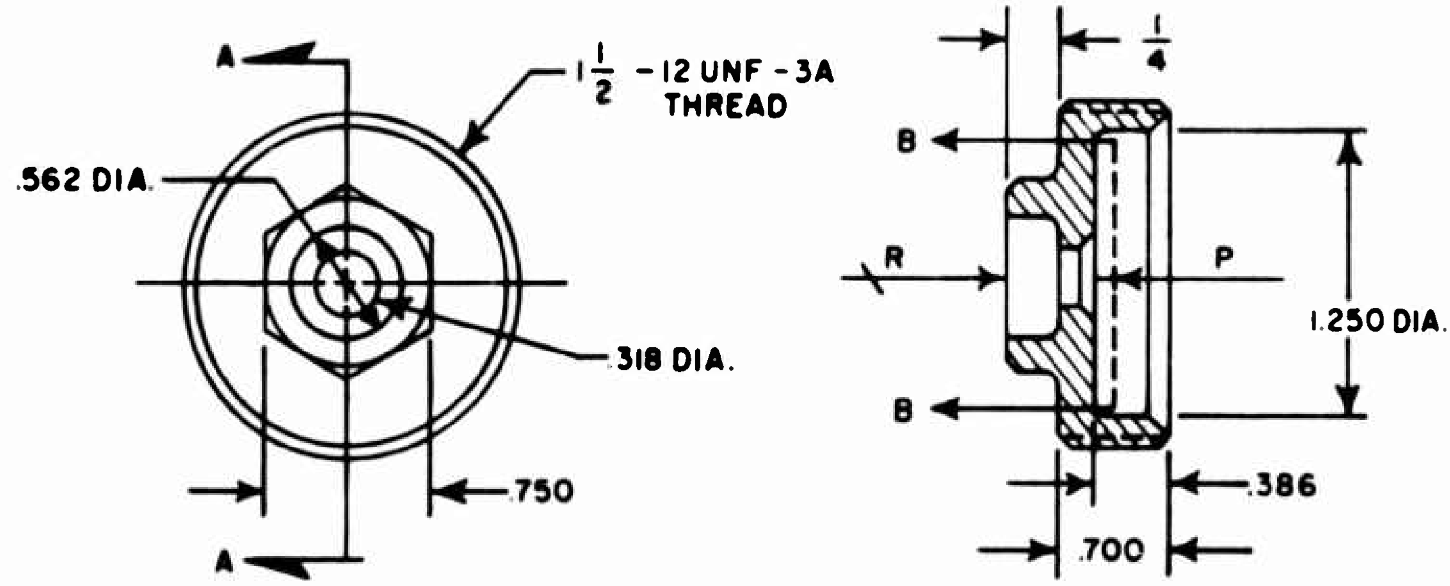
$$M.S. = \frac{156000}{136000} - 1 = \underline{+0.15}$$

CARTRIDGE RETAINER CAP ANALYSIS

(Reference Drawing 63D14378)

p = 70000 psi (burst)

(Maximum breech burst pressure)



Section A-A

$$P = \frac{\pi}{4}D^2 p$$

Material 4130 Stl bar

H.T. 160-180000 psi

D = O.D. of cartridge body retainer (Reference page 91)

$P = 0.785(1.303)^2(70000) = 93300$ lbs. (Ult)

Length of engaged thread = 0.625 in.

Pitch diameter = 1.45 in.

Shear check at 1 1/2-12UNF-3A thread

$$A_s = \pi\,(\text{P.D.})\frac{L}{2} = (3.14)(1.45)\left(\frac{0.625}{2}\right) = 1.42$$

$$f_s = \frac{P}{A} = \frac{93300}{1.42} = 65700 \text{ psi}$$

F_s = 100000 psi

$$\text{M.S.} = \frac{100000}{65700} - 1 = \underline{+0.52}$$

Shear check at 1.250 diameter, Section B-B

$P = 93300$ lbs. (Ult)
$D = 1.250$ in. (Reference page 92)
$L = (0.700 - 0.386) = 0.314$ in.

$$A_s = \pi DL = (3.14)(1.25)(0.314) = 1.23 \text{ in.}^2$$

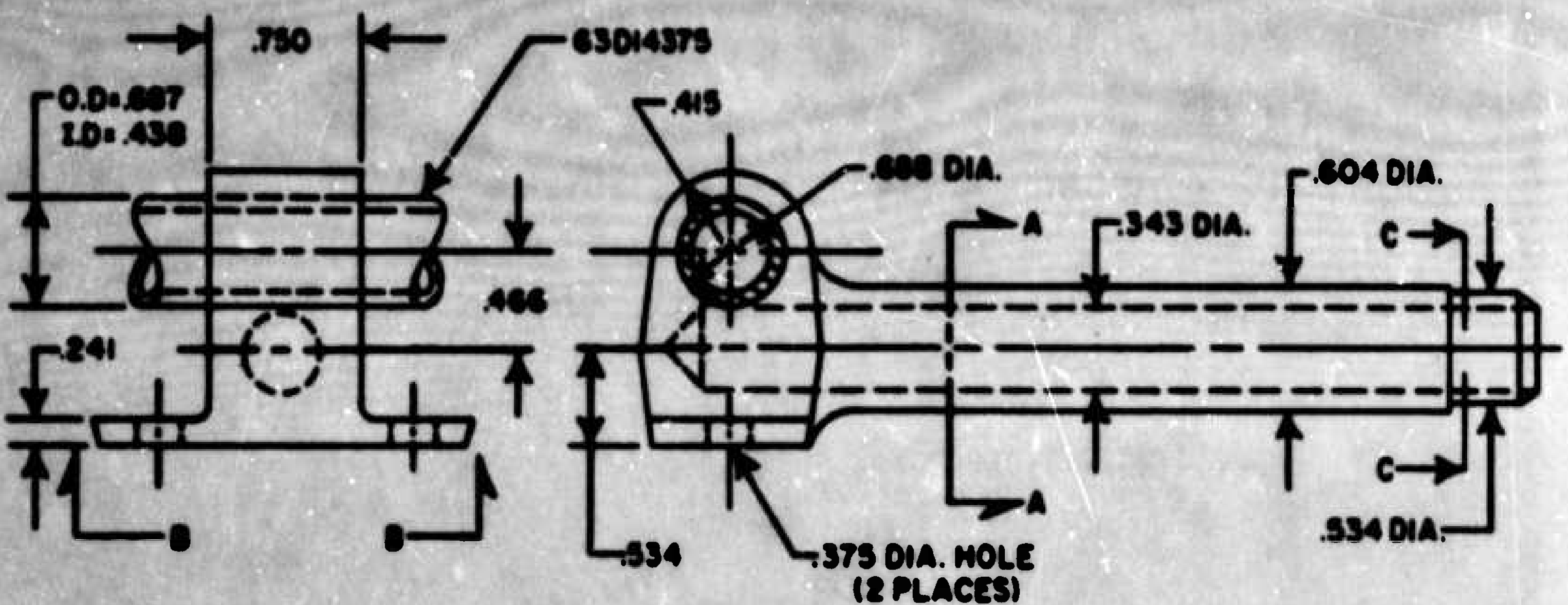
$$f_s = \frac{P}{A} = \frac{93300}{1.23} = 75800 \text{ psi}$$

$$F_s = 100000 \text{ psi}$$

$$M.S. = \frac{100000}{75800} - 1 = \underline{+0.32}$$

GAS TUBE TEE ANALYSIS

(Reference Drawings 63H14376, 63D14374, 63D14375)



Material 4130 Stl tube and 4130 Stl forging

H. T. 180-200000 psi (Reference Drawing 63D14374)

Hoop tension check at Section A-A and C-C

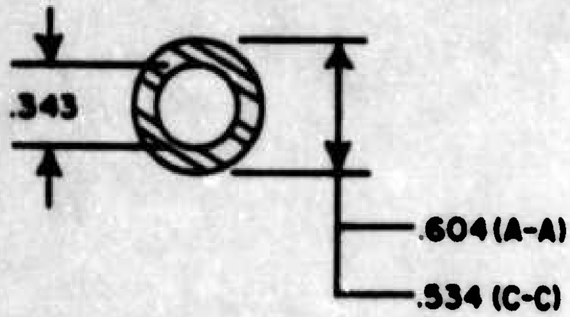
$p = 70000$ psi (burst)

$R_{A-A} = \dfrac{0.604 + 0.343}{4} = 0.237$ in.

$t_A = \dfrac{0.604 - 0.343}{2} = 0.1305$ in.

$f_t = \dfrac{pR}{t} = \dfrac{(70000)(0.237)}{0.1305} = 127000$ psi

$F_{tu} = 180000$ psi



(Section A-A) M. S. $= \dfrac{180000}{127000} - 1 = \underline{+0.42}$

Section C-C

$$R_{c-c} = \frac{0.534 + 0.343}{4} = 0.219 \text{ in.}$$

$$t_{c-c} = \frac{0.534 - 0.343}{2} = 0.0905 \text{ in.}$$

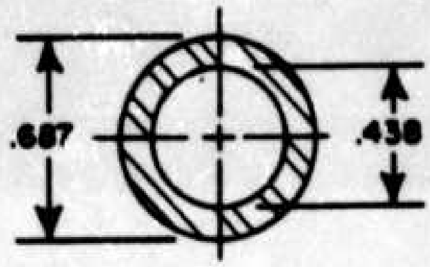
$$f_t = p\frac{R}{t} = \frac{70000(0.219)}{0.0905} = 170000 \text{ psi}$$

$$F_{tu} = 180000 \text{ psi}$$

$$\text{(Section C-C) M.S.} = \frac{180000}{170000} - 1 = \underline{+0.06}$$

Gas tube, hoop tension check
(Reference Drawing 63D14375)

$$R = \frac{0.687 + 0.438}{4} = 0.281 \text{ in.}$$



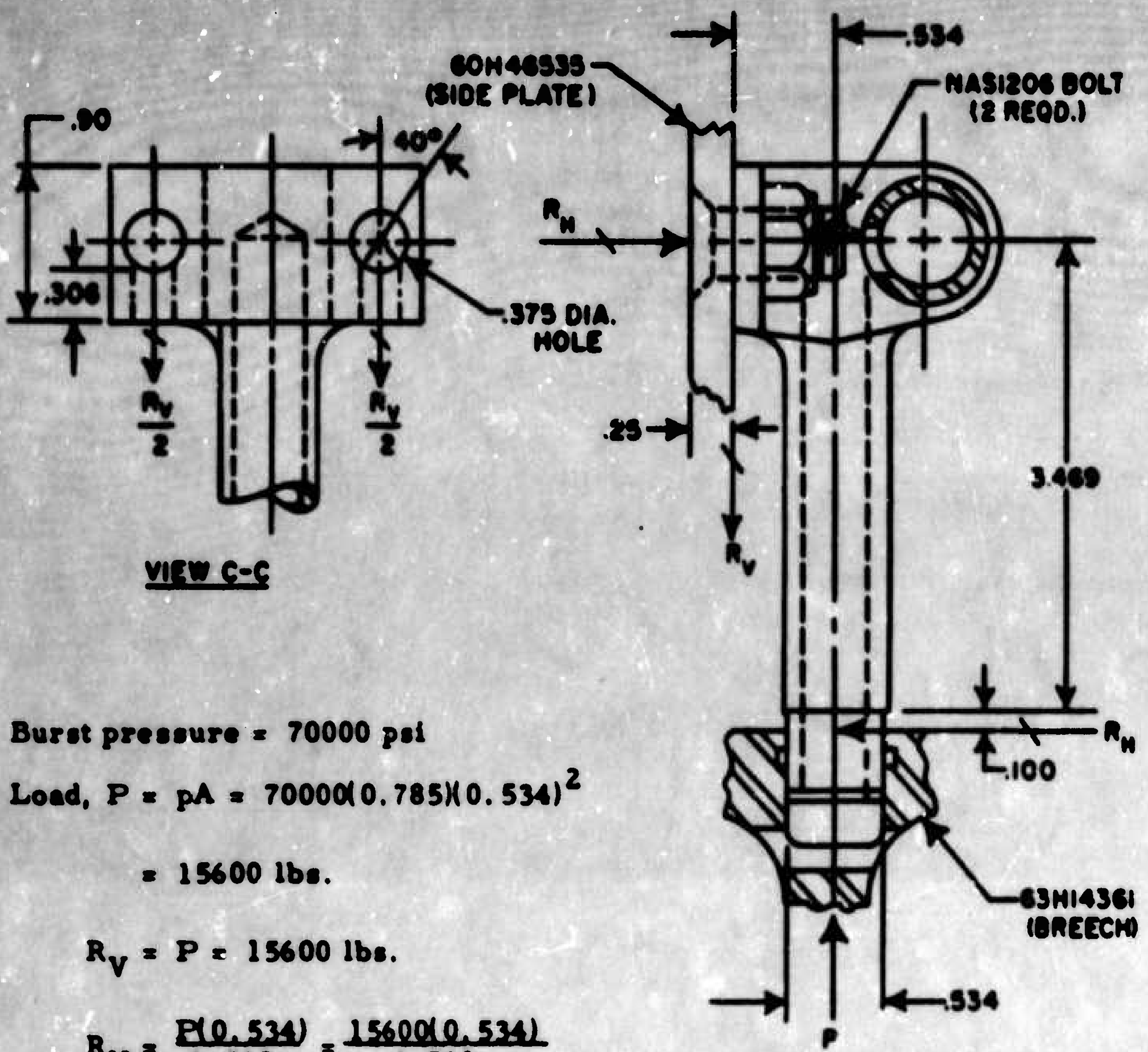
$$t = \frac{0.687 - 0.438}{2} = 0.1245 \text{ in.}$$

$$P = p\frac{R}{t} = \frac{70000(0.281)}{0.1245} = 158000 \text{ psi}$$

$$F_{tu} = 180000 \text{ psi}$$

$$\text{M.S.} = \frac{180000}{158000} - 1 = \underline{+0.14}$$

Gas Tube Tee Attachment



Burst pressure = 70000 psi

Load, $P = pA = 70000(0.785)(0.534)^2$

$= 15600$ lbs.

$R_V = P = 15600$ lbs.

$$R_H = \frac{P(0.534)}{3.569} = \frac{15600(0.534)}{3.569}$$

$= 2340$ lbs.

Side Plate and Tee Attachment

Side plate   7075-T6; 0.250 thick

Bolt   NAS1206 (0.375 diameter) C'S'K'

Ult allowable attachment = 8280 lbs./bolt (Reference MIL-HNDBK-5)

Applied load per bolt $= \frac{R_V}{2} = \frac{15600}{2} = 7800$ lbs.

$$M.S. = \frac{8280}{7800} - 1 = +0.06$$

Shear-out check at 0.375 diameter attachment holes (view C-C)

Applied load per bolt = 7800 lbs (Reference page 96)

Shear area $A_s = 2(0.306)(0.241) = 0.1475 \text{ in.}^2$

$$f_s = \frac{R}{A_s} = \frac{7800}{0.1475} = 52800 \text{ psi}$$

$$F_s = 109000 \text{ psi}$$

$$M.S. = \frac{109000}{52800} - 1 = \underline{1.06}$$

Allowable shear per bolt

$F_{s(bolt)} =$ 10500 lbs. (single) (Reference MIL-HNDBK-5)

$$\text{Shear (bolt) } M.S. = \frac{10500}{7800} - 1 = \underline{+0.35}$$

Gas tube in shear at breech

$$A_s = 0.785 \left[(0.534)^2 - (0.343)^2\right] = 0.131 \text{ in.}^2$$

$P_s = P_H =$ 2340 lbs. (Reference page 96)

$$f_s = \frac{P}{A} = \frac{2340}{0.131} = 17900 \text{ psi}$$

$$F_s = 109000 \text{ psi}$$

$$M.S. = \frac{109000}{17900} - 1 = \underline{5.10}$$

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5 Roark, R. J., Formulas for Stress and Strain, Third Edition, McGraw-Hill Book Company, Inc., 1954.