MAU-12A/A BOMB EJECTOR RACK
STRESS ANALYSIS
Final Report

Prepared by
D. E. O'Bannon

TECHNICAL DOCUMENTARY REPORT NO. WL TDR-64-33

June 1964

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

Project ESP 01236
When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report is made available for study upon the understanding that the Government's proprietary interests in and relating thereto shall not be impaired. In case of apparent conflict between the Government's proprietary interests and those of others, notify the Staff Judge Advocate, Air Force Systems Command, Andrews AF Base, Washington 25, DC.

This report is published for the exchange and stimulation of ideas; it does not necessarily express the intent or policy of any higher headquarters.

Qualified requesters may obtain copies of this report from DDC. Orders will be expedited if placed through the librarian or other staff member designated to request and receive documents from DDC.
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
CONTENTS

Lists of Figures and Tables iv
List of Reference Drawings v
Summary of Minimum Margins of Safety vi

Introduction 1

Structural Description 1

Load Analysis 2
  Applied Loads and Store Reactions 2
  Aircraft Attachment Reactions 5
  Linkage Mechanism Reactions 11

Structural Stress Analysis 27
  Body Analysis 28
  Linkage Mechanism and Drag-fitting Analysis 46
  Ballistic Gas System Analysis 87

References 98

Distribution 99
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sign convention and geometry - aircraft attachment reactions</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Linkage mechanism geometry</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Static balance of rack for load condition No. 2</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>Body loads for load condition No. 2</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>Shear and moment diagrams (vertical plane) load condition No. 2</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Shear and moment diagrams (horizontal plane) load condition No. 2</td>
<td>31</td>
</tr>
<tr>
<td>7</td>
<td>Static balance of rack for load condition No. 6</td>
<td>32</td>
</tr>
<tr>
<td>8</td>
<td>Body loads for load condition No. 6</td>
<td>33</td>
</tr>
<tr>
<td>9</td>
<td>Shear and moment diagrams (vertical plane) load condition No. 6</td>
<td>34</td>
</tr>
<tr>
<td>10</td>
<td>Shear and moment diagrams (horizontal plane) load condition No. 6</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>Linkage mechanism system</td>
<td>47</td>
</tr>
<tr>
<td>12</td>
<td>Ballistic gas system</td>
<td>88</td>
</tr>
</tbody>
</table>

LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Applied loads and store reactions</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Calculation of aircraft attachment reactions</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Calculation of linkage mechanism reactions</td>
<td>25</td>
</tr>
</tbody>
</table>
## LIST OF REFERENCE DRAWINGS

### AIR FORCE DRAWINGS - MAU-12A/A BOMB EJECTOR RACK

<table>
<thead>
<tr>
<th>Reference Drawing</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>62B13022</td>
<td>Bolt, Mounting, Breech</td>
</tr>
<tr>
<td>60C46530</td>
<td>Link, Connecting, Shackle</td>
</tr>
<tr>
<td>60C46538</td>
<td>Clevis, Guide, Over-Center Spring</td>
</tr>
<tr>
<td>60C46540</td>
<td>Trunnion, Clevis</td>
</tr>
<tr>
<td>60C46541</td>
<td>Bellcrank, Inflight, Safety Lock</td>
</tr>
<tr>
<td>63C14370</td>
<td>Rod, Shackle Actuating, Forward</td>
</tr>
<tr>
<td>63C14371</td>
<td>Rod, Shackle Actuating, Aft</td>
</tr>
<tr>
<td>63C14383</td>
<td>Pin, Linkage</td>
</tr>
<tr>
<td>64C13032</td>
<td>Piston, Slave</td>
</tr>
<tr>
<td>60D46528</td>
<td>Shackle, 30-inch Spacing</td>
</tr>
<tr>
<td>63D14368</td>
<td>Body, Retainer Cartridge</td>
</tr>
<tr>
<td>64D13082</td>
<td>Plug, Slave Piston, Retaining</td>
</tr>
<tr>
<td>63D14374</td>
<td>Tube, Gas, Assembly of</td>
</tr>
<tr>
<td>63D14375</td>
<td>Tube, Gas</td>
</tr>
<tr>
<td>63D14378</td>
<td>Retainer, Cartridge</td>
</tr>
<tr>
<td>63D14379</td>
<td>Retainer, Cartridge, Assembly of</td>
</tr>
<tr>
<td>60H46522</td>
<td>Block, Cylinder, Ejection Piston</td>
</tr>
<tr>
<td>60H46534</td>
<td>Sideplate, Left Hand</td>
</tr>
<tr>
<td>60H46535</td>
<td>Sideplate, Right Hand</td>
</tr>
<tr>
<td>63H14361</td>
<td>Breech, Bomb Ejector, Rack</td>
</tr>
<tr>
<td>63H14366</td>
<td>Block, Orifice Housing</td>
</tr>
<tr>
<td>63H14376</td>
<td>Tee, Connecting, Gas Tube</td>
</tr>
<tr>
<td>63J14362</td>
<td>Bellcrank, Actuating, Rod</td>
</tr>
<tr>
<td>63J14363</td>
<td>Shackle, 14-inch Spacing</td>
</tr>
<tr>
<td>63D14369</td>
<td>Fitting, Drag, Vertical, Assembly of</td>
</tr>
<tr>
<td>Part</td>
<td>Refer to page</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Side plate</td>
<td>39</td>
</tr>
<tr>
<td>Swaybrace</td>
<td>41</td>
</tr>
<tr>
<td>Swaybrace</td>
<td>42</td>
</tr>
<tr>
<td>Swaybrace</td>
<td>43</td>
</tr>
<tr>
<td>Swaybrace (Cylinder block)</td>
<td>44</td>
</tr>
<tr>
<td>Swaybrace (Cylinder block)</td>
<td>45</td>
</tr>
<tr>
<td>Swaybrace</td>
<td>49</td>
</tr>
<tr>
<td>Forward 30&quot; shackle</td>
<td>53</td>
</tr>
<tr>
<td>Aft 30&quot; shackle</td>
<td>54</td>
</tr>
<tr>
<td>Aft 30&quot; shackle</td>
<td>55</td>
</tr>
<tr>
<td>Aft 30&quot; shackle</td>
<td>57</td>
</tr>
<tr>
<td>Forward link connector</td>
<td>59</td>
</tr>
<tr>
<td>Forward 14&quot; shackle</td>
<td>61</td>
</tr>
<tr>
<td>Forward 14&quot; shackle</td>
<td>62</td>
</tr>
<tr>
<td>Aft 14&quot; shackle</td>
<td>65</td>
</tr>
<tr>
<td>Aft 14&quot; shackle</td>
<td>66</td>
</tr>
<tr>
<td>Forward actuating rod</td>
<td>68</td>
</tr>
<tr>
<td>Forward actuating rod</td>
<td>69</td>
</tr>
<tr>
<td>Center bellcrank</td>
<td>71</td>
</tr>
<tr>
<td>Center bellcrank</td>
<td>72</td>
</tr>
<tr>
<td>Safety lock bellcrank</td>
<td>76</td>
</tr>
<tr>
<td>Clevis trunnion</td>
<td>80</td>
</tr>
<tr>
<td>Aft actuating rod</td>
<td>82</td>
</tr>
</tbody>
</table>
# SUMMARY OF MINIMUM MARGINS OF SAFETY (cont'd)

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

*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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>( P_x )</th>
<th>( P_y )</th>
<th>( P_z )</th>
<th>( M_y )</th>
<th>( M_z )</th>
<th>( R^f_x )</th>
<th>( R^f_y )</th>
<th>( R^f_z )</th>
<th>( R^{SBL}_x )</th>
<th>( R^{SBL}_y )</th>
<th>( R^{SBR}_x )</th>
<th>( R^{SBR}_y )</th>
<th>( R^{SBR}_z )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>1,440</td>
<td>3,400</td>
<td>-16,460</td>
<td>-194,000</td>
<td>410,600</td>
<td>0</td>
<td>8,212</td>
<td>30,935</td>
<td>21,500</td>
<td>0</td>
<td>1,440</td>
<td>-8,212</td>
<td>17,198</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>290</td>
<td>7,030</td>
<td>-16,200</td>
<td>-31,700</td>
<td>-451,800</td>
<td>0</td>
<td>-9,036</td>
<td>24,651</td>
<td>0</td>
<td>17,000</td>
<td>290</td>
<td>9,036</td>
<td>35,782</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>1,330</td>
<td>4,810</td>
<td>-17,900</td>
<td>-133,300</td>
<td>355,500</td>
<td>0</td>
<td>7,110</td>
<td>27,293</td>
<td>19,820</td>
<td>0</td>
<td>1,330</td>
<td>-7,110</td>
<td>16,141</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>1,330</td>
<td>3,360</td>
<td>-17,900</td>
<td>-133,300</td>
<td>455,800</td>
<td>0</td>
<td>9,076</td>
<td>31,444</td>
<td>23,600</td>
<td>0</td>
<td>1,330</td>
<td>-9,076</td>
<td>22,132</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>3,000</td>
<td>2,450</td>
<td>-18,900</td>
<td>-321,000</td>
<td>347,000</td>
<td>0</td>
<td>6,940</td>
<td>33,727</td>
<td>17,970</td>
<td>0</td>
<td>3,000</td>
<td>-6,940</td>
<td>12,432</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>3,000</td>
<td>26,900</td>
<td>-18,900</td>
<td>-321,000</td>
<td>267,000</td>
<td>0</td>
<td>5,340</td>
<td>45,744</td>
<td>29,500</td>
<td>0</td>
<td>3,000</td>
<td>-5,340</td>
<td>30,833</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>15,000</td>
<td>4,500</td>
<td>-9,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12,148</td>
<td>2,840</td>
<td>0</td>
<td>15,000</td>
<td>0</td>
<td>6,492</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>-15,000</td>
<td>6,750</td>
<td>450</td>
<td>0</td>
<td>0</td>
<td>-15,000</td>
<td>0</td>
<td>0</td>
<td>4,395</td>
<td>155</td>
<td>0</td>
<td>15,120</td>
<td>11,750</td>
</tr>
</tbody>
</table>

**Note**: 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 verifies 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

Loads and reactions shown in positive directions.

View looking aft
## Table 2

**Calculation of Aircraft Attachment**

Applied and reacting loads are shown in pounds. M

**Notes:**
1. For constants, reference figure 1 and 2
2. For loads source, reference page 3

<table>
<thead>
<tr>
<th>Condition</th>
<th>( p_x )</th>
<th>( p_y )</th>
<th>( p_z )</th>
<th>( p_{SBL} )</th>
<th>( p_{SBR} )</th>
<th>( p_x )</th>
<th>( p_y )</th>
<th>( p_z )</th>
<th>( p_{SBL} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>8,212</td>
<td>30,935</td>
<td>-21,500</td>
<td>0</td>
<td>1,440</td>
<td>-8,212</td>
<td>17,198</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>-9,036</td>
<td>24,651</td>
<td>0</td>
<td>-17,000</td>
<td>290</td>
<td>9,036</td>
<td>35,782</td>
<td>-33,600</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>7,110</td>
<td>27,293</td>
<td>-19,820</td>
<td>0</td>
<td>1,330</td>
<td>-7,110</td>
<td>16,141</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>9,076</td>
<td>31,244</td>
<td>-23,600</td>
<td>0</td>
<td>1,330</td>
<td>-9,076</td>
<td>22,132</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>6,940</td>
<td>33,727</td>
<td>-17,970</td>
<td>0</td>
<td>3,000</td>
<td>-6,940</td>
<td>12,432</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>5,340</td>
<td>45,744</td>
<td>-29,500</td>
<td>0</td>
<td>3,000</td>
<td>-5,340</td>
<td>30,833</td>
<td>-34,200</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>12,148</td>
<td>-2,840</td>
<td>0</td>
<td>15,000</td>
<td>0</td>
<td>6,492</td>
<td>-7,850</td>
</tr>
<tr>
<td>8</td>
<td>-15,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-4,395</td>
<td>0</td>
<td>0</td>
<td>15,120</td>
<td>-11,750</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>( \frac{p_{SBR} - p_{SBL}}{x} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{y} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{z} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{x} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{y} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{z} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{x} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{y} )</th>
<th>( \frac{p_{SBR} - p_{SBL}}{z} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5,694</td>
<td>33,365</td>
<td>136,525</td>
<td>-33,365</td>
<td>-85,471</td>
<td>2,053</td>
<td>10,265</td>
<td>-2,053</td>
<td>-10,265</td>
</tr>
<tr>
<td>2</td>
<td>14,213</td>
<td>-36,713</td>
<td>-107,950</td>
<td>36,713</td>
<td>213,360</td>
<td>-2,259</td>
<td>-11,295</td>
<td>2,259</td>
<td>11,295</td>
</tr>
<tr>
<td>3</td>
<td>-3,574</td>
<td>28,888</td>
<td>125,857</td>
<td>-28,888</td>
<td>-53,657</td>
<td>1,777</td>
<td>8,887</td>
<td>-1,777</td>
<td>-8,887</td>
</tr>
<tr>
<td>4</td>
<td>-6,599</td>
<td>36,876</td>
<td>149,860</td>
<td>-36,876</td>
<td>-99,060</td>
<td>2,269</td>
<td>11,345</td>
<td>-2,269</td>
<td>-11,345</td>
</tr>
<tr>
<td>5</td>
<td>-5,139</td>
<td>28,197</td>
<td>114,109</td>
<td>-28,197</td>
<td>-77,152</td>
<td>1,735</td>
<td>8,675</td>
<td>-1,735</td>
<td>-8,675</td>
</tr>
<tr>
<td>6</td>
<td>14,467</td>
<td>21,696</td>
<td>187,325</td>
<td>-21,696</td>
<td>217,170</td>
<td>1,335</td>
<td>6,675</td>
<td>-1,335</td>
<td>-6,675</td>
</tr>
<tr>
<td>7</td>
<td>3,321</td>
<td>0</td>
<td>18,034</td>
<td>0</td>
<td>49,847</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>4,970</td>
<td>0</td>
<td>26,924</td>
<td>0</td>
<td>74,612</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
**Table 2**

**CALCULATION OF AIRCRAFT ATTACHMENT REACTIONS (ULTIMATE)**

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

**TIPS:**
1. For constants, reference figure 1 and general equations, pages 9 and 10.
2. For loads source, reference page 3.

<table>
<thead>
<tr>
<th>( P^a_y )</th>
<th>( P^a_z )</th>
<th>( P^a_{SBL} )</th>
<th>( F^a_{SBR} )</th>
<th>( 1.25 P^f )</th>
<th>( 0.184\left(\frac{P^f_{x}}{P^a} \cdot P^a_{x}\right) )</th>
<th>( 0.25 P^a_z )</th>
<th>( 1.25 P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-8,212</td>
<td>17,198</td>
<td>0</td>
<td>-13,460</td>
<td>38,669</td>
<td>265</td>
<td>-19,479</td>
<td>4,799</td>
</tr>
<tr>
<td>9,036</td>
<td>35,782</td>
<td>-33,600</td>
<td>0</td>
<td>30,814</td>
<td>53</td>
<td>-15,402</td>
<td>58,945</td>
</tr>
<tr>
<td>-7,110</td>
<td>16,141</td>
<td>0</td>
<td>-8,450</td>
<td>34,116</td>
<td>245</td>
<td>-17,957</td>
<td>4,035</td>
</tr>
<tr>
<td>-9,076</td>
<td>22,132</td>
<td>0</td>
<td>-15,600</td>
<td>39,055</td>
<td>245</td>
<td>-21,382</td>
<td>5,533</td>
</tr>
<tr>
<td>-6,940</td>
<td>12,432</td>
<td>0</td>
<td>-12,150</td>
<td>42,159</td>
<td>552</td>
<td>-16,281</td>
<td>3,108</td>
</tr>
<tr>
<td>-5,340</td>
<td>30,833</td>
<td>-34,200</td>
<td>0</td>
<td>57,180</td>
<td>552</td>
<td>-26,727</td>
<td>7,708</td>
</tr>
<tr>
<td>0</td>
<td>6,492</td>
<td>-7,850</td>
<td>0</td>
<td>15,185</td>
<td>2,760</td>
<td>-2,573</td>
<td>1,623</td>
</tr>
<tr>
<td>0</td>
<td>15,120</td>
<td>-11,750</td>
<td>0</td>
<td>0</td>
<td>-2,760</td>
<td>-3,982</td>
<td>3,780</td>
</tr>
</tbody>
</table>

\[ \begin{align*}
1.25 P^f_{y} & \quad 0.25 P^a_{y} & \quad 1.25 P^a_{y} & \quad R_{x,f} & \quad R_{y,f} & \quad R_{z,f} & \quad M_{x,f} & \quad R_{x,a} & \quad R_{y,a} & \quad R_{z,a} \\
1.25 & \quad 0.25 & \quad 1.25 & \quad 1 & \quad 25 + 26 & \quad 11 + 12 - 14 - 19 + 24 & \quad 19 & \quad 16 & \quad 12 - 17
\end{align*} \]

Reactions at aircraft attachment points:

<table>
<thead>
<tr>
<th>( P^a_{y} )</th>
<th>( P^a_{z} )</th>
<th>( P^a_{SBL} )</th>
<th>( F^a_{SBR} )</th>
<th>( 1.25 P^f )</th>
<th>( 0.184\left(\frac{P^f_{x}}{P^a} \cdot P^a_{x}\right) )</th>
<th>( 0.25 P^a_z )</th>
<th>( 1.25 P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10,265</td>
<td>-2,053</td>
<td>-10,265</td>
<td>0</td>
<td>21,412</td>
<td>15,156</td>
<td>-169,890</td>
<td>1,440</td>
</tr>
<tr>
<td>-11,295</td>
<td>2,259</td>
<td>11,295</td>
<td>0</td>
<td>-20,745</td>
<td>6,520</td>
<td>144,663</td>
<td>290</td>
</tr>
<tr>
<td>8,887</td>
<td>-1,777</td>
<td>-8,887</td>
<td>0</td>
<td>19,048</td>
<td>12,369</td>
<td>-154,745</td>
<td>1,330</td>
</tr>
<tr>
<td>11,345</td>
<td>-2,269</td>
<td>-11,345</td>
<td>0</td>
<td>23,597</td>
<td>12,385</td>
<td>-186,736</td>
<td>1,330</td>
</tr>
<tr>
<td>8,675</td>
<td>-1,735</td>
<td>-8,675</td>
<td>0</td>
<td>18,011</td>
<td>23,322</td>
<td>-142,306</td>
<td>3,000</td>
</tr>
<tr>
<td>6,575</td>
<td>-1,335</td>
<td>-6,675</td>
<td>0</td>
<td>20,488</td>
<td>23,297</td>
<td>-209,021</td>
<td>3,000</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,201</td>
<td>13,749</td>
<td>-18,034</td>
<td>15,000</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-15,000</td>
<td>1,794</td>
<td>-10,522</td>
<td>-26,924</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4,970</td>
<td>11,015</td>
<td>-4,432</td>
<td>-4,432</td>
</tr>
</tbody>
</table>
Table 2
TACHMENT REACTIONS (ULTIMATE)
pounds. Moments are shown in inch-pounds.
Figure 1 and general equations, pages 9 and 10
page 3

<table>
<thead>
<tr>
<th>1</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( P_{a}^{SBR} )</td>
<td>( P_{a}^{SBL} )</td>
<td>( 1.25 P_{z}^{f} )</td>
<td>( 0.184(\overline{P}<em>{x}^{f}+\overline{P}</em>{x}^{a}) )</td>
<td>( (\overline{P}<em>{x}^{SBR}+\overline{P}</em>{x}^{SBL}) \times 0.906 )</td>
<td>( 0.096 \times )</td>
<td>( 0.25 P_{z}^{a} )</td>
<td>( 1.25 P_{z}^{a} )</td>
<td>( (P_{x}^{SBR}+\overline{P}_{x}^{SBL}) \times 0.906 )</td>
</tr>
<tr>
<td>0</td>
<td>-33,600</td>
<td>0</td>
<td>0</td>
<td>-13,460</td>
<td>38,669</td>
<td>265</td>
<td>-19,479</td>
<td>4,299</td>
<td>21,497</td>
</tr>
<tr>
<td>-33,600</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30,814</td>
<td>53</td>
<td>-15,402</td>
<td>8,945</td>
<td>44,727</td>
<td>-30,442</td>
</tr>
<tr>
<td>0</td>
<td>-8,450</td>
<td>34,116</td>
<td>245</td>
<td>-17,957</td>
<td>4,035</td>
<td>20,176</td>
<td>-7,656</td>
<td>6,823</td>
<td>8,384</td>
</tr>
<tr>
<td>0</td>
<td>-15,600</td>
<td>39,055</td>
<td>245</td>
<td>-21,382</td>
<td>5,533</td>
<td>27,665</td>
<td>-14,134</td>
<td>7,811</td>
<td>9,983</td>
</tr>
<tr>
<td>0</td>
<td>-12,150</td>
<td>42,159</td>
<td>552</td>
<td>-16,281</td>
<td>3,108</td>
<td>15,540</td>
<td>-11,008</td>
<td>8,432</td>
<td>7,601</td>
</tr>
<tr>
<td>-34,200</td>
<td>0</td>
<td>57,180</td>
<td>552</td>
<td>-26,727</td>
<td>7,708</td>
<td>38,514</td>
<td>-30,985</td>
<td>11,436</td>
<td>12,478</td>
</tr>
<tr>
<td>-7,850</td>
<td>0</td>
<td>15,185</td>
<td>2,760</td>
<td>-2,573</td>
<td>1,623</td>
<td>8,115</td>
<td>-7,112</td>
<td>3,037</td>
<td>1,201</td>
</tr>
<tr>
<td>-11,750</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-2,760</td>
<td>3,982</td>
<td>3,780</td>
<td>18,900</td>
<td>-10,645</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 1.25 P_{a}^{\gamma} )</td>
<td>( R_{x}^{f} )</td>
<td>( R_{y}^{f} )</td>
<td>( R_{z}^{f} )</td>
<td>( M_{x}^{f} )</td>
<td>( M_{y}^{f} )</td>
<td>( M_{z}^{f} )</td>
<td>( d_{x} )</td>
<td>( d_{y} )</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>25</td>
<td>26</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>-20</td>
<td>-21</td>
</tr>
<tr>
<td>1.25</td>
<td>7</td>
<td>( 1 )</td>
<td>( 25 )</td>
<td>( +26 )</td>
<td>( 11 )</td>
<td>( +12 )</td>
<td>( 13 )</td>
<td>( +14 )</td>
<td>( -20 )</td>
</tr>
</tbody>
</table>

Reactions at aircraft attachment points

<table>
<thead>
<tr>
<th>18</th>
<th>17</th>
<th>16</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{a}^{SBR} ) ( -f )</td>
<td>( 0.906 )</td>
<td>( 0.423 )</td>
<td>( 5 )</td>
<td>( 4 )</td>
<td>( 3 )</td>
<td>( 2 )</td>
<td>( 1 )</td>
<td>( 0 )</td>
<td>( -1 )</td>
</tr>
</tbody>
</table>

| 0     | -15,000 | 1,794  | -10,522 | -26,924 | 0      | 4,970  | 11,015 | -74,612 | 7,734  | 9,094  |

7
AIRCRAFT ATTACHMENT REACTIONS

General Equations for Reactions

Vertical Reactions

\[ F_z = f (25) + (P_x^f + P_x^a) (3.688) + \left( P_{SBR}^f + P_{SBL}^f \right) \cos 25^\circ (20) - P_{z}^a (5) - R_z (20) = 0 \]

\[ R_z^f = 1.25 P_z^f + 0.184 (P_x^f + P_x^a) + 0.906 \left( P_{SBR}^f + P_{SBL}^f \right) - 0.25 P_z^a \]

\[ P_z^a = 1.25 (P_x^f + P_x^a) (3.688) - P_z^f (5) + \left( P_{SBR}^a + P_{SBL}^a \right) \cos 25^\circ (20) - R_z^a (20) = 0 \]

\[ R_z^a = 1.25 P_z^a - 0.184 (P_x^f + P_x^a) + 0.906 \left( P_{SBR}^a + P_{SBL}^a \right) - 0.25 P_z^f \]

Longitudinal Reactions

\[ R_x^f = P_x^f \]
\[ R_x^a = P_x^a \]

Lateral Reactions

\[ P_y^f (25) + 20 \sin 25^\circ P_{SBR}^f - 20 \sin 25^\circ P_{SBL}^f - P_y^a (5) - R_y^f (20) = 0 \]

\[ R_y^f = 1.25 P_y^f + 0.423 \left( P_{SBR}^f - P_{SBL}^f \right) - 0.25 P_y^a \]

\[ P_y^a (25) + 20 \sin 25^\circ P_{SBR}^a - 20 \sin 25^\circ P_{SBL}^a - P_y^f (5) - R_y^a (20) = 0 \]

\[ R_y^a = 1.25 P_y^a + 0.423 \left( P_{SBR}^a - P_{SBL}^a \right) - 0.25 P_y^f \]

(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.

\[
M^f_x + P^f_y(4.063) + \left(P^f_{SBR} - P^f_{SBL}\right)(6.350) = 0
\]

\[
M^f_x = -P^f_y(4.063) - \left(P^f_{SBR} - P^f_{SBL}\right)(6.350)
\]

\[
M^a_x + P^a_y(4.063) + \left(P^a_{SBR} - P^a_{SBL}\right)(6.350) = 0
\]

\[
M^a_x = -P^a_y(4.063) - \left(P^a_{SBR} - P^a_{SBL}\right)(6.350)
\]
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
DIMENSION CALCULATIONS

(Reference page 13)

\[ \tan \theta = \frac{1.187}{3.875} \]

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

\[ \sin \varphi = \sin^{-1} 0.060 = 0.0565 \]

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

\[ \delta = 90^\circ - \theta = 90 - 17.04 \]

\[ \delta = 72.96^\circ \]

\[ \sin \gamma = \sin^{-1} 0.060 = 0.0198 \]

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

\[ \sin \alpha = \frac{1.500}{1.375} = 1.090 \]

\[ \alpha = \sin^{-1} 1.090 = 47.48^\circ \]

\[ \beta = \alpha + \theta - \gamma \]

\[ = 47.48 + 17.04 - 1.26 \]

\[ \beta = 63.26^\circ \]

\[ \epsilon = \theta - \gamma \]

\[ = 17.04 - 1.26 = 15.78^\circ \]

Distance -- X and Y:

\[ \tan \omega = \frac{0.781}{0.400} = 1.952 \]

\[ \omega = \tan^{-1} 1.952 = 62.89 \]

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

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

\[ \theta' = 6.83^\circ \]

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

\[ \sin \theta' = \frac{Y}{\overline{EN}} \]

\[ Y = \overline{EN} \sin \theta' = (0.878)(0.118) \]

\[ Y = 0.104 \text{ in.} \]

\[ \tan \theta' = \frac{Y}{X} \]

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

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

\[ h = 1.062 \sin 20.28 = 0.368 \text{ in.} \]
\[\overline{EK} = \sqrt{(0.750)^2 + (0.875)^2} = 1.153 \text{ in.}\]

\[\gamma = \varphi + \theta = 3.24 + 17.04 = 20.28^\circ \quad \text{(Reference page 14)}\]

\[\tan \varepsilon = \frac{0.750}{0.875} = 0.857\]

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

\[\beta = \varepsilon - \gamma = 40.60 - 20.28 = 20.32^\circ\]

\[\sin \beta = \frac{a}{\overline{EK}}\]

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

\[\cos \beta = \frac{b}{\overline{EK}}\]

\[b = (1.153)(0.938) = 1.082 \text{ in.}\]
DISTANCE TO LINE OF ACTION FROM POINT E

(Reference page 15)

\[
\sin \alpha = \frac{d_1}{EK}
\]

\[
a = 90 - (\beta + \lambda) = 90 - (20.32 + 12.68)
\]

\[
a = 90.00 - 33.00 = 57.00^\circ
\]

\[
d_1 = EK \sin 57^\circ = (1.153)(0.838) = 0.968 \text{ in.}
\]

\[
\overline{EH} = \sqrt{(3.875)^2 + (1.187)^2} = 4.05 \text{ in.}
\]

\[
\sin \gamma = \frac{d_2}{EH}, \quad \gamma = 1.264^\circ
\]

\[
d_2 = EH \sin 1.264^\circ = (4.05)(0.0198) = 0.080 \text{ in.}
\]

\[
\tan \theta = \frac{1.084}{5.007} = 0.217
\]

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

\[
\phi' = \theta - \theta' = 6.83^\circ
\]

(Reference page 14)

\[
\phi' = 12.24 - 6.83 = 5.41^\circ
\]

\[
\sin \phi' = \frac{d_3}{EN}, \quad \overline{EN} = 0.878 \text{ in.} \quad \text{(Reference page 14)}
\]

\[
d_3 = EN \sin 5.41 = (0.878)(0.0943) = 0.083 \text{ in.}
\]
FORWARD 30-INCH SHACKLE REACTIONS

(Reference Drawing 60D46528)

General Equations for Reactions

\[ \Sigma M_A = 0 : 0.750 P_z - 1.750 R_{G^{'}x} = 0 \]

\[ R_{G^{'}x} = \frac{0.750 P_z}{1.750} = 0.428 P_z \]

\[ \Sigma F_z = 0 : R_{Az} = P_z \]

\[ \Sigma F_x = 0 : R_{G^{'}x} + R_{Ax} = 0 \]

\[ R_{Ax} = -R_{G^{'}x} = -0.428 P_z \]

\[ M_{Ax} = 3.125 P_y \]
FORWARD 14-INCH SHACKLE REACTION
(Reference Drawing 63J14363)

Loads and reactions shown in positive directions

General Equation for Reactions

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

\[ \overline{CH'} = 2.07 \text{ in.} \]

\[ \Delta C = \tan^{-1} \frac{1.500}{1.375} = \tan^{-1} 1.090 \]

\[ \Delta C = 47.48^\circ \]

\[ \therefore \varphi = 90 - [\Delta C + \theta] \]

\[ \varphi = 90 - [47.48 + 12.24] \]

\[ \varphi = 30.28^\circ \]

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

\[ d = 1.788 \text{ in.} \]
\[ \Sigma M_c = 0 \Rightarrow 1.750 P_G^t - 1.788 R_H^t = 0 \]

\[
R_H^t = \frac{1.750}{1.788} P_G^t = 0.980 P_G^t
\]

\[ \Rightarrow R_H^t = 0.980 \left[ 0.428 P_z^f \right] = 0.4195 P_z^f \]

\[ \Sigma F_z = 0 \Rightarrow R_{cz} = R_H^t \sin \theta \\
= 0.212 R_H^t \\
\Rightarrow R_{cz} = 0.212 \left[ 0.4195 P_z^f \right] \\
= 0.0889 P_z^f \]

\[ \Sigma F_x = 0 \Rightarrow R_{cx} + R_H^t \cos \theta - P_G^t = 0 \\
R_{cx} = P_G^t - 0.976 R_H^t \\
= P_G^t - 0.976 \left[ 0.980 P_G^t \right] \quad \text{(Reference page 18)} \\
= 0.044 P_G^t = 0.044 \left[ 0.428 P_z^f \right] \quad \text{(Reference page 17)} \\
= 0.0188 P_z^f \]
AFT 30-INCH SHACKLE REACTIONS
(Reference Drawing 60D46528)

Loads and reactions shown in Positive directions

General Equations for Reactions

\[ \sum M_{By} = 0 : R_G (1.750) - P_z^a (0.750) = 0 \]

\[ R_G = \frac{0.750}{1.750} P_z^a = 0.428 P_z^a \]

\[ \sum F_z = 0 : R_{Bz} = P_z^a \]

\[ \sum F_x = 0 : R_{Bx} = -R_G = -0.428 P_z^a \]

\[ M_{Bx} = 3.125 P_y^a \]
AFT 14-INCH SHACKLE REACTIONS
(Reference Drawing 63J14363)

General Equations for Reactions

\[ \bar{H} D = \sqrt{(1.375)^2 + (1.500)^2} = 2.07 \text{ in.} \]

\[ \cos \varphi = \frac{d}{\bar{H} D} \]

\[ \bar{H} D \cos 26.74^\circ = d \]

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

\[ \Sigma M_D = 0 \]

\[ R_H d = 1.75 P_G \]

\[ R_H = \frac{1.75}{1.848} P_G = 0.948 P_G \]

\[ R_H = 0.948 \left[ 0.428 P^a_z \right] \quad \text{(Reference page 20)} \]

\[ = 0.406 P^a_z \]

21
\[ \Sigma F_z = 0 \]

\[ R_{Dz} = R_H \sin 15.78^\circ = 0.2718 \, R_H = \frac{0.1103 \, P^a_z}{P^a} \]

\[ \Sigma F_x = 0 \]

\[ R_{Dx} + R_H \cos 15.78^\circ \, P_G = 0 \]

\[ R_{Dx} = P_G - (0.962) \, R_H = P_G - (0.962)(0.948) \, P_G \]

\[ \therefore R_{Dx} = 0.090 \, P_G = 0.090 \left[ 0.428 \, P^a_z \right] = 0.0386 \, P^a_z \]
BELLCRANK REACTIONS
(Reference Drawing 63J1436Z)

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

\[ \sum M_E = 0 \]

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

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

\[ = 0.0858 P_{H'} + 0.0827 P_H \]

\[ = 0.0858 \left[ 0.4195 P_z^f \right] + 0.0827 \left[ 0.4061^a_z \right] \]  
(Reference pages 19 and 21)

\[ = 0.036 P_z^f + 0.0336 P_z^a \]

\[ M_{Ex} = R_K \sin 12.68(0.875) \]  
(Reference Drawing 63J1436Z for dimensions)

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

\[ = 0.00692 P_z^f + 0.00645 P_z^a \]
\[ M_{Ez} = R_K \cos 12.68 (0.875) \]
\[ = (0.875)(0.975) \left[ 0.036 P^f_z + 0.0336 P^a_z \right] \]
\[ = 0.0307 P^f_z + 0.02865 P^a_z \]

\[ \Sigma F_z = 0 \]
\[ R_{Ez} + P_{Hi} \sin 12.24^\circ + P_H \sin 15.78^\circ - R_K \sin 12.68^\circ = 0 \]
\[ R_{Ez} = 0.2195 R_K - 0.212 P_{Hi} - 0.272 P_H \]
\[ P_{Hi} = 0.4195 P^f_z \) (Reference page 19)\]
\[ P_H = 0.406 P^a_z \) (Reference page 21)\]
\[ R_K = 0.036 P^f_z + 0.0336 P^a_z \) (Reference page 23)\]
\[ R_{Ez} = 0.2195 \left[ 0.036 P^f_z + 0.0336 P^a_z \right] - 0.212 \left[ 0.4195 P^f_z \right] \]
\[ - 0.272 \left( 0.406 P^a_z \right) \]
\[ = 0.0079 P^f_z + 0.00738 P^a_z - 0.1105 P^a_z - 0.0889 P^f_z \]
\[ = -0.081 P^f_z - 0.103 P^a_z \]

\[ \Sigma F_x = 0 \]
\[ R_{Ex} + P_{Hi} \cos 12.24 - P_H \cos 15.78 + R_K \cos 12.68 = 0 \]
\[ R_{Ex} = -0.976 P_{Hi} + 0.9625 P_H - 0.975 R_K \]
\[ = -0.976 \left[ 0.4195 P^f_z \right] + 0.9625 \left[ 0.406 P^a_z \right] \]
\[ -0.975 \left[ 0.036 P^f_z + 0.0336 P^a_z \right] \]
\[ = -0.410 P^f_z + 0.3904 P^a_z - 0.0351 P^f_z - 0.0328 P^a_z \]
\[ = -0.4451 P^f_z + 0.3576 P^a_z \]
### Table 3
CALCULATION OF LINKAGE MECHANISM REACTION

Applied and reacting loads are shown in pounds. Moments are calculated.

**NOTES:**
1. For constants and general equations, reference page 7.
2. For load source, reference page 7.

| Edition | p\text{f} & p\text{z} & p\text{a} & p\text{z} & 0.036 p\text{f} & 0.0307 p\text{f} & 0.081 p\text{f} & 0.445 p\text{f} & p\text{a} |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 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     | 2,211   | 10,972  |
| 3       | 7,110   | 27,293  | -7,110  | 16,141  | 983     | 189     | 838     | 2,148   | 15,012  |
| 4       | 9,076   | 31,244  | -9,076  | 22,132  | 1,125   | 216     | 959     | 2,531   | 15,012  |
| 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       |

<table>
<thead>
<tr>
<th>Edition</th>
<th>M_{Ax}</th>
<th>R_{H}</th>
<th>R_{cz}</th>
<th>R_{cx}</th>
<th>R_{G}</th>
<th>R_{Bx}</th>
<th>R_{Bz}</th>
<th>M_{Bx}</th>
<th>R_{H}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.125</td>
<td>0.4195</td>
<td>0.0889</td>
<td>0.0188</td>
<td>0.428</td>
<td>-22</td>
<td>4</td>
<td>3.125</td>
<td>0.406</td>
</tr>
<tr>
<td>2</td>
<td>25,663</td>
<td>12,977</td>
<td>2,750</td>
<td>582</td>
<td>7,361</td>
<td>-7,361</td>
<td>17,198</td>
<td>-25,663</td>
<td>6,982</td>
</tr>
<tr>
<td>3</td>
<td>-28,238</td>
<td>10,341</td>
<td>2,191</td>
<td>463</td>
<td>15,315</td>
<td>-15,315</td>
<td>35,782</td>
<td>-28,238</td>
<td>14,527</td>
</tr>
<tr>
<td>4</td>
<td>22,219</td>
<td>11,449</td>
<td>2,426</td>
<td>513</td>
<td>6,908</td>
<td>-6,908</td>
<td>16,141</td>
<td>-22,219</td>
<td>6,553</td>
</tr>
<tr>
<td>5</td>
<td>28,363</td>
<td>13,107</td>
<td>2,778</td>
<td>587</td>
<td>9,422</td>
<td>-9,422</td>
<td>22,132</td>
<td>-28,363</td>
<td>8,986</td>
</tr>
<tr>
<td>6</td>
<td>21,688</td>
<td>14,148</td>
<td>2,998</td>
<td>634</td>
<td>5,321</td>
<td>-5,321</td>
<td>12,432</td>
<td>-21,688</td>
<td>5,047</td>
</tr>
<tr>
<td>7</td>
<td>16,688</td>
<td>19,190</td>
<td>4,067</td>
<td>860</td>
<td>13,197</td>
<td>-13,197</td>
<td>30,833</td>
<td>-16,688</td>
<td>12,518</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>5,096</td>
<td>1,080</td>
<td>228</td>
<td>2,779</td>
<td>-2,779</td>
<td>6,492</td>
<td>0</td>
<td>2,636</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6,471</td>
<td>-6,471</td>
<td>15,120</td>
<td>0</td>
<td>0</td>
<td>6,139</td>
</tr>
</tbody>
</table>
Table 3
CALCULATION OF LINKAGE MECHANISM REACTIONS (ULTIMATE)
All reactions are shown in pounds. Moments are shown in inch-pounds.
1. For constants and general equations, reference pages 17 through 24
2. For load source, reference page 7

<table>
<thead>
<tr>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_z$</td>
<td>$P'_z$</td>
<td>$P'_z$</td>
<td>$P_z$</td>
<td>$P'_z$</td>
<td>$P_z$</td>
<td>$P_z$</td>
<td>$P_z$</td>
<td>$P_z$</td>
<td>$P_z$</td>
</tr>
<tr>
<td>2</td>
<td>0.081</td>
<td>2</td>
<td>0.4451</td>
<td>2</td>
<td>0.036</td>
<td>4</td>
<td>0.00645</td>
<td>4</td>
<td>0.0287</td>
</tr>
<tr>
<td>2</td>
<td>950</td>
<td>2,506</td>
<td>13,769</td>
<td>578</td>
<td>111</td>
<td>493</td>
<td>1,773</td>
<td>6,150</td>
<td>13,240</td>
</tr>
<tr>
<td>757</td>
<td>1,997</td>
<td>10,972</td>
<td>1,202</td>
<td>231</td>
<td>1,025</td>
<td>3,689</td>
<td>12,796</td>
<td>10,551</td>
<td>-10,551</td>
</tr>
<tr>
<td>838</td>
<td>2,211</td>
<td>12,148</td>
<td>542</td>
<td>104</td>
<td>462</td>
<td>1,664</td>
<td>5,772</td>
<td>11,681</td>
<td>-11,681</td>
</tr>
<tr>
<td>959</td>
<td>2,531</td>
<td>13,907</td>
<td>744</td>
<td>143</td>
<td>634</td>
<td>2,282</td>
<td>7,914</td>
<td>13,372</td>
<td>-13,372</td>
</tr>
<tr>
<td>373</td>
<td>2,732</td>
<td>15,012</td>
<td>418</td>
<td>80</td>
<td>356</td>
<td>1,282</td>
<td>4,446</td>
<td>14,435</td>
<td>-14,435</td>
</tr>
<tr>
<td>404</td>
<td>3,705</td>
<td>20,361</td>
<td>1,036</td>
<td>199</td>
<td>883</td>
<td>3,179</td>
<td>11,026</td>
<td>19,578</td>
<td>-19,578</td>
</tr>
<tr>
<td>373</td>
<td>984</td>
<td>5,407</td>
<td>218</td>
<td>42</td>
<td>186</td>
<td>660</td>
<td>7,322</td>
<td>5,199</td>
<td>-5,199</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>508</td>
<td>97</td>
<td>433</td>
<td>1,559</td>
<td>5,407</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{Bx}$</td>
<td>$R_H$</td>
<td>$R_{Dy}$</td>
<td>$R_{DX}$</td>
<td>$R_K$</td>
<td>$M_{E_x}$</td>
<td>$M_{E_z}$</td>
<td>$R_{E_z}$</td>
<td>$R_{E_x}$</td>
<td></td>
</tr>
<tr>
<td>198</td>
<td>3,125</td>
<td>0.406</td>
<td>0.1103</td>
<td>0.0386</td>
<td>0.5 + 10</td>
<td>0.6 + 11</td>
<td>0.7 + 12</td>
<td>0.8 - 13</td>
<td>0.9 + 14</td>
</tr>
<tr>
<td>782</td>
<td>+28,238</td>
<td>14,527</td>
<td>3,947</td>
<td>1,381</td>
<td>2,089</td>
<td>402</td>
<td>1,782</td>
<td>5,686</td>
<td>1,824</td>
</tr>
<tr>
<td>141</td>
<td>+22,219</td>
<td>6,553</td>
<td>1,780</td>
<td>623</td>
<td>1,525</td>
<td>263</td>
<td>1,300</td>
<td>3,875</td>
<td>-6,376</td>
</tr>
<tr>
<td>132</td>
<td>+28,363</td>
<td>8,986</td>
<td>2,441</td>
<td>854</td>
<td>1,869</td>
<td>359</td>
<td>1,593</td>
<td>4,813</td>
<td>-5,993</td>
</tr>
<tr>
<td>132</td>
<td>-21,688</td>
<td>5,047</td>
<td>1,371</td>
<td>480</td>
<td>1,632</td>
<td>313</td>
<td>1,391</td>
<td>4,014</td>
<td>-10,566</td>
</tr>
<tr>
<td>1833</td>
<td>-16,688</td>
<td>12,518</td>
<td>3,401</td>
<td>1,190</td>
<td>2,683</td>
<td>516</td>
<td>2,287</td>
<td>-6,884</td>
<td>-9,335</td>
</tr>
<tr>
<td>492</td>
<td>0</td>
<td>2,636</td>
<td>716</td>
<td>251</td>
<td>655</td>
<td>126</td>
<td>559</td>
<td>-1,653</td>
<td>-3,085</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
<td>6,139</td>
<td>1,668</td>
<td>584</td>
<td>508</td>
<td>97</td>
<td>433</td>
<td>-1,559</td>
<td>5,407</td>
</tr>
</tbody>
</table>
### NISM REACTIONS (ULTIMATE)

s. Moments are shown in inch-pounds.

- See reference pages 17 through 24.

<table>
<thead>
<tr>
<th>( P_z )</th>
<th>( P_z^a )</th>
<th>( R_y )</th>
<th>( R_z )</th>
<th>( R_{Gz} )</th>
<th>( R_{Ax} )</th>
<th>( R_{Az} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1451</td>
<td>0.0336</td>
<td>0.00645</td>
<td>0.0287</td>
<td>0.1031</td>
<td>0.3576</td>
<td>0.428</td>
</tr>
<tr>
<td>451</td>
<td>0.0336</td>
<td>0.00645</td>
<td>0.0287</td>
<td>0.1031</td>
<td>0.3576</td>
<td>0.428</td>
</tr>
<tr>
<td>13,769</td>
<td>578</td>
<td>111</td>
<td>493</td>
<td>1,773</td>
<td>6,150</td>
<td>13,240</td>
</tr>
<tr>
<td>10,972</td>
<td>1,202</td>
<td>231</td>
<td>1,025</td>
<td>3,689</td>
<td>12,796</td>
<td>10,551</td>
</tr>
<tr>
<td>12,148</td>
<td>542</td>
<td>104</td>
<td>462</td>
<td>1,664</td>
<td>5,772</td>
<td>11,681</td>
</tr>
<tr>
<td>13,907</td>
<td>744</td>
<td>143</td>
<td>634</td>
<td>2,282</td>
<td>7,914</td>
<td>13,372</td>
</tr>
<tr>
<td>15,012</td>
<td>418</td>
<td>80</td>
<td>356</td>
<td>1,282</td>
<td>4,446</td>
<td>14,435</td>
</tr>
<tr>
<td>20,361</td>
<td>1,036</td>
<td>199</td>
<td>883</td>
<td>3,179</td>
<td>11,026</td>
<td>19,578</td>
</tr>
<tr>
<td>5,407</td>
<td>218</td>
<td>42</td>
<td>186</td>
<td>669</td>
<td>2,322</td>
<td>5,199</td>
</tr>
<tr>
<td>0</td>
<td>508</td>
<td>97</td>
<td>433</td>
<td>1,559</td>
<td>5,407</td>
<td>0</td>
</tr>
</tbody>
</table>

### R

<table>
<thead>
<tr>
<th>( R_{H} )</th>
<th>( R_{Dz} )</th>
<th>( R_{Dx} )</th>
<th>( R_{K} )</th>
<th>( M_{Ex} )</th>
<th>( M_{Ez} )</th>
<th>( R_{Ez} )</th>
<th>( R_{Ex} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>106</td>
<td>0.1103</td>
<td>0.0386</td>
<td>0.0386</td>
<td>0.0386</td>
<td>0.0386</td>
<td>0.0386</td>
<td>0.0386</td>
</tr>
<tr>
<td>6,982</td>
<td>1,807</td>
<td>664</td>
<td>1,692</td>
<td>325</td>
<td>1,443</td>
<td>-4,279</td>
<td>-7,619</td>
</tr>
<tr>
<td>4,527</td>
<td>3,947</td>
<td>1,381</td>
<td>2,089</td>
<td>402</td>
<td>1,782</td>
<td>-5,686</td>
<td>1,824</td>
</tr>
<tr>
<td>6,553</td>
<td>1,780</td>
<td>623</td>
<td>1,525</td>
<td>293</td>
<td>1,300</td>
<td>-3,875</td>
<td>-6,376</td>
</tr>
<tr>
<td>8,986</td>
<td>2,441</td>
<td>854</td>
<td>1,869</td>
<td>359</td>
<td>1,593</td>
<td>-4,813</td>
<td>-5,993</td>
</tr>
<tr>
<td>5,047</td>
<td>1,371</td>
<td>480</td>
<td>1,632</td>
<td>313</td>
<td>1,391</td>
<td>-4,014</td>
<td>-10,566</td>
</tr>
<tr>
<td>2,518</td>
<td>3,401</td>
<td>1,190</td>
<td>2,683</td>
<td>516</td>
<td>2,287</td>
<td>-6,884</td>
<td>-9,335</td>
</tr>
<tr>
<td>2,636</td>
<td>716</td>
<td>251</td>
<td>655</td>
<td>126</td>
<td>559</td>
<td>-1,653</td>
<td>-3,085</td>
</tr>
<tr>
<td>6,139</td>
<td>1,668</td>
<td>584</td>
<td>508</td>
<td>97</td>
<td>433</td>
<td>-1,559</td>
<td>5,407</td>
</tr>
</tbody>
</table>
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
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

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

\[ 20R_f^{zR} = -3144 - 39800 + 6375 - 662 - 1365 + 4785 - 32680 + 33000 + 702500 + 5530 = 674539 \]

\[ R_f^{zR} = \frac{674539}{20} = 33727 \text{ lbs.} \]

\[ \Sigma F_z = 0: 28932 - 33727 + 2033 - 3631 - 107 + 1700 - R_a^{zR} + 9356 = 0 \]

\[ R_a^{zR} = 4556 \text{ lbs.} \]

Left-hand Side Plate

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

\[ (20)R_f^{zL} = -3144 - 91100 + 6375 - 2980 - 6160 + 6875 - 29240 + 33000 + 407500 + 5530 = 326656 \]

\[ R_f^{zL} = \frac{326656}{20} = 16333 \text{ lbs.} \]

\[ \Sigma F_z = 0: 16812 - 16333 + 2033 - 3253 - 482 + 1700 - R_a^{zL} + 21476 = 0 \]

\[ R_a^{zL} = 21953 \text{ lbs.} \]
SIDE PLATE, BENDING AND TENSION SECTION A-A

Side Plate Material
7075-T6 aluminum plate

Allowables (reference MIL-HDBK-5)

\[ F_{tu} = 77000 \text{ psi} \]
\[ F_{ty} = 67000 \text{ psi} \]
\[ F_{su} = 46000 \text{ psi} \]

Section Properties

\[ I_{y-y} = \frac{(0.245)(5.5)^3}{12} (2) = 5.11 \text{ in.}^4 \]

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

\[ I_{z-z} = A_d^2 \]

\[ = (2.45)(1.500-0.122)^2 \]

\[ = 4.65 \text{ in.}^4 \]

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

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

\[ M_{z-z(\text{total})} = 5340(2.813) = 15000 \text{ in.-lbs.}; \]

\[ I_y = \frac{I_{y-y}}{2} = \frac{5.11}{2} = 2.55 \]

\[ f_{by-y} = \frac{M_{y}c_{z}}{I_y} = \frac{(81900)(2.50)}{2.55} \]

\[ = 80300 \text{ psi (right-hand side plate)} \]
WL TDR-64-33

\[ f_{bz-z} = \frac{M_c z}{I_z} = \frac{(1500)(1.5)}{4.65} \]

\[ = 4840 \text{ psi} \]

\[ A = \frac{A_{(tota)}l}{2} = \frac{2.45}{2} = 1.225 \text{ in.}^2 \]

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

Bending Modulus of Rupture

\[ F_{br} = 1.5 F_{ty} = 1.5(67000) = 100500 \text{ psi} \]

\[ R_{by} = \frac{80300}{100500} = 0.798 \]

\[ R_{bz} = \frac{4840}{100500} = 0.048 \]

\[ \text{(Bend and tension M.S.} = \frac{1}{0.798 + 0.048 + 0.104} \]

\[ = 1 = +0.05 \]

\[ R_t = \frac{7990}{77000} = 0.104 \]

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

\[ \text{(Shear) M.S.} = \frac{46000}{23600} -1 = +0.95 \]
SWAYBRACE ANALYSIS
Bending and Shear Condition No. 6 (Reference figure 7)

Mat'1 60H46522
4340 Stl forging
H. T. 180-200 ksi

\[ P_{sbl} = 34200 \text{ lbs.} \]

SECTION B-B
(REF. PAGE 33)
Material: 4340 Stl forging
H.T.: 180-200 ksi

\[ F_{tu} = 180000 \text{ psi} \]
\[ F_{ty} = 163000 \text{ psi} \]
\[ F_{su} = 109000 \text{ psi} \]
\[ P_s = 34200 \text{ lbs.} \]

(Reference page 40)

Thread: Pitch diameter = 0.745 in.

\[ A_s = \pi \left( P.D. \frac{1}{2} \right) \]
\[ = 3.14 \times (0.745 \times 0.5) = 0.585 \text{ in.}^2 \]

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

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

Section D-D

Bending and Shear

\[ P_s = 34200 \text{ lbs.} \]
\[ M_x = 34200 \times 1.0 = 34200 \text{ in.-lbs.} \]
\[ I_x = 0.091 \text{ in.}^4 \]
\[ A_s = 1.62 \text{ in.}^2 \]

\[ f_b = \frac{M_c}{I} = \frac{(34200)(0.44)}{0.091} \]
\[ f_b = 165000 \text{ psi} \]

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

(Reference page 40)

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

(Shear) M.S. = \frac{109000}{21100} - 1 = +4.16
Section C-E

Bending and Shear

\[ P_s = 34200 \text{ lbs.} \]

\[ \text{Moment arm} = 2.05 \text{ in.} \]

\[ M_x = 34200(2.05) = 70000 \text{ in.-lbs.} \]

\[ A_s = 1.83 \text{ in.}^2 \]

\[ Q = 0.252 \text{ in.}^3 \]

\[ I = 0.1596 \text{ in.}^4 \]

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

\[ f_b = 241000 \text{ psi} \]

Bending Modulus of Rupture

\[ F_B = f_m + Kf_o \]

\[ K = \frac{2Q}{l/c} - 1 = \frac{(2)(0.252)(0.55)}{0.1596} - 1 = 0.74 \]

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

\[ f_{b(yield)} = \frac{(70000)(0.55)}{0.1596} = 160000 \text{ psi(yield)} \]

\[ f_s = \frac{34200}{1.83} = 18700 \text{ psi} \]

\[ F_{su} = 109000 \text{ psi} \]
Section F-F

Bending and Shear

\[ P_s = 34200 \text{ lbs.} \]
\[ M_x = 34200 (3.35) = 114500 \text{ in.-lbs.} \]
\[ A_s = 3.173 \text{ in.}^2 \]
\[ Q = 0.470 \text{ in.}^3 \]
\[ I_{x-x} = 0.320 \text{ in.}^4 \]
\[ f_b = \frac{M c}{I} = \frac{(114500)(0.625)}{0.320} \]
\[ f_b = 224000 \text{ psi} \]

Bending Modulus of Rupture

\[ F_B = f_m + K f_o \]
\[ K = \frac{2Q}{l/c} - 1 = \frac{(2)(0.470)(0.625)}{(0.32)} - 1 = 0.835 \]
\[ F_B = f_{ty} + 0.835 f_{ty} = 1.835 (163000) = 299000 \text{ psi} \]

(Bend, Ult) M.S. = \[\frac{299000}{224000} - 1 = +0.33\]

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

(Bend, Yield) M.S. = \[\frac{163000}{149300} - 1 = +0.09\]

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

(Shear) M.S. = \[\frac{109000}{10800} - 1 = +9.10\]
Section G-G

Bending and Compression

\[ P_s = 34200 \text{ lbs.} \]  
(Reference page 40)

\[ M_x = (34200)(6.125) = 209400 \text{ in.-lbs.} \]

Compression Load

\[ P_z = P_s \cos 25^\circ = 34200(0.906) = 31000 \text{ lbs.} \]

Shear Load

\[ P_y = P_s \sin 25^\circ = 34200(0.4225) = 14450 \text{ lbs.} \]

\[ I = 0.855 \text{ in.}^4 \]

\[ A = 2.034 \text{ in.}^2 \]

\[ t = \frac{1.875 - 1.375}{2} = 0.25 \]

\[ \frac{D}{t} = \frac{1.375}{0.25} = 5.5 \]

\[ f_b = \frac{M_c}{I} = \frac{(209400)(0.938)}{0.855} = 228400 \text{ psi (ult)} \]

\[ R_b = \frac{228400}{270000} = 0.847 \]

\[ f_c = \frac{P_z}{A} = \frac{31000}{2.034} = 15200 \text{ psi (ult)} \]

\[ R_c = \frac{15200}{179000} = 0.085 \]

\[ \text{(Ult) M.S.} = \frac{1}{[0.847 + 0.085]} - 1 = +0.07 \]
AIRCRAFT ATTACHMENT CONDITION NO. 6

Maximum Reaction Load
(Reference page 40)

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

\[
R = 43400 + 7750
\]

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

Bearing and Shear-out Analysis

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

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

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

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

\[
e/l_s = 1.0
\]

.: use \( F_{br} = 180000 \text{ psi} \)

\[
F_{wu} = 109000 \text{ psi}
\]

(Reference MIL-HNDBK-5)

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

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

<table>
<thead>
<tr>
<th>Condition</th>
<th>$P_{z}^{f}$</th>
<th>$P_{y}^{f}$</th>
<th>$P_{z}^{a}$</th>
<th>$P_{y}^{a}$</th>
<th>$P_{G}-G'$</th>
<th>$P_{H}-N$</th>
<th>$P_{M}-H$</th>
<th>$P_{G}-G$</th>
<th>$P_{K}-F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-24,651</td>
<td>-9,036</td>
<td>-35,782</td>
<td>9,036</td>
<td>-10,551</td>
<td>-10,341</td>
<td>-14,527</td>
<td>-15,315</td>
<td>+2,089</td>
</tr>
<tr>
<td>6</td>
<td>-45,744</td>
<td>5,340</td>
<td>-30,833</td>
<td>-5,340</td>
<td>-19,578</td>
<td>-19,190</td>
<td>-12,518</td>
<td>-13,197</td>
<td>+2,683</td>
</tr>
</tbody>
</table>

*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)

\[ F_{tu} = 160000 \text{ psi} \]

\[ F_{ty} = 140000 \text{ psi} \]

\[ F_{su} = 100000 \text{ psi} \]

\[ F_{bu} = 219000 \text{ psi} \]

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

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

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

\[ P_z^f = 45744 \text{ lbs.} \]

\[ R_{Gz} = 19578 \text{ lbs.} \]

\[ R_{Ax} = -19578 \text{ lbs.} \]

\[ R_{Az} = 45744 \text{ lbs.} \]

\[ P_y^f = 5340 \text{ lbs.} \]

\[ M_{Ax} = 16688 \text{ in.-lbs.} \]

Condition No. 6
ultimate loads
and reactions
(Reference page 25)
Bending and Shear at Section A-A

\[ M_x = P_z f (0.35) \]
\[ = 45744 (0.35) = 16000 \text{ in.-lbs. (Ult)} \]
\[ f_{bx} = \frac{M_c y}{I_x} = \frac{(16000)(0.45)}{0.0564} = 127500 \text{ psi} \]

\[ M_y = P_y f (0.35) \]
\[ = 1870 (0.35) = 1870 \text{ in.-lbs. (Ult)} \]
\[ f_{by} = \frac{M_c y}{I_y} = \frac{(1870)(0.465)}{0.0603} = 14400 \text{ psi} \]

\[ f_{btot} = f_{bx} + f_{by} = 127500 + 14400 = 141900 \text{ psi} \]

\[ M.S. = \frac{160000}{141900} - 1 = 0.13 \]

\[ P_{total} = \sqrt{P_y^2 + P_z^2} = \sqrt{(5340)^2 + (45744)^2} \]
\[ = 46000 \text{ lbs.} \]

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

\[ f_s = \frac{46000}{0.837} = 55000 \text{ psi} \]

\[ M.S. = \frac{100000}{55000} - 1 = 0.82 \]
Bending and Shear at Section B-B

\( R_G' = 19578 \text{ lbs (Reference page 48)} \)

\[
\begin{align*}
A &= \frac{\pi}{4}D^2 = 0.785 (0.436)^2 = 0.149 \text{ in.}^2 \\
I &= \frac{\pi}{64}D^4 = \frac{\pi}{64} (0.436)^4 = 0.001755 \text{ in.}^4 \\
M &= \frac{R_G'L}{2} = \frac{19578}{2} (0.136) = 1330 \text{ in.-lbs.} \\
f_s &= \frac{R_G'}{2A} = \frac{19578}{2(0.149)} = 65600 \text{ psi} \\
\text{(Shear) M.S.} &= \frac{100000}{65600} - 1 = 0.52 \\
f_b &= \frac{Mc}{I} = \frac{1330(0.218)}{0.001755} = 165000 \text{ psi} \\
\text{Bending Modulus of Rupture} \quad F_B = 265000 \text{ psi (Reference MIL-HDBK-5)} \\
\text{M.S.} &= \frac{265000}{165000} - 1 = 0.60
\end{align*}
\]
SIDE PLATE ATTACHMENT REACTIONS
SECTION C-C

Left-hand Side Plate

\[ R_{Az}^L = \frac{R_{Az}}{2} - \frac{M_{Ax}}{2.75} \]
\[ = \frac{45744}{2} - \frac{16688}{2.75} \]
\[ = 16812 \text{ lbs. (Ult)} \]

\[ R_{Ax}^L = \frac{R_{Ax}}{2} = \frac{-19578}{2} = -9789 \text{ lbs.} \]

Right-hand Side Plate

\[ R_{Az}^R = \frac{R_{Az}}{2} + \frac{M_{Ax}}{2.75} = \frac{45744}{2} + \frac{16688}{2.75} \]
\[ = 22872 + 6060 = 28932 \text{ lbs.} \]

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

Maximum Load

\[ R = \sqrt{\left( \frac{R_{Az}}{2} \right)^2 + \left( \frac{R_{Ax}}{2} \right)^2} = \sqrt{(28932)^2 + (9789)^2} \]
\[ R = 30500 \text{ lbs. (Ult)} \]

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

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

\[ \text{(Shear) M.S.} = \frac{100000}{51200} - 1 = +0.96 \]
Combined Bending, Tension and Shear, Section D-D
(Reference page 48 for applied loads and reactions)

\[ ELEM \]

<table>
<thead>
<tr>
<th>ELEM NO.</th>
<th>A</th>
<th>X</th>
<th>AX</th>
<th>AX^2</th>
<th>Io</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.540</td>
<td>0.675</td>
<td>0.364</td>
<td>0.246</td>
<td>0.082</td>
</tr>
<tr>
<td>2</td>
<td>0.260</td>
<td>0.605</td>
<td>0.157</td>
<td>0.095</td>
<td>0.003</td>
</tr>
<tr>
<td>3</td>
<td>0.540</td>
<td>0.675</td>
<td>0.364</td>
<td>0.246</td>
<td>0.082</td>
</tr>
<tr>
<td>Σ</td>
<td>1.340</td>
<td>0.885</td>
<td>0.587</td>
<td>0.167</td>
<td></td>
</tr>
</tbody>
</table>

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

\[ I_{y-y} = 0.587 + 0.167 = 0.754 \]

\[ I_{y'-y'} = 0.754 - 1.340(0.659)^2 = 0.172 \text{ in.}^4 \]

\[ I_{x-x} = \frac{(1.35)(1.84)^3}{12} - \frac{(1.10)(1.04)^3}{12} = 0.597 \text{ in.}^4 \]

\[ M_{x-x} = P_f (2.450) = (5340)(2.450) = 13080 \text{ in.-lbs.} \]

\[ M_{y'-y'} = P_f (0.90) - R_G (1.075) = 45744 (0.90) - 19578 (1.075) = 20150 \text{ in.-lbs.} \]

\[ f_{bx-x} = \frac{M_{c_{y-y}}}{I_{x-x}} = \frac{(13080)(0.92)}{0.597} = 20140 \text{ psi} \]

\[ f_{by-y} = \frac{M_{c_{x-x}}}{I_{y-y}} = \frac{(20150)(0.691)}{0.172} = 81000 \text{ psi} \]

\[ f_t = \frac{P_f}{A} = \frac{45744}{1.340} = 34100 \text{ psi} \]
WL TDR-64-33

Torsion Shear

\[ \tau = \frac{P_f}{y} = 5340 \times 0.90 = 4800 \text{ in.-lbf}. \]

\[ f_s = \frac{3\tau}{a t_1^2 + 2b t_2} \]

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

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

\[ f_{t_{\text{max}}} = f_{bx-x} + f_{by-y} + f_t \]

\[ = 20140 + 81000 + 34100 \]

\[ = 135240 \text{ psi} \]

\[ R_t = \frac{135240}{160000} = 0.844 \]

\[ R_s = \frac{32200}{100000} = 0.322 \]

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

\[
\begin{align*}
    P^a_z &= 35782 \text{ lbs.} \\
    P^a_y &= 9036 \text{ lbs.} \\
    R_G &= 15315 \text{ lbs.} \\
    R_{Bx} &= -15315 \text{ lbs.} \\
    R_{Bz} &= 35782 \text{ lbs.} \\
    M_{Bx} &= 28238 \text{ lbs.} \\
\end{align*}
\]

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

\[
\begin{align*}
    A &= 0.837 \text{ in.}^2; \ c_y = 0.45 \text{ in.}; \ I_x = 0.0564 \text{ in.}^4 \\
    I_y &= 0.0603 \text{ in.}^4; \ c_x = 0.465 \text{ in.} \\
    M_x &= P^a_z (0.35) = (35782)(0.35) = 12500 \text{ in.-lbs.} \\
    M_y &= P^a_y (0.35) = (9036)(0.35) = 3160 \text{ in.-lbs.} \\
    f_{btotal} &= \frac{(12500)(0.45)}{0.0564} + \frac{(3160)(0.465)}{0.0603} = \\
    f_{btotal} &= 99700 + 24600 = 124300 \text{ psi} \\
\end{align*}
\]

\[
\begin{align*}
    M.S. &= \frac{160000}{124300} - 1 = +0.28 \\
\end{align*}
\]
\[ P_{\text{smax}} = \sqrt{P_y^2 + P_z^2} = \sqrt{(9036)^2 + (35782)^2} \]

\[ P_{\text{smax}} = 36900 \text{ lbs.} \]

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

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

**Shear and Bending, Section B-B**

*(Reference pages 48 and 50 for sketch and properties)*

\[ A = 0.149 \text{ in.}^2 \]

\[ I = 0.001755 \text{ in.}^4 \]

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

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

\[ \text{Shear (ult) M. S.} = \frac{100000}{51400} - 1 = 0.95 \]

\[ f_b = \frac{M c}{I} = \frac{(1042)(0.218)}{0.001755} = 129400 \text{ psi} \]

\[ \text{Bending M. S.} = \frac{160000}{129400} - 1 = 0.24 \]
WL TDR-64-33

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

Side Plate Attachment Reactions

Left-hand Side Plate

\[
R_{Bz}^L = \frac{R_{Bz}}{2} - \frac{M_{Bx}}{2.75} = \frac{35782}{2} - \frac{28238}{2.75} = 17891 - 10270 = 7621 \text{ lbs. (Ult)}
\]

\[
R_{Bx}^L = \frac{R_{Bx}}{2} = \frac{15315}{2} = 7658 \text{ lbs. (Ult)}
\]

Right-hand Side Plate

\[
R_{Bz}^R = \frac{R_{Bz}}{2} + \frac{M_{Bx}}{2.75} = \frac{35782}{2} + \frac{28238}{2.75} = 17891 + 10270 = 28161 \text{ lbs. (Ult)}
\]

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

Maximum Load

\[
R = \sqrt{\left(\frac{R_{Bz}^R}{2}\right)^2 + \left(\frac{R_{Bx}^R}{2}\right)^2} = \sqrt{(28161)^2 + (7658)^2} = 29150 \text{ lbs. (Ult)}
\]

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

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

\[
\text{Shear (Ult) M.S.} = \frac{100000}{48900} - 1 = +1.04
\]
Combined Bending, Tension and Shear, Section D-D
(Reference pages 48 and 52 for section sketch and properties)

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

\[ M_{x-x} = P_y (2.450) = 9036 (2.45) = 22100 \text{ in.-lbf.} \]

\[ M_y = 35782 (0.90) - 15315 (1.075) = 15700 \text{ in.-lbf. (Ult)} \]

\[ f_{by} = \frac{M_{cy}}{I_y} = \frac{(15700)(0.691)}{0.191} = 56800 \text{ psi} \]

\[ f_{bx} = \frac{M_{cy}}{I_x} = \frac{(22100)(0.92)}{0.597} = 34100 \text{ psi} \]

\[ f_t = \frac{P_z}{A} = \frac{35782}{1.340} = 26700 \text{ psi} \]

Torque: \( \tau = P_y (0.90) = 9036 (0.90) = 8120 \text{ in.-lbf.} \)

\[ f_{\text{torque}} = \frac{3(8120)}{(0.4565)^*} = 53450 \text{ psi} \]

*Reference page 53

\[ f_{t_{\text{max}}} = f_{bx} + f_{by} + f_t = 34100 + 56800 + 26700 = 117600 \text{ psi} \]

\[ R_t = \frac{117600}{160000} = 0.735 \]

\[ R_s = \frac{53450}{100000} = 0.535 \]

\[ M.S. = \frac{1}{(0.735)^2 + (0.535)^2}^{1/2} - 1 = +0.10 \]
FORWARD LINK CONNECTING ANALYSIS

(Reference Drawing 60C46530)

Stl material 4340 forging
H.T. 160-180 ksi

$P_G' = 19578$ lbs. (Ult)

(Reference pages 25 and 47)

\[ A = 0.295 \times 0.690 = 0.203 \text{ in.}^2 \]

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

\[ \rho = \sqrt{\frac{1}{A}} = \sqrt{0.00147/0.203} = 0.085 \text{ in.} \]

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

\[ \frac{L'}{\rho} = \frac{1.94}{0.085} = 22.8 \]

\[ \therefore F_c = 160000 \text{ psi (crippling)} \]
Stress Allowables

\[
\begin{align*}
F_{tu} &= 160,000 \text{ psi} \\
F_{ty} &= 140,000 \text{ psi} \\
F_{bru} &= 219,000 \text{ psi} \\
F_{bry} &= 189,000 \text{ psi}
\end{align*}
\]

Applied load \( P_{G'} \) (Ult) = 19,578 lbs. (Total) (Reference page 58)

Compression, Section A-A

\[
\text{Load} = \frac{P_{G'}}{2} = \frac{19,578}{2} = 9,789 \text{ lbs.}
\]

\[
\text{Area} = 0.295 \times 0.690 = 0.203 \text{ in.}^2
\]

\[
f_c = \frac{P}{A} = \frac{9,789}{0.203} = 48,200 \text{ psi}
\]

\[
(\text{Ult}) \ M.S. = \frac{160,000}{48,200} - 1 = +2.32
\]

Bearing Stress

\[
A_{bru} = (\text{Dia.} \times \text{Thick})
\]

\[
= (0.438) \times (0.295) = 0.129 \text{ in.}^2
\]

\[
f_{bru} = \frac{P_{G'}}{2A_{bru}} = \frac{19,578}{2(0.129)} = 75,800 \text{ psi}
\]

\[
(\text{Ult}) \ M.S. = \frac{219,000}{75,800} - 1 = +1.89
\]
FORWARD 14-INCH SHACKLE ANALYSIS

(Reference Drawing 63J14363)

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

SECTION A-A

$R_{cz} = 4067$ 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)

\[ A = \frac{\pi D^2}{4} = 0.785 (0.436)^2 = 0.149 \text{ in.}^2 \]
\[ P'_{G'} = 19578 \text{ lbs.} \]
(Reference page 60)
\[ f_{su} = \frac{P'_{G'}}{2A} = \frac{19578}{2(0.149)} = 65700 \text{ psi} \]
Ult shear M.S. = \[ \frac{109000}{65700} - 1 = +0.66 \]
\[ I = \frac{\pi D^4}{64} = \frac{\pi (0.436)^4}{64} = 0.001765 \text{ in.}^4 \]
\[ M = \frac{P'_{G'}}{2} L = \frac{19578}{2} (0.136) = 1330 \text{ in.-lbs.} \]
\[ f_b = \frac{Mc}{I} = \frac{(1330)(0.218)}{0.001765} = 164000 \text{ psi (Ult)} \]
Ult bending M.S. = \[ \frac{180000}{164000} - 1 = +0.10 \]

Determination for the Ult Vertical Load \( P'_z \)
(Reference page 60)
\[ F_{tu} = 180000 \text{ psi} \]
\[ F_{tu} = \frac{Mc}{I} = 6M \frac{bh^2}{(0.562)(0.739)^2} = 19.5M \]
\[ M = \frac{180000}{19.5} = 9240 \text{ in.-lbs.} \]
\[ M = 1'_{z} L = P'_{z} (0.30) = 9240 \]
\[ P'_{z} = \frac{9240}{0.30} = 30800 \text{ lbs. (Ult) Allowable} \]
\[ R_{H'} = \frac{30800(0.68)}{1.788} = 11700 \text{ lbs. (Not critical)} \]

Section D-D
Bending and Compression, Section C-C

Applied load, \( R_1 = \frac{P_G}{2} = 9789 \text{ lbs. (Ult)} \)
(Reference page 60)

Moment arm, \( L = 0.350 \text{ in.} \)
(Reference page 60)

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

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

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

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

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

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

\[
f_{c_{max}} = f_c + f_b
\]

\[
= 27200 + 128000
\]

\[
= 155200 \text{ psi (Ult)}
\]

\[
M.S. = \frac{179000}{155200} - 1 = +0.15
\]
Lug and Pin Analysis; Bearing

**Loading Condition No. 6**

Axial load, $R_H = 19190$ lbs (Ult)

(Bearing Area)

$$A_{shk} = (1.83-0.75)(0.4062) = 0.439 \text{ in.}^2$$

$$A_{rod} = (0.720)(0.4062) - \frac{1}{4}(0.312)^2 = 0.292 - 0.076 = 0.216 \text{ in.}^2$$

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

$$f_{br(rod)} = \frac{R_H}{A_{rod}} = \frac{19190}{0.216} = 88800 \text{ psi (Ult)}$$

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

$$F_{ty} = 140000 \text{ psi}$$

$$F_{bru} = 219000 \text{ psi}$$

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

**Shear Stress**

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

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

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

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

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

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

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

Bearing M. S. = $\frac{219000}{59400} - 1 = +2.69$
AFT 14-INCH SHACKLE ANALYSIS
(Reference Drawing 63J14362)

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

Loading Condition No. 2

\[
\begin{align*}
P_G &= 15315 \text{ lbs.} \\
R_H &= 14527 \text{ lbs.} \\
R_{Dx} &= 1381 \text{ lbs.} \\
R_{Dz} &= 3947 \text{ lbs.}
\end{align*}
\]

(\text{Ult})

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

\[
\begin{align*}
A &= 0.149 \text{ in.}^2 \\
c &= 0.218 \text{ in.}
\end{align*}
\]

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

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

\[
\text{Shear M. S.} = \frac{109000}{51400} - 1 = 1.12
\]

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

\[
\text{Bending (Ult) M. S.} = \frac{180000}{128800} - 1 = +0.40
\]
WL TDR-64-33

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

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

\[ I_y = 0.006 \text{ in.}^4, \quad c = 0.225 \text{ in.} \]
\[ A = 0.360 \text{ in.}^2, \quad \text{Moment arm, } L = 0.350 \text{ in.} \]

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

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

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

\[ f_{c_{\text{max}}} = f_b + f_c \]

\[ = 100800 + 21300 \]

\[ = 122100 \text{ psi} \]

\[ M.S. = \frac{179000}{122100} - 1 = +0.46 \]
Lug and Pin Analysis; Bearing

Loading condition No. 2

Axial load

\[ R_H = 14527 \text{ lbs. (Ult)} \]

(Reference page 25)

Bearing Area

\[ A_{(shk)} = (1.83 - 0.75)(0.4062) \]

\[ = 0.439 \text{ in.}^2 \]

\[ A_{(rod)} = (0.720)(0.4062) \]

\[ = 0.292 \text{ in.}^2 \]

\[ f_{br(shk)} = \frac{R_H}{A_{(shk)}} = \frac{14527}{0.439} = 33100 \text{ psi} \]

\[ f_{br(rod)} = \frac{R_H}{A_{(rod)}} = \frac{14527}{0.292} = 49800 \text{ psi} \]

Ult bearing M.S. = \[ \frac{219000}{49800} - 1 = 3.40 \]

Shear allowable

\[ \tau_s = 28700 \text{ lbs. (Reference page 63)} \]

\[ \tau_{(pin)} \text{Ult shear M.S.} = \frac{28700}{14527} - 1 = 0.97 \]
FORWARD SHACKLE ACTUATING ROD ANALYSIS

(Reference Drawing 63C14370)

Compression Stress
Condition No. 6; \( P_{Hi} = 19190 \text{ lbs. (Ult)} \) (Reference pages 25 and 47)

Material: 4130 Stl bar
H.T.: 160-180 ksi

\[
\begin{align*}
A &= \frac{\pi}{4} \left[ D_o^2 - D_i^2 \right] = 0.785 \left[ (0.625)^2 - (0.312)^2 \right] \\
&= 0.230 \text{ in.}^2 \\
I &= \frac{\pi}{64} \left[ D_o^4 - D_i^4 \right] = 0.0491 \left[ (0.625)^4 - (0.312)^4 \right] \\
&= 0.00717 \text{ in.}^4 \\
L' &= \frac{L}{\sqrt{C}} = \frac{5.110}{1} = 5.110 \\
\rho &= \sqrt{A} = \sqrt{0.00717} = 0.177 \text{ in.} \\
L' &= 5.110 \sqrt{0.177} = 28.8 \\
F_c &= 156000 \left[ 1 - \frac{156000(28.8)^2}{4 \times (29)^2 \times 10^6} \right] = 138500 \text{ psi (Allowable)} \\
f_c &= \frac{19190}{0.230} = 83400 \text{ psi} \\
M.S. &= \frac{138500}{83400} - 1 = +0.67
\end{align*}
\]
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.

\[ P_{H'} = 19190 \text{ lbs. (Ult)} \] (Reference page 68)

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

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

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

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

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

Shear stress

Allowable \( I_s = 28700 \text{ lbs. (Reference page 63)} \)

\[ M.S. = \frac{28700}{19190} - 1 = +0.49 \]
CENTER BELLCRANK ANALYSIS
(Reference Drawing 63J14362)

Lug and Pin Analysis
(Reference pages 25 and 47)
Loading condition No. 6

\[ P_{H}' = 19190 \text{ lbs.} \]
\[ P_H = 12518 \text{ lbs.} \]
\[ R_K = 2683 \text{ lbs.} \]
\[ R_{Ez} = -6884 \text{ lbs.} \]
\[ R_{Ex} = -9335 \text{ lbs.} \]
\[ M_{Ez} = 2287 \text{ in.-lbs.} \]

Material
4130 Stl forging
H. T. 160-180000 psi

Allowables
\[ F_{tu} = 160000 \text{ psi} \]
\[ F_{su} = 100000 \text{ psi} \]
\[ F_{bru} = 287000 \text{ psi} \]
(Reference MIL-HNDBK-5)
Bending and Shear Check at Section A-A
(Reference page 70)

Section A-A

Left-hand Reaction

\[ R_{Ez}^l = \frac{R_{Ez}}{2} = \frac{6884}{2} = 3442 \text{ lbs. (Down)} \]

\[ R_{Ex}^l = \frac{R_{Ex}}{2} + \frac{M_{Ez}}{2.254} = \frac{9335}{2} + \frac{2287}{2.254} = 5683 \text{ lbs. (Forward)} \]

\[ M = \left[ (3442)^2 + (5683)^2 \right]^{1/2} = 6380 \text{ in.-lbs. (Ult)} \]

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

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

\[ f_0 = \frac{M_c}{I} = \frac{6300(0.405)}{0.020} = 127600 \text{ psi} \]

\[ R_b = \frac{127600}{160000} = 0.797 \]

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

\[ R_s = \frac{16400}{100000} = 0.164 \]

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

$M_E$ (Due to pinned shut firing)

$p = 70000 \text{ psi (burst pressure)}$

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

$L_1 = 1.062 \text{ in.}; L_2 = 0.875 \text{ in.}$

$M_E = pA L_1$

$= 70000(0.084)(1.062)$

$= 6250 \text{ in.-lbs.}$

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

Shear-out Check

$A_s = 2L_3 t = 2(0.170)(0.23) = 0.078 \text{ in.}^2$

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

$F_s = 100000 \text{ psi (Reference page 70)}$

$M.S. = \frac{100000}{91500} - 1 = +0.10$
Bearing at Point H′
(Reference page 70)

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

\[ P_{H′} = 19190 \text{ lbs. (Ult) (Reference page 70)} \]

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

\[ \text{Ult bearing M.S.} = \frac{287000}{126000} - 1 = +1.28 \]

Bearing at Point H
(Reference page 70)

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

\[ P_{H} = 12518 \text{ lbs. (Reference page 70)} \]

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

\[ \text{(Bearing) M.S.} = \frac{287000}{98000} - 1 = +1.93 \]

*Ult allowables, reference page 70
Tension at Point "K"; $R_K = 2683$ lbs. (Ult) (Reference page 70)

Lug Check (Analysis per Reference 3)

\[ W = \frac{0.560}{0.257} = 2.18 \quad \Rightarrow \quad K_t = 0.97 \]
\[ A_{br} = (0.257)(0.230) = 0.059 \text{ in.}^2 \]
\[ D = \frac{0.257}{0.230} = 1.12 \quad \Rightarrow \quad K_{br} = 0.975 \]
\[ A_t = (0.560 - 0.257)(0.230) = 0.0697 \text{ in.}^2 \]

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. = \[ \frac{9200}{2683} - 1 = +2.42 \]
WL TDR-64-33

SAFETY LOCK BELLCRANK ANALYSIS
(Reference Drawing 60G46541)

\[ P_0 = \frac{M_E}{1.0} \]
\[ M_E = 6250 \text{ in.-lbs.} \] (Due to inadvertent firing, reference page 72)

Compression Check at Section A-A

\[ P_0 = \frac{M_E}{1.0} = \frac{6250}{1.0} = 6250 \text{ lbs. (Ult)} \]

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

\[ f_c = \frac{6250}{0.141} = 44300 \text{ psi} \]

Material 4130 Stl forging
H.T. 160-180000 psi

Shear Check at 0.498 diameter shoulder

\[ P_s = \frac{P}{2} = \frac{6250}{2} = 3125 \text{ lbs. (Ult)} \]

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

\[ f_s = \frac{3125}{0.1185} = 26400 \text{ psi} \]

M.S. = \frac{\sqrt[95000]}{26400} - 1 = + 2.60
Bending and Shear Analysis, Section B-B

\[ M = \frac{P_o}{2} L \]
\[ = \frac{(6250)(1.365)}{2} = 4270 \text{ in.-lbs.} \]

\[ I = \frac{\pi}{64} \left[ D_o^4 - D_i^4 \right] \]
\[ = \frac{\pi}{64} \left[ (0.685)^4 - (0.312)^4 \right] \]
\[ = 0.0103 \text{ in.}^4 \]

\[ A_s = \frac{\pi}{4} \left[ D_o^2 - D_i^2 \right] \]
\[ = 0.785 \left[ (0.685)^2 - (0.312)^2 \right] \]
\[ = 0.293 \text{ in.}^2 \]

\[ f_b = \frac{M c}{I} = \frac{(4270)(0.3425)}{0.0103} = 142000 \text{ psi} \]

\[ M.S. = \frac{160000}{142000} - 1 = +0.13 \]

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

\[ M.S. = \frac{95000}{10700} - 1 = +7.87 \]
OVER-CENTER GUIDE CLEVIS ANALYSIS
(Reference Drawing 60C46538)

Loading condition No. 6
Ult tension load

\[ P_K = 2683 \text{ lbs.} \]

(Reference pages 25 and 47)

Material 4130 Stl bar
H. T. 125000 psi

Stress Allowables
\[ F_{tu} = 125000 \text{ psi} \]
\[ F_{ty} = 103000 \text{ psi} \]
\[ F_{su} = 82000 \text{ psi} \]
\[ F_{bru} = 194000 \text{ psi} \]

(Reference MIL-HNDBK-5)

\[ A_t = \frac{\pi}{4} D^2 = 0.785 \left(\frac{0.25}{2}\right)^2 = 0.049 \text{ in.}^2 \]

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

M. S. = \frac{125000}{54800} - 1 = +1.28
Lug and Pin Analysis (Analysis per Reference 3)

\[
\frac{2683 \text{ lbs}}{2} = P_k
\]

\[
\begin{align*}
W &= \frac{0.624}{0.250} = 2.49 \quad \{ K_t = 0.95 \} \\
\frac{D}{t} &= \frac{0.250}{0.094} = 2.60 \quad \{ K_{br} = 1.10 \} \\
\frac{a}{D} &= \frac{0.312}{0.250} = 1.25 \\
A_{br} &= (0.250 \times 0.094) = 0.0235 \text{ in.}^2 \\
A_t &= (0.624 - 0.25 \times 0.094) = 0.0351 \text{ in.}^2
\end{align*}
\]

Shear-Bearing Allowable

\[
P_{br} = K_{br} A_{br} F_{tu}
\]

\[
= (1.1 \times 0.0235 \times 125000)
\]

\[
= 3230 \text{ lbs.}
\]

Tension Allowable

\[
P_t = K_t A_t F_{tu}
\]

\[
= (0.95 \times 0.0351 \times 125000)
\]

\[
= 4160 \text{ lbs.}
\]

Applied load = \[
\frac{2683}{2} = 1342 \text{ lbs.}
\]

\[
\text{Ult M.S.} = \frac{3230}{1342} - 1 = +1.40
\]

78
CLEVIS TRUNNION ANALYSIS
(Reference Drawing 60C46540)

Loading condition No. 6
Ult tension load

\[ P_K = 2683 \text{ lbs.} \] (Reference page 77)

Static Balance of Clevis Trunnion

\[ \sum M_L = 0 \quad P_K (0.375 + 0.120) - R_R (2.490 + 0.240) = 0 \]

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

\[ \sum F_V = 0 \quad P_K - R_L - R_R = 0 \]

\[ R_L = P_K - R_R = 2683 - 487 = 2196 \text{ lbs.} \]
Bending and Shear Analysis

Maximum bending moment

\[ M_x = R_L \times (0.495) \]

\[ = 2196 \times (0.495) = 1088 \text{ in.-lbs.} \]

Maximum shear load

\[ R_L = 2196 \text{ lbs.} \]

\[ I_x = 0.003 \text{ in.}^4 \]

\[ A_s = 0.100 \text{ in.}^2 \]

\[ f_b = \frac{M_c}{I} = \frac{(1088)(0.213)}{0.003} = 79000 \text{ psi} \]

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

\[ F_{tu} = 160000 \text{ psi} \]

\[ F_{su} = 100000 \text{ psi} \]

\[ R_b = \frac{79000}{160000} = 0.493 \]

\[ R_s = \frac{21960}{100000} = 0.2196 \]

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

\[ = \frac{1}{\left[ (0.493)^2 + (0.220)^2 \right]^{1/2}} - 1 = 0.85 \]
AFT SHACKLE ACTUATING ROD ANALYSIS
(Reference Drawing 63C14371)

Compression Stress

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

Material 4130 Stl bar
H. T. 160-180 ksi

Allowables

\[
\begin{align*}
F_{tu} &= 160000 \text{ psi} \\
F_{su} &= 100000 \text{ psi} \\
F_{bru} &= 287000 \text{ psi}
\end{align*}
\]

(Reference MIL-HNDDBK-5)

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

\[ l = 0.00306 \text{ in.}^4 \]

\[ \rho = 0.125 \text{ in.} \]

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

\[ F_c = 141000 \text{ psi} \]

\[ f_c = \frac{F_c}{A} = 14527 \text{ psi} = 74200 \text{ psi} \]

\[ M.S. = \frac{141000}{74200} = 1 = 0.90 \]
Compression and Bending

\[ R_H = 14527 \text{ lbs. (Ult)} \] (Reference page 81)

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

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

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

\[ M_y = 436 \text{ in.-lbs. (Ult)} \]

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

\[ f_b = 65500 \text{ psi} \]

\[ f_c = \frac{R_H}{2A} = \frac{14527}{2(0.156)} = 46600 \text{ psi} \]

\[ f_{c_{\max}} = f_c + f_b \]

\[ = 46600 + 65500 \]

\[ = 112100 \text{ psi} \]

\[ M.S. = \frac{160000}{112100} - 1 = 0.43 \]
Lug and Pin Analysis, Bearing and Shear

Loading condition No. 2

Axial load, \( R_H = 14527 \text{ lbs. (Ult)} \)

(Reference page 25)

Bearing area

\[
A_{rod} = (1.00 - 0.718)(0.406) = 0.1145 \text{ in.}^2
\]

\[
A_{bell} = (0.688 - 0.375)(0.406) = 0.127 \text{ in.}^2
\]

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

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

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

\[
M.S. = \frac{287000}{127000} - 1 = +1.26
\]

Allowable Shear Load per Pin

\[
P_{s} = 28700 \text{ lbs. (Reference page 63)}
\]

\[
M.S. = \frac{28700}{14527} - 1 = +0.97
\]
**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

Bending, Section A-A

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

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

$$f_b = \frac{6M}{bh^2} = \frac{(6)(6900)}{(2.5)(0.531)^2} = 59000 \text{ psi}$$

Bending M. S. $= \frac{160000}{59000} - 1 = 1.71$
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-BK-5)

\[
R_{cx} = \frac{p}{n} = \frac{P}{3}
\]

\[
R_{Mx} = -\frac{M_y}{\Sigma x^2 + \Sigma y^2}
\]

\[
R_{My} = \frac{M_x}{\Sigma x^2 + \Sigma y^2}
\]

\[
R_{total} = \sqrt{(R_{cx} + R_{Mx})^2 + R_{My}^2}
\]

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

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

<table>
<thead>
<tr>
<th>E.L.E.M.</th>
<th>x</th>
<th>y</th>
<th>( x^2 )</th>
<th>( y^2 )</th>
<th>( M_x )</th>
<th>( M_y )</th>
<th>( R_{cx} )</th>
<th>( R_{Mx} )</th>
<th>( R_{My} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.375</td>
<td>-0.373</td>
<td>0.140</td>
<td>0.139</td>
<td>7725</td>
<td>-7675</td>
<td>5000</td>
<td>+7400</td>
<td>+7400</td>
</tr>
<tr>
<td>2</td>
<td>-0.188</td>
<td>-0.373</td>
<td>0.035</td>
<td>0.139</td>
<td>-3870</td>
<td>-7675</td>
<td>5000</td>
<td>+7400</td>
<td>-3730</td>
</tr>
<tr>
<td>3</td>
<td>-0.188</td>
<td>0.742</td>
<td>0.035</td>
<td>0.550</td>
<td>-3870</td>
<td>15300</td>
<td>5000</td>
<td>-14750</td>
<td>-3730</td>
</tr>
<tr>
<td>Σ</td>
<td></td>
<td></td>
<td>0.210</td>
<td>0.828</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E.L.E.M.</th>
<th>( (R_{cx} + R_{Mx})^2 )</th>
<th>( R_{My}^2 )</th>
<th>( R_{total} )</th>
<th>( R_{L.H.} )</th>
<th>( R_{R.H.} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>154x10^6</td>
<td>55.0x10^6</td>
<td>14480 lbs.</td>
<td>7240</td>
<td>7240</td>
</tr>
<tr>
<td>2</td>
<td>154x10^6</td>
<td>13.9x10^6</td>
<td>12080 lbs.</td>
<td>6490</td>
<td>6490</td>
</tr>
<tr>
<td>3</td>
<td>95x10^6</td>
<td>13.9x10^6</td>
<td>10440 lbs.</td>
<td>5220</td>
<td>5220</td>
</tr>
</tbody>
</table>

(Bolt) M.S. = \( \frac{7300}{7240} - 1 = +0.01 \)
Minimum shear-out area

\[ A_s = 2(0.316 \times 0.245) = 0.1553 \text{ in}^2 \]

\[ P_2 = 6490 \text{ lbs. (Reference page 85)} \]

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

Reference 60H46534 and 60H46535

Material: 7075-T6 Al aly plate

\[ F_{tu} = 77000 \text{ psi} \]

\[ F_{ty} = 67000 \text{ psi} \]

\[ F_{su} = 46000 \text{ psi} \]

\[ F_{bru} = 146000 \text{ psi} \]

(Shear) M. S. \[ = \frac{46000}{41700} - 1 = 0.10 \]

\[ A_{br} = (0.316 \times (0.245 - 0.06)) = 0.0585 \text{ in}^2 \]

\[ P_1 = 7240 \text{ lbs. (Reference page 85)} \]

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

(Bearing) M. S. \[ = \frac{146000}{123800} - 1 = 0.18 \]
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

\[ p = 70000 \text{ psi (burst)} \]

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
\[ p = 70000 \text{ psi (burst)} \]

Material 4340 Stl forging
H. T. 180-200 ksi

Material       4340 Stl forging
H. T.       180-200 ksi

Stress Allowables
\[ F_{tu} = 180000 \text{ psi} \]
\[ F_{ty} = 160000 \text{ psi} \]
\[ F_{su} = 109000 \text{ psi} \]
\[ \text{M.S.} = \frac{180000}{178000} - 1 = +0.01 \]

Hoop tension check through slave piston chamber
\[ f_t = \frac{R}{t} = \frac{70000 \left( \frac{0.742}{0.289} \right)}{0.193} = 111400 \text{ psi} \]
\[ \text{M.S.} = \frac{180000}{111400} - 1 = +0.61 \]

Thread analysis
(Reference page 90)
SLAVE PISTON ANALYSIS
(Reference Drawing 64C13032)

Material: 17-4 ph cres bar
H.T.: 180-215 ksi

Compression

\[ P = pA = 70000 \times (0.785)(0.389)^2 = 8300 \text{ lbs.} \]

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

\[ A''_c = (0.785)(0.310)^2 = 0.075 \text{ in.}^2 \]

\[ f_c = \frac{P}{A} = \frac{8300}{0.061} = 136000 \text{ psi} \quad \frac{M.S.}{136000} - 1 = +0.32 \]

SLAVE PISTON PLUG ANALYSIS
(Reference Drawing 64D13082)

Material: 17-4 ph cres bar
H.T.: 180-215 ksi

Thread shear check

\[ P = 70000 \times (0.785)(0.610)^2 = 20500 \text{ lbs.} \]

Length of engaged thread = 0.405 in.

Pitch diameter = 0.745 in.

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

\[ f_s = \frac{P}{A} = \frac{20500}{0.475} = 43200 \text{ psi} \quad \frac{M.S.}{43200} - 1 = +1.84 \]

\[ F_s = 123000 \text{ psi} \]
CARTRIDGE BODY CONTAINER ANALYSIS

(Reference Drawing 63D14368)

Maximum pressure \( p = 70000 \text{ psi (burst)*} \)

*Breech burst pressure

\[
\begin{align*}
\text{Material} &\quad 4130 \text{ Stl bar} \\
H.T. &\quad 160-180 \text{ ksi}
\end{align*}
\]

Hoop tension check at Section B-B

\[
p' = 25000 \text{ psi (Cartridge case burst pressure)}
\]

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

\[
M.S. = \frac{160000}{121000} - 1 = +0.32
\]

Compression check at 'O' ring groove

\[
F_c = p\left(\frac{3}{4}\right)(D_o^2 - D_i^2)
\]

\[
p = 70000 \text{ psi (After rupture of cartridge case)}
\]

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

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

\[
f_c = \frac{29200}{0.214} = 136000 \text{ psi}
\]

\[
F_c = 156000 \text{ psi}
\]

\[
M.S. = \frac{156000}{136000} - 1 = +0.15
\]
CARTRIDGE RETAINER CAP ANALYSIS

(Reference Drawing 63D14378)

\[ p = 70000 \text{ psi (burst)} \]

(Maximum breech burst pressure)

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

Material: 4130 Stl bar
H.T.: 160-180000 psi

\[ D = \text{O.D. of cartridge body retainer (Reference page 91)} \]

\[ P = 0.785 (1.303)^2 (70000) = 93300 \text{ lbs. (Ult)} \]

Length of engaged thread = 0.625 in.

Pitch diameter = 1.45 in.

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

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

\[ f_s = \frac{P}{A_s} = \frac{93300}{1.42} = 65700 \text{ psi} \]

\[ F_s = 100000 \text{ psi} \]

\[ M.S. = \frac{100000}{65700} - 1 = 0.52 \]
Shear check at 1.250 diameter, Section B-B

\[ P = 93300 \text{ lbs. (Ult)} \]
\[ D = 1.250 \text{ in.} \]
\[ L = (0.700-0.386) = 0.314 \text{ in.} \]

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

\[ f_s = \frac{P}{A_s} = \frac{93300}{1.23} = 75800 \text{ psi} \]

\[ F_s = 100000 \text{ psi} \]

\[ \text{M.S.} = \frac{100000}{75800} - 1 = +0.32 \]
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

\[ p = 70000 \text{ psi (burst)} \]

\[ R_{A-A} = \frac{0.604 + 0.343}{2} = 0.237 \text{ in.} \]

\[ t_A = \frac{0.604 - 0.343}{2} = 0.1305 \text{ in.} \]

\[ f_t = \frac{pR}{t} = \frac{70000 \times 0.237}{0.1305} = 127000 \text{ psi} \]

\[ F_{tu} = 180000 \text{ psi} \]

(Section A-A) M. S. = \[ \frac{180000}{127000} - 1 = +0.42 \]
WL TDR-64-33

Section C-C

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

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

\[ f_t = \frac{P}{t} = \frac{70000(0.219)}{0.0905} = 170000 \text{ psi} \]

\[ F_{tu} = 180000 \text{ psi} \]

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

Gas tube, hoop tension check

(Reference Drawing 63D14375)

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

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

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

\[ F_{tu} = 180000 \text{ psi} \]

\[ \text{M.S.} = \frac{180000}{158000} - 1 = +0.14 \]
Burst pressure = 70000 psi

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

\[ = 15600 \text{ lbs.} \]

\( R_Y = P = 15600 \text{ lbs.} \)

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

\[ = 2340 \text{ lbs.} \]

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 = \( \frac{R_Y}{2} = \frac{15600}{2} = 7800 \text{ lbs.} \)

\[ M.S. = \frac{8280}{7800} - 1 = +0.06 \]
Shear-out check at 0.375 diameter attachment holes (view C-C)

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

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

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

\[F_s = 109000 \text{ psi}
\]

\[M.S. = \frac{109000}{52800} - 1 = 1.06\]

Allowable shear per bolt

\[F_s(bolt) = 10500 \text{ lbs. (single) (Reference MIL-HNDBK-5)}\]

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

Gas tube in shear at breech

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

\[P_g = P_H = 2340 \text{ lbs. (Reference page 96)}\]

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

\[F_s = 109000 \text{ psi}
\]

\[M.S. = \frac{109000}{17900} - 1 = 5.10\]
REFERENCES