STRUCTURAL ANALYSIS REPORT
LARRR-300

LASER RANGING RETRO-REFLECTOR
(300 CORNER)

APOLLO 15

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               J. F. Corcoran

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              D. L. Dewhirst
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              J. M. Brueger
              J. M. Brueger
INTRODUCTION

This report consists of the stress analysis performed to substantiate the structural integrity of the LRRR-300 and all of its associated hardware.

All analyses were based on a total package weight of 100 lbs. except for the Plan Grid Analysis Program used on the Array Structures which was based on an LRRR weight of 85 lbs. The LRRR weight, for the CRD, was calculated to be 80.2 lbs.

The ultimate loads used were obtained by multiplying the given limit loads by a factor of 1.5.

In most cases, the margins of safety are high. Low margins of safety are based on conservative assumptions and a more rigorous analysis would show a higher margin.

Items not shown in this report have been investigated and have high margins of safety using defined load factors.
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REFERENCES

1. GAC Interface Drawing LID 360-22837, December 3, 1970.


# SUMMARY OF CONDITIONS

The following conditions were considered in determining the structural integrity of the LRRR-300:

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<td>Twenty G's limit load (30 G's ultimate) acting independently along each major axis in the stowed position during flight.</td>
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<td>2.</td>
<td>Force emission capability of the suited astronaut of 30 pounds limit (45 pounds ultimate) in any direction.</td>
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<td>Two G's ultimate load in the un-deployed and deployed configuration during earth handling.</td>
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FINAL ANALYSIS
LRRR-300

LARGE ARRAY INPUT DATA
PLANE GRID ANALYSIS PROGRAM

LOADING CONDITION: REF. DYNAMICS LOADS IN DYNAMICS ANALYSIS REPORT ATM-936

CONTROL DATA:

NUMBER OF NODES  NN = 40
NUMBER OF MEMBERS  NM = 48
NUMBER OF RESTRAINED NODES  NRN = 4
NUMBER OF RESTRAINTS  NRC = 4
NUMBER OF LOADING CONDITIONS  NLC = 1
NUMBER OF PROBLEMS  NSC = 1

REFERENCE DATA:

YOUNG'S MODULUS, E : 10^7 PSI
POISSON'S RATIO, V : .30

SUPPORT CONDITIONS:

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C = 1.23186 in,  Q = .025

BEAMS ALONG Y- Y DIRECTION
I = .23469 in^4/IN,  J = .0027974 in^4/IN
C = 1.253 in,  Q = .025

(2) SECTION PROPERTY CALCULATIONS OMITTED TO SIMPLIFY REPORT
(1) REF. NO. 9
FINAL ANALYSIS LRRR-300

LARGE ARRAY - NODAL POINT AND MEMBER NUMBER ARRANGEMENT

PLANE GRID ANALYSIS PROGRAM - REF. NO. 9

LOCAL MEMBER COORDINATES

GLOBAL COORDINATES
## FINAL ANALYSIS  LRRR - 300

### LARGE ARRAY SECTIONAL PROPERTIES

#### PLANE GRID ANALYSIS PROGRAM

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### FINAL ANALYSIS

**LRIRR-300**

**LARGE ARRAY SECTIONAL PROPERTIES**

(CONT'D)

**PLANE GRID ANALYSIS PROGRAM**

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**REV. NO. 9**

1. REV. DIAGRAM, PAGE 2
2. SECTION PROPERTIES, PAGE 1
### Final Analysis

**LRRZ-300**

**LARGE ARRAY MEMBER MOMENTS AND STRESSES**

**PLANE GRID ANALYSIS PROGRAM**

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The stresses tabulated on this page and the following page are the peak stresses developed in the array. In comparing these stress levels with the design strength properties of the array material, it is obvious the array has adequate structural strength.

1. Ref. No. 9
2. Al. alloy 6061-T6 per QQ-A-250/11
3. Moments in in-1bs \& Stresses in psi - from computer output

BxA 542
### Final Analysis

#### Laser Array

**Member Moments and Stresses** (Cont'd)

**Plane Grid Analysis Program**

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**Note:** Moments in N in, Stresses in ksi. From computer output, see note page 5

---

1. **REF No. 9**
2. **Moments in N in, Stresses in ksi.** From computer output, see note page 5
LOADING CONDITION: REF. DYNAMICS LOADS IN DYNAMICS ANALYSIS REPORT ATM-936

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REFERENCE DATA:

- YOUNG'S MODULUS, E : 10^7 PSI
- POISSON'S RATIO, \( \nu \) : .30

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BEAMS ALONG THE Y-Y DIRECTION

\[ I = .21427 \text{ in}^4, \quad J = .0027828 \text{ in}^6, \quad C = 1.23502 \text{ in}, \quad \varphi = .025 \]

(2) SECTION PROPERTY CALCULATIONS OMITTED TO SIMPLIFY REPORT

(1) REF. NO. 9
FINAL ANALYSIS - LRRR-300

SMALL ARRAY - NODEL POINT AND MEMBER NUMBER ARRANGEMENT

PLANE GRID ANALYSIS PROGRAM 1

LOCAL
MEMBER
COORDINATES

GLOBAL
COORDINATES

KEY NO. 9
### Final Analysis

**LRRR-300**

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1. Ref. Diagram, Page 8: Section Properties, Page 7
2. Ref. No. 9

---

Bx A 842
## Final Analysis

**LRRP-300**

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1. Moments in in-lbs & Stresses in psi - from computer output
2. Ref. No. 9
3. See note, page 5
FINAL ANALYSIS LRRR-300

BOLT PATTERN - LEFT & RIGHT FORWARD INTERFACE BRACKETS

ANALYSIS TO LARGE ARRAY Dwg. 2347230 - 231

COND. 1

Assumptions:
1. Bracket Load = 3000 lbs
2. 75-25 load distribution between bolt patterns of each flange
3. Friction between bracket and array neglected

Bolt Pattern Load:
\[ P_{B.P.} = 0.75 \quad P_{B.KT} = 2250 \text{ lbs} \]

Direct Force on Bolts:
\[ F = \frac{2250}{5} = 450 \text{ lbs} \]

Bolt Pattern Moment:
\[ M_{B.P.} = 3.05(2250) = 6880 \text{ in.-lbs} \]

Constant of Proportionality of Bolt Pattern, \( K \):
\[ K = \frac{6880}{2(1.788)^2 + 2(1.54)^2 \times 24^2} = 3760 \]

Moment Force on Bolt (A):
\[ F_A = K \times r_A = 3760(1.788) \]
\[ = 2960 \text{ lbs} \]

Total Force at Bolt (A):
\[ F_{TOT_A} = F + F_A = 3410 \text{ lbs} \]

Bolt Designation:
NAS 6704 U4 Bolt

Single Shear Strength = 4650 lbs

Bolt Margin of Safety:
\[ M.S. = \frac{4650}{3410} - 1 = \frac{1.36}{1} \]

Conservatively assume loads acting in line
Ref. No. 5, Page 239
Bracket assumed to take total L/R^3 force
FINAL ANALYSIS LRRR-300
RETRO REFLECTOR STRUCTURE (LARGE ARRAY) Dwg. 2347205

BEARING CHECK - INTERFACE BRACKET ATTACH BOLTS AGAINST ARRAY

LOADS ON ARRAY

BRACKET LOAD AT BOLT (A):

1) \[ F_{\text{tot}} = 3410 \]

BEARING PROPERTIES

BOLT DIA = .250
ARRAY WALL THICKNESS = .156
\[ A_w = D t = .039 \]

BEARING STRESSES

MATL: 6061-T6 AL. ALLOY \( F_{uy} = 42 \text{ ksi} \)

\[ F_{uy} = 88 \text{ ksi,} \quad f_{br} = \frac{F_{\text{tot}}}{A_w} = \frac{3410}{.039} = 87.5 \text{ ksi} \]

2) \[ M.S. = \frac{F_{br}}{f_{br}} - 1 = 1.00 \]

2) BEARING FACTOR NEGLECTED DUE TO CONSERVATISM IN THE ANALYSIS

1) REF. PAGE 11
FINAL ANALYSIS  LRRR-300

3) Bracket, Interface - Left Forward

SECTION A-A

LOADS & MOMENTS

1) Mounting Pin Load = 3000 lbs

Compression = 3000 cos 39° = 2330 lbs

Shear = 3000 sin 39° = 1890 lbs

B.M. = 1.21 (3000) = 3630 in-lbs

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<td>0.0012</td>
<td>0.0004</td>
<td>0.087</td>
<td>0.00012</td>
</tr>
<tr>
<td>2</td>
<td>0.2178</td>
<td>0.110</td>
<td>0.0240</td>
<td>0.0087</td>
<td>0.050</td>
<td>0.00054</td>
</tr>
<tr>
<td>3</td>
<td>0.0352</td>
<td>0.073</td>
<td>0.0026</td>
<td>0.0009</td>
<td>0.087</td>
<td>0.00027</td>
</tr>
<tr>
<td>4</td>
<td>0.0046</td>
<td>0.310</td>
<td>0.0252</td>
<td>0.0062</td>
<td>0.230</td>
<td>0.00342</td>
</tr>
<tr>
<td>5</td>
<td>0.0007</td>
<td>0.248</td>
<td>0.0017</td>
<td>-</td>
<td>0.088</td>
<td>0.00005</td>
</tr>
</tbody>
</table>

\[
\overline{Z} ' = \frac{\sum A Z'}{A} = 0.16
\]

\[
I_{21} = I_{02} + A_{2} Z'^{2} = 0.00662 \quad I_{2c} = 0.0376
\]

\[
Q_{2} ' = (1.12 (16)^{2}) + \frac{11(16)107}{2} + \frac{23 (1.16)107}{2} = 0.0115
\]

\[
K_{2} ' = 2Q_{2} ' / I_{2c} = .92 \frac{lbs}{in} 1.0
\]

2) This analysis covers the right forward interface bracket also.

1) Ref: Page 11

2) Assume mounting pin shifted to bottom of slot.
FINAL ANALYSIS LRRR-300

BRACKET, INTERFACE - LEFT FORWARD

SECTION A-A (cont'd)

STRESSES MAT'L: TITANIUM 6AL-4V COND A

\[ F_u = 130 \text{ ksi} \]

\[ F_{2u} = F_{2u} = 130 \text{ ksi} \]

\[ f_b = \frac{3030}{0.0376} = 96.5 \text{ ksi} \]

\[ R_b = 0.743 \]

\[ F_{cy} = 126 \text{ ksi} \]

\[ f_c = \frac{2330}{0.3408} = 6.84 \text{ ksi} \]

\[ R_c = 0.054 \]

\[ F_{3u} = 80 \text{ ksi} \]

\[ f_s = \frac{1890}{0.3408} = 5.55 \text{ ksi} \]

\[ R_s = 0.069 \]

\[ U = \left[ \left( R_b + R_c \right)^2 + R_s^2 \right]^{1/2} = 0.80 \]

\[ M.S. = \frac{1}{U} - 1 = 4.25 \]
3 FINAL ANALYSIS LRRR-300

3) BRACKET INTERFACE - LEFT FORWARD

BEARING CHECK - MOUNTING PINS AGAINST BRACKET

LOADS ON BRACKET

1) MOUNTING PIN LOAD = 8000/165
   \[ P = \frac{3000}{12} = 25000 \text{ lb/in}^2 \]

BEARING PROPERTIES

BRACKET HOLE Dia. = .391 = D_1
MOUNTING PIN Dia. = .3779 = D_2
EFFECTIVE BEARING LENGTH = 1.12

BRACKET MATERIAL:
TITANIUM; 6AL-4V
\[ F_{cy} = 176 \text{ ksi} \]
\[ E_1 = 16 \times 10^6 \text{ PSI} \]
\[ V_1 = .32 \]

MOUNTING PIN MATERIAL:
STEEL
\[ E_2 = 29 \times 10^6 \text{ PSI} \]
\[ V_2 = .32 \]

STRESSES

\[ F_{cy} = 176 \text{ ksi} \]
\[ T' = .748 \left( \frac{D_1 - D_2}{D_1 D_2} \right)^{\frac{1}{2}} \left( \frac{1 - V_2^2}{E_1} + \frac{1 - V_1^2}{E_2} \right)^{\frac{1}{2}} = 126 \text{ ksi} \]

\[ M.S. = \frac{F_{cy}}{T'} - 1 = +0 \]

3) THIS ANALYSIS COVERS THE RIGHT FORWARD INTERFACE BRACKET ALSO.
2) REF. NO. 4, TABLE XIV, CASE C
1) REF. PAGE II
FABRICATION LRKR-300

BOLT PATTERN - LEFT REAR INTERFACE BRACKET TO LARGE ARRAY

Dwg. 2347232 (Cont. 1)

LOADS

ASSUMPTIONS:

Ref. Page 11

Bolt Pattern Load:

\[ P_{BR} = 0.75 P_{Pkt} \]

\[ = 0.75 (3000) = 2250 \text{ lbs} \]

Direct Force on Bolts:

\[ F = \frac{2250}{4} = 562.5 \text{ lbs} \]

Bolt Pattern Moment:

\[ M_{BR} = 2.32 (2250) = 5220 \text{ in.-lbs} \]

Constant of Proportionality of Bolt Pattern, \( K \):

\[ K = \frac{5220}{4 (0.51)^2} \]

Moment Force at Bolt (A):

\[ F_A = K \cdot 5020 (0.51) = 2560 \text{ lbs} \]

Total Force at Bolt (A):

\[ F_{Total} = F + F_A = 3123 \text{ lbs} \]

Bolt Designation:

NAS 6704 U4 BOLT

Single Shear Strength = 4650 lbs

Margin of Safety:

\[ M.S. = \frac{4650}{3123} - 1 = 1.48 \]

1. Crack assumed to take total load's force.
2. Assumed point of load application.
3. Ref. No. 5, Page 239
4. Consistently assume loads acting in line.
**Final Analysis**

**Bracket, Interface - Left Rear**

**Socket Analysis**

**Socket Loads**

\[ V_1 = \frac{P_{brk} (d + \frac{1}{2})}{L - L_{br}} + \frac{P_{ex} R}{2} \]

\[ = \frac{3000 \times (0.445) + 3000}{0.238} \]

\[ = 7100 \text{ lbs} \]

**Socket Properties**

\[ D = 0.39 \quad \frac{L_D}{L} = 0.845 \]

\[ L = 0.32 \quad \frac{L_{br}}{L} = 0.28 \]

\[ \bar{t} = 0.249 \]

\[ a = 0.44 \quad a_0 = 1.13 \]

**Socket Allowables**

**Material:** Titanium 6Al-4V Cond. A

\[ \frac{F_{ly}}{E} = 130 \text{ kpsi} \]

\[ \frac{F_{ly}}{E} = 120 \text{ kpsi} \]

\[ E = 16 \times 10^6 \text{ psi} \]

\[ \sigma_{y} = \frac{F_{ly}}{E} + 0.002 = 0.0095 \]

**Yield Check**

\[ V_y = \left[ \frac{D + \bar{t}}{a} \right] C_y D L_{br} E C_l y \]

\[ = \left[ \frac{0.44 + 0.249}{0.44} \right] \cdot 1.60 \times 0.92 \times (16 \times 10^6) \times 0.0095 \]

\[ = 8640 \text{ lbs} \]

\[ M.S. = \frac{V_y}{1.15 V_1} - 1 = 0.06 \]

---

**Notes:**

1. Refer to Section 2.60
2. Refer to Page 11
3. Externalized
4. Lifting radius
BEARING CHECK  ATTACH BOLTS AGAINST BRACKET

LOAD

BRACKET LOAD AT BOLT (N):

1. \( F_{\text{total}} = 3123 \text{ lbs} \)

BEARING PROPERTIES

BOLT DIA = 0.25
BRACKET WALL THICKNESS = 0.12
\( A_b = d t = 0.03 \)

BEARING STRESSES
MATL: TITANIUM GR-24 V COND. A

\( F_{by} = 174 \text{ ksi} \)
\( F_{br} = \frac{3123}{0.03} = 104,2 \)

\( M.S. = \frac{F_{by}}{F_{br}} = 1 = 1.11 \)

(2) BEARING FACTOR
(1) KEY PAGE 10
FINAL ANALYSIS  LRRK-300

BOLT PATTERN ANALYSIS

RIGHT REAR INTERFACE BRACKET TO

LARGE ARRAY  Dwg. 2347233

LOADS

ASSUMPTIONS:

1. BRACKET LOAD = 3000 lbs
2. FRICTION BETWEEN BRACKET AND ARRAY NEGLECTED

BOLT PATTERN LOAD:

\[ P_{bp} = P_{ort} = 3000 \text{ lbs} \]

DIRECT FORCE ON BOLTS:

\[ F = \frac{3000}{4} = 750 \text{ lbs} \]

BOLT PATTERN MOMENT:

\[ M_{bp} = 1.78(3000) = 5350 \text{ in-lbs} \]

CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, \( K \):

\[ K = \frac{5350}{4(753)^2} = 2340 \]

MOMENT FORCE ON BOLT (A):

\[ F_A = K \times 2340(1.753) = 1780 \text{ lbs} \]

TOTAL FORCE AT BOLT (A):

\[ F_{tot} = F + F_A = 2530 \text{ lbs} \]

BOLT DESIGNATION

NAS 6704-U-4 BOLT

SINGLE SHEAR STRENGTH = 4650 lbs

BOLT MARGIN OF SAFETY

\[ M.S. = \frac{4650}{2530} - 1 = 0.83 \]

3. CONSERVATIVELY ASSUME LOADS ACTING IN LINE.
2. KEY: NO. 5, PAGE 239
1. BRACKET ASSUMED TO TAKE TOTAL LOAD
FINAL ANALYSIS LRRZ-300

BRACKET INTERFACE - RIGHT REAR

SECTION A-A

LOADS & MOMENTS

1. \( P_{BKT} = 3000 \text{ in-lbs} \)
   \[ M_{AX} = 1.04 \times P_{BKT} = 3120 \text{ in-lbs} \]
   \[ M_{AY} = 1.32 \times P_{BKT} = 3960 \text{ in-lbs} \]

SECTION PROPERTIES

\[ A = 0.80 (2.08) - 0.675 (1.88) = 395 \]
\[ A_{FLANGE} = 0.80 (1.10) = 0.88 \]
\[ I_x = \frac{0.80 (2.08)^2}{12} - 0.675 (1.88)^2 = 1.24 \]
\[ I_{YC} = \frac{0.88}{1.04} = 0.257 \]
\[ Q_x = \frac{0.80 (1.04)^2}{2} - 0.675 (1.84)^2 = 1.135 \]
\[ K_x = \frac{2Q_x}{I_{YC}} - \frac{2(1.135)}{0.257} = 1.24 \]

FLEXURAL CENTER LOCATION:
\[ b = 0.74 \quad h = 1.18 \quad t = 0.125 \]

STRESSES

\[ M_0 = 130 \text{ ksi} \]
\[ F_b = 159 \text{ ksi} \]
\[ f_b = \frac{3120}{2.17} = 14.4 \text{ ksi} \]
\[ F_s = 80 \text{ ksi} \]
\[ f_s = \frac{3000}{3.95} = 7.6 \text{ ksi} \]

REF. NO. 4, TABLE II CASE S

TORQUE TAKEN OUT AS FLANGE SHEAR

\[ U = \left[ R_b^2 + (R_s + R_{SP})^2 \right]^{1/2} = 0.42 \]

M.S. = \( \frac{1}{J} - 1 = \pm 1.38 \)

DATE: 12-16-70 PAGE 20
REPORT No. ATM-954
MODEL LRRZ-300
**Final Analysis**

**LRRR-300**

**Bracket, Rear Support**

**DWG. 2347348**

---

### Loads

The most critical condition for the rear support bracket was found to be condition No. 3 with the astronaut exerting a 45 pound force in the negative Y direction. The array is at a 10° attitude.

Load in Leg Assy & Lugs A & A' due to a 26 array weight of 200 pounds.

\[
Z_B = \frac{11.42(200)}{22.88} = 100 \text{ lbs}
\]

\[
P_{BC} = \frac{Z_B}{\cos 69°} = \frac{100}{\cos 69°} = 280 \text{ lbs}
\]

\[
P_{CD} = P_{BC} \cos 21° = 280 \cos 21° = 261 \text{ lbs}
\]

At A:

\[
X_A = \frac{9.21 \ P_{CD}}{11.95} = \frac{9.21(261)}{11.95} = 201 \text{ lbs}
\]

\[
Z_A = -0.50 \ P_{RAA'} = -50 \text{ lbs}
\]
Final Analysis  LRRR-300
Bracket, Rendezvous Support  Dwg. 2347348

Loads (Cont'd)

At \( A' \)

\[
X_{A1} = \frac{2.74 \times 20}{11.95} = 2.74(20) = 60 \text{ lb}
\]

\[
Z_{A1} = -50 \times \frac{R}{A} = -50 \text{ lb}
\]

Loads on lugs \( A \) & \( A' \) due to astronaut handling load of 45 pound ultimate in the (-y) direction. Since the array is considerably stiffer in the y direction than the leg assy, assume the astronaut load is transferred directly to the lugs at \( A \) & \( A' \).

At \( A' \)

\[
X_A = -X_{A1} = \frac{36.4(45)}{11.95} = 137 \text{ lb}
\]

\[
Z_A = -Z_{A1} = \frac{27.2(45)}{11.95} = 103 \text{ lb}
\]

\[Y_A = Y_{A1} = -45 \text{ lb} \] (100-0 distribution depending on lug being analyzed)

Then:

\[
X_{A1\text{tot}} = 201 + 137 = 338 \text{ lb}
\]

\[
Z_{A1\text{tot}} = -50 + 103 = 53 \text{ lb}
\]

\[Y_A = -45 \text{ lb} \] (100-0 distribution depending on lug being analyzed)

And

\[
X_{A1\text{tot}} = 60 - 137 = -77 \text{ lb}
\]

\[
Z_{A1\text{tot}} = -50 - 103 = -153 \text{ lb}
\]

\[Y_A = -45 \text{ lb} \]
**Final Analysis**

**LRRR-300**

**Bracket, Rear Support**

**Bracket Twist Investigation During Deployment**

**LRRR-300 Deployed with Array at 10° Attitude**

** Loads **

1. **Loads at (A) & (A') due to Astronaut Load Applied in the (-Y) Direction**

   \[ X_A = -X_A' = 137 \text{ lbs} \]

   \[ Z_A = -Z_A' = 103 \text{ lbs} \]

   \[ Y_A = Y_A' \text{ Neglect} \]

Assume Bracket is Held Fixed at Stiffener containing \( LUG \) (A) with Stiffener containing \( LUG \) (A') Free to Deflect (Twist) due to the Applied Loads.

Conservatively assume Bracket Sections between Stiffeners (A) & (A') are as shown in sketch.

**Torque on Section:**

\[ T = 3.41 (137) = 467 \text{ in-lbs} \]

**Section Torsional Constant, } \]

Assume a Box Section, Where:

\[ a = 3.0 \quad b = 0.55 \quad t_1 = t_2 = 0.05 \]

\[ K = \frac{2 \pi t_1 (a-t) (b-t)}{a t + b t - t_1^2 - t_2^2} \]

\[ = \frac{2 (0.05) (2.95) (0.50)}{3.0 (0.05) + 0.55 (0.05) - 0.05^2} = 0.063 \]

**Bracket Twist \( \theta \)**

\[ \theta = CL = \frac{467(11.95)}{.063 (4 \times 10^6)} = 0.0221 \text{ radians} \approx 1^\circ 16' \]

---

2. **Ref. No. 4, Table IV Case II.**

1. **Ref. Page 22**
Final Analysis  LRRR-300
Bracket, Rear Support

Lug Analysis - Lug A

Lug Loads

\[ X_A = 338 \text{ 1bs} \]
\[ Z_A = 53 \text{ 1bs} \]

Resultant \( P_{lug} = (X_A^2 + Z_A^2)^{1/2} = 343 \text{ 1bs} \)

Lug Properties

\[ D = 0.25 \quad A_{br} = 0.0625 \]
\[ t = 0.25 \quad A_t = (W-0.1) \times 0.0625 \]
\[ a = 0.25 \quad q_d = 1.0 \quad K_{br} = 0.83 \]
\[ w = 0.50 \quad u/d = 2.0 \quad K_a = 0.90 \]
\[ R = 0.125 \quad \theta = 0^\circ \quad e = 0.125 \]
\[ R/e = 1.0 \quad K_t = 1.18 \quad A_{AV} = K_t K_e = 1.18(0.125) = 0.15 \quad K_e = 2.25 \]

Lug Allowables

Mat'ld: Al-Alloy 2024-T351
\[ P_{lub} = 62 \text{ ksi} \]
\[ P_{lux} = 59 \text{ ksi} \]

Assume \( P_{lug} \) acting transversely

\[ P_{lug} = K_{br} A_{br} P_{lux} \]
\[ = 0.25(0.0625) 59000 = 920 \text{ 1bs} \]

\[ M.S. = \frac{P_{lux}}{1.15 P_{vug}} \]

Ref. Page 22
Ref. No. 3, Section 2.30
Fitting Factor
Final Analysis  LRR-Z-300  
Bracket, Rear Support

LOADS

The condition is the same as that on page 21 except the astronaut load is exerted in the (-2) direction. (See sketch)

Loads due to astronaut force:

\[ Z_B = \frac{36.4(45)}{22.88} = 71.5 \text{ lb} \]

\[ P_{BC} = \frac{Z_B}{\cos 69^\circ} = 200 \text{ lb} \]

\[ P_{BD} = P_{BC} \cos 21^\circ = 188 \text{ lb} \]

At A

\[ X_A = \frac{9.21 P_{BD}}{11.95} = \frac{9.21(188)}{11.95} = 145 \text{ lb} \]

\[ Z_A = .50 (Z_B - 45) = 13.6 \text{ lb} \]

At A'

\[ X_{A'} = \frac{2.74 (188)}{11.95} = 43 \text{ lb} \]

\[ Z_{A'} = .50 (Z_B - 45) = 13.6 \text{ lb} \]

Total Loads (Ref. Pages 21 & 22)

\[ Z_{B\text{tot}} = Z_B + Z_A = 100 + 71.5 = 171.5 \text{ lb} \]

\[ P_{B\text{tot}} = P_{BC} + P_{BD} = 280 + 200 = 480 \text{ lb} \]

\[ P_{D\text{tot}} = P_{BD} + P_{A\text{tot}} = 261 + 188 = 449 \text{ lb} \]

\[ X_{A\text{tot}} = X_A + X_{A\text{tot}} = 201 + 145 = 346 \text{ lb} \]

\[ Z_{A\text{tot}} = Z_A + Z_{A\text{tot}} = -50 + 13.6 = -36.4 \text{ lb} \]

\[ X_{A\text{tot}} = X_A + X_{A\text{tot}} = 60 + 43 = 103 \text{ lb} \]

\[ Z_{A\text{tot}} = Z_A + Z_{A\text{tot}} = -50 + 13.6 = -36.4 \text{ lb} \]
FINAL ANALYSIS  LRPP-300

BRACKET, REAR SUPPORT

SECTION AT SUPPORT LEG SOCKET

LOADS & MOMENTS

\[ \begin{align*}
X_A &= 346 \text{ Ibs} \\
Z_A &= -364 \text{ Ibs} \\
M_{2A} &= -2.74 X_A = -2.74 (346) = 948 \text{ in}-\text{lbs} \\
M_{1A} \text{ (TORQUE)} &= 3.41 X_A = 1180 \text{ in}-\text{lbs} \\
\text{SHEAR} &= (X_A^2 + Z_A^2)^{1/2} = 348 \text{ Ibs}
\end{align*} \]

SECTION PROPERTIES

ASSUME SECTION CONFIGURATION AS SHOWN

\[ \begin{align*}
A &= 2(3.0) .05 + 2 (.45) .05 = .545 \\
\frac{I_z}{I_{y/c}} &= \frac{3.0 (.55)^3 - 2.90 (.45)^3}{12} = .0196 \\
\frac{I_{y/c}}{I_z} &= \frac{.0196}{.0275} = .0713 \\
Q_y &= 3.0 (.05) .25 + 2 (.225) .05 = .04 \\
K_2 &= \frac{2Q_y}{J_{y/c}} = \frac{2 (.04)}{.0713} = 1.12
\end{align*} \]

STRESSES

\[ \begin{align*}
F_{Bu} &= 71.5 \text{ KSI} \\
\frac{f_b}{f_{bu}} &= \frac{948}{.0713} = 13.3 \text{ KSI} \\
R_B &= .186 \\
F_{SU} &= 37 \text{ KSI} \\
\frac{f_S}{f_{su}} &= \frac{348}{.365} = 1.01 \text{ KSI} \\
R_S &= .027 \\
\frac{f_S^2}{f_{ST}} &= \frac{1180}{2(.05)2.95(1.05)} = 8.0 \text{ KSI} \quad R_{ST} = .216
\end{align*} \]

\[ U = \left[ R_B^2 + (R_S + R_{ST})^2 \right]^{1/2} = .253 \]

\[ M.S. = \frac{1}{U} - 1 = 2.95 \]

\[ \text{REF. NO. 4, TABLE IV} \]

\[ \text{REF. PAGE 25} \]
Final Analysis **LRRP-300**

Bracket, Rear Support

**SECTION A-A** (See Page 24)

**LOADS & MOMENTS**

\[
X_A = 346 \text{ lbs} \\
Y_A = -364 \text{ lbs} \\
Z_A = 45 \text{ lbs}
\]

**SECTION PROPERTIES**

\[
A = 0.50 (75) = 0.125 \\
I_y = \frac{25 (50)^3}{12} = 0.0026 I_x = 0.0052 K_y = 1.5 \quad K_x = 1.5
\]

**STRESSES**

\[
F_{x0} = 90 \text{ KSI} \\
F_{y0} = 217 \text{ KSI} \\
F_{z0} = 349 \text{ KSI}
\]

\[
\sigma_x = \frac{41}{0.0052} = 7.9 \text{ KSI} \quad \sigma_y = \frac{317}{0.0104} = 30.5 \text{ KSI} \quad \sigma_z = \frac{349}{0.125} = 2.79 \text{ KSI}
\]

\[
\tau_{xy} = \sigma_x = 7.9 \text{ KSI} \quad \tau_{yz} = \sigma_y = 30.5 \text{ KSI} \quad \tau_{zx} = \sigma_z = 2.79 \text{ KSI}
\]

\[
L = \left\{ \left[ (R_{x0} - R_{y0})^2 + R_{z0}^2 \right]^{\frac{1}{2}} + R_{z0}^2 \right\}^{\frac{1}{2}} = 0.375
\]

\[
M.S. = \frac{1}{L} = 1.67
\]

---

Ref. Page 25
FINAL ANALYSIS LRRR-300
BRACKET, REAR SUPPORT

SOCKET ANALYSIS AT POINT D

SOCKET LOADS & MOMENTS

1. \( M_{y0} = 1985 \text{ in}-\text{lb} \)

\[ V_i = \frac{M_{y0}}{L-L_{br}} = \frac{1985}{.76} = 2610 \text{ lb} \]

SOCKET PROPERTIES

2. \( L = 1.0 \), \( D = .48 \), \( L/D = 2.08 \), \( L_{br}/L = .24 \), \( L_{br} = .24 \)

3. \( \alpha = .30 \), \( \gamma = .75 \), \( C_L = .50 \)

ALLOWABLE SOCKET LOADS

MAT'L: 2024-T351 Al. Alloy \( F_{u0} = 62 \text{ KSI} \)

\[ V_u = C_L D L_{br} F_{u0} \]

\[ = .50 (.48)(.24)(62000) \]

\[ = 3570 \text{ lb} \]

\[ M.S. = \frac{V_u}{1.15 V_i} = 1 = 4.19 \]

FITTING FACTOR

BASED ON \( \gamma = 1.75 \)

SHORT SIDE OF LEG ASSUMED AS \( D \)

REF. NO. 3, SECTION 2.6 - SOCKET CONSIDERED A LOOSE FIT

REF. PAGE 35
Final Analysis LRRE-300

Bracket, Rear Support

Bearing Check

Leg Attach Pins Against Bracket

Loads & Moment on Bracket

1. \[ X_D = -449 \text{ 165} \]
2. \[ M_D = -1985 \text{ in.-}165 \]

Bearing Load:

\[ P_b = \frac{50(M_D + X_D)}{2} \]
\[ = \frac{50(1985) + 449}{2} = 1730 \text{ 165} \]

Assume 60-40 Distribution Between Pins:

\[ P_{\text{fr}}/P_{\text{n}} = 0.60 \]
\[ P_{\text{fr}} = 1040 \text{ 165} \]

Bearing Properties

Pin Dia = 0.188
Bracket Socket Wall Thickness = 0.12
\[ A_{br} = D_{t} = 0.0225 \]

Bearing Stresses

Mat' L: 2024-T351 Al. Alloy \[ F_{u} = 62 \text{KSI} \]

\[ F_{xy} = 71 \text{KSI} \]
\[ f_{br} = \frac{1040}{0.0225} = 46.2 \text{ KSI} \]

\[ M.S. = \frac{F_{xy}}{15f_{br}} = 1 = 3.02 \]

3. Bearing Factor

2. Conservatively Assume 50% of Socket Moment Taken Out in the Pins

Ref: Page 36
FINAL ANALYSIS LZRR - 300

ATTACH PIN REAR SUPPORT BRACKET TO LEG ASSY

PIN LOADS

1. $X_D = -449.165$
2. $M_Y_D = -198.5165$

\[
F_{PN} = \frac{0.50 M_Y_D + X_D}{0.66} = 1730.165
\]

ASSUME 60-40 DISTRIBUTION BETWEEN PINS.

\[
P_{PN} = 0.60 (1730) = 1040.165
\]

PIN PROPERTIES

PIN DESIGNATION: NAS 561C-6

DOUBLE SHEAR ALLOWABLE = 4400 165
SINGLE SHEAR \( '' \) = 2200 165

PIN MARGIN OF SAFETY

\[
M.S. = \frac{2200}{1040} - 1 = 1.11
\]

2. CONSERVATIVELY ASSUME 50% OF SOCKET MOMENT TAKEN OUT IN THE PINS.
1. REF. PAGE 36
Final Analysis: LRRZ-300

Clevis, Rear Pivot

Section A-A

Loads & Moments

\[ X_A = -338/165 \]
\[ Y_A = 45/165 \]
\[ Z_A = -53/165 \]

\[ M_{X_A} = \frac{0.30Z_A}{2} \cos 35^\circ - \frac{0.50Y_A \sin 35^\circ}{2} \]
\[ = \frac{50(-338)}{2} \cdot \frac{819}{2} - \frac{50(45)}{2} \cdot 574 \]
\[ = 34.6 \text{ in}-\text{lb} \]

\[ M_{Y_A} = 0.23X_A + 0.34Z_A \cos 35^\circ \]
\[ -0.34Y_A \sin 35^\circ \]
\[ = 0.23(-338) + 0.34(-53) \cdot 819 - 0.34(45) \cdot 574 \]
\[ = 101.3 \text{ in}-\text{lb} \]

\[ M_{Z_A} = 0.50X_A - 0.34Y_A \cos 35^\circ - 0.34Z_A \sin 35^\circ \]
\[ = 0.50(-338) - 0.34(45) \cdot 819 - 0.34(-53) \cdot 574 \]
\[ = 166.8 \text{ in}-\text{lb} \]

Tension = \[ Z_A \sin 35^\circ + Y_A \cos 35^\circ \]
\[ = -53(819) + 45(819) = 6.4 \text{ in}-\text{lb} \]

Shear = \[ (Z_A \cos 35^\circ - Y_A \sin 35^\circ) \cdot X_A \]
\[ = [-53 \cdot (819) - 45 \cdot (574)] \cdot 338 = 346 \text{ in}-\text{lb} \]

Section Properties

\[ A = 2.0(0.09) = 0.18 \]
\[ I_x = \frac{0.09(2.0)^3}{12} = 0.06 \]
\[ I_{x/c} = 0.06 \]
\[ K_x = 1.5 \]
\[ b = 0.09 \]

\[ I_2 = \frac{2.0(0.09)^3}{12} = 0.00012 \]
\[ I_{y/c} = 0.00012 \]
\[ K_2 = 1.5 \]

Volume of Section, \( V = \frac{b^2(3a-b)}{12} = \frac{(0.09)^2[3(2.0) - 0.09]}{12} = 0.004 \text{ in}^3 \)

References:
2. Reference No. 3, Section 2.4
Final Analysis - LIRR-300

CLEVIS, REAR PIVOT

SECTION A-A (cont'd)

Stresses

Al. Alloy 2024-T351  $E_o = 62$ ksi

\[ F_1 = 90.0 \text{ ksi} \]
\[ f_{by} = \frac{36.6}{106} = 0.35 \text{ ksi} \]
\[ f_{2y} = \frac{166.8}{1002.66} = 0.13 \text{ ksi} \]

\[ F_{u1} = 62 \text{ ksi} \]
\[ f_c = \frac{6.4}{18} = 0.36 \text{ ksi} \]

\[ F_{s1} = 37 \text{ ksi} \]
\[ f_s = \frac{346}{18} = 19.3 \text{ ksi} \]

\[ T_{ul} = 2V_{s0} = 2(0.08) 37 = 2.296 \text{ in-k} \]

\[ M_{S1} = 0.101 \text{ in-kg} \]

\[ R_{1} = 0.004 \]
\[ R_{2} = 0.006 \]
\[ R_{3} = 0.052 \]

\[ R_{ap} = 0.341 \]

\[ U = \left[ \left( \frac{R_{ap}^2}{R_{1}^2 + R_{2}^2} \right) + \left( \frac{R_{ap}^2}{R_{3}^2 + R_{ap}^2} \right) \right]^{1/2} = 0.80 \]

\[ M.S. = \frac{1}{U} - 1 = +0.25 \]

Ref. No. 3, Section 2.4

BxA 542
Final Analysis LRRR-300
CLEVIS, REAR PIVOT

LUG ANALYSIS

LOADS

For lug loads, assume a 60-40 distribution

Transverse load = .60 X A = .60(53) = -31.8 lb
Axial load = .40 X A = .40(-338) = -20.3 lb

Lug Properties

\[
\begin{align*}
D &= 0.25, \quad A_c = 0.6 - 0.045 \\
R &= 0.18, \quad A_t = (W-0.6) = 0.063 \\
q &= 0.30, \quad q/6 = 1.20, \quad K_t = 0.94 \\
W &= 6.60, \quad W/D = 2.40, \quad K_e = 0.94 \\
R &= 0.125, \quad E = A - R = 0.175, \quad R_e = 0.715, \quad \theta = 0^\circ \quad K_f = 1.12 \\
A_{br} &= K_f / 2E = 1.12(0.175) = 0.785, \quad K_{f_b} = 0.50
\end{align*}
\]

Allowable Lug Loads

Alloy 2024-T351 \( F_{tu} = 62 \text{ ksi} \)

Tension:

\[
P_t = K_f A_t F_{tu} = 0.94(0.063)62000 = 3670 \text{ lb}
\]

Shear-Bearing

\[
P_{br} = K_{br} A_{br} F_{tu} = 0.96(0.045)62000 = 2680 \text{ lb}
\]

Transverse

\[
P_{tu} = K_{tu} A_{tu} F_{tu} = 0.50(0.045)62000 = 1390 \text{ lb}
\]

\[
M.S. = \frac{1}{1.15(R_{tu}R_{tu})^{1/6}} = -1 = \text{AMPLE}
\]

Fitting Factor

Ref. No. 3, Section 2.3

Ref. page 22, loads assumed in coordinate system
Final Analysis  LRRRZ-300
Pivot Pin, Rear

Pin Loads

\[ X_a = -338 \text{ in-lb} \]
\[ Z_a = -53 \text{ in-lb} \]

Resultant Pin Load:
\[ P_{\text{RM}} = (X_a^2 + Z_a^2)^{1/2} \]
\[ = 343 \text{ in-lb} \]
\[ \text{B.M.} = 0.60 P_{\text{RM}} (0.09 + 0.02 + 0.125) = 48.5 \text{ in-lb} \]

Pin Properties

\[ \text{OD} = 0.25 \quad A = 0.0491 \quad I = 0.0019 \quad \frac{t}{c} = 0.00152 \quad d/c = 2.0 \]

Stresses

MAT'L: AISI 304 Stainless Steel  \[ F_{tu} = 75 \text{ ksi} \]

Bending Check

\[ F_b = 124 \text{ ksi} \quad \frac{F_b}{Ic} = \frac{48.5}{0.00152} = 31.9 \text{ ksi} \]

M.S. = \[ \frac{F_b}{Ic} - 1 = 2.38 \]

Shear Force

\[ F_{su} = 40 \text{ ksi} \quad \frac{F_{su}}{F_t} = \frac{0.60(343)}{0.0491} = 4.19 \text{ ksi} \]

M.S. = \[ \frac{F_{su}}{F_t} - 1 = \text{AMPLE} \]

1. Assume a 60-40 load distribution
2. Ref. Page 22
3. Fitting Factor
Final Analysis LRRZ-300

LEG ASSY

LOADS

At A, A':

\[ X_{A_{TOT}} + X_{A'_{TOT}} = 449 \text{ lbs} \]
\[ Z_{A_{TOT}} + Z_{A'_{TOT}} = -72.8 \text{ lbs} \]

At C:

\[ X_C = P_{C_{TOT}} = -449 \text{ lbs} \]
\[ Z_C = -Z_{E_{TOT}} = -171.5 \text{ lbs} \]

At E:

\[ \sum M_D = 0 = 4.42(X_{A_{TOT}} + X_{A'_{TOT}}) - 12.35Z_C - 21.6E \]
\[ Z_E = \frac{4.42(449) - 12.35(-171.5)}{21.6} = 190 \text{ lbs} \]

At D:

\[ Z_D = -\left( Z_{A_{TOT}} + Z_{A'_{TOT}} + Z_C + Z_E \right) \]
\[ = -(-72.8 - 171.5 + 190) = 543 \text{ lbs} \]
\[ X_D = X_{A_{TOT}} + X_{A'_{TOT}} = 449 \text{ lbs} \]
\[ \sum M_D = 4.42(X_{A_{TOT}} + X_{A'_{TOT}}) = 1985 \text{ in-lbs} \]

FREE BODY DIAGRAM OF LEG ASSY:

\[ Z_{D_{TOT}} \text{ on leg:} \]
\[ Z_{D_{TOT}} = Z_{A_{TOT}} + Z_{A'_{TOT}} + Z_D = -18.5 \text{ lbs} \]
Final Analysis LRRZ-300

LEG ASSY (cont'd)

SECTION A-A (REF PAGES 35)

LOADS AND MOMENTS

Axial Compression = 449.165

Bending Moment = 1985 in-lb

Shear = 185.165 (NEGLECT)

SECTION PROPERTIES

\[ A = 47.47 = 454 \]

\[ I_y = \frac{47(47)^3}{12} = 0.00839 \]

\[ I_{y/} = 0.0357 \quad K_y = 1.5 \]

\[ I_z = \frac{47(47)^3}{12} = 0.03574 \]

\[ I_{z/} = 0.0737 \quad K_z = 1.5 \]

STRESSES

AL. ALLOY 2024-T351 \[ \sigma_{\text{u}} = 62 \text{ KS} \]

\[ \sigma_{\text{y}} = 40 \text{ KS} \]

\[ \sigma_{\text{c}} = 36 \text{ KS} \]

\[ f_b = \frac{1985}{0.0357} = 55.6 \text{ KS} \]

\[ f_c = \frac{449}{0.156} = 975 \text{ KS} \]

\[ P_{\text{is}} = \frac{1}{R_b + R_c} = 1.54 \]
**FINAL ANALYSIS LRRR - 300**

**DIAGONAL SUPPORT ASSY**

**COLUMN ANALYSIS OF TUBE** (PIN 234734-1)

**LOADS**

**LOAD AT FOOT Y**: (SEE SKETCH PAGE 21)

\[ Y_e = \frac{-36.4 (45)}{21.6} = -76 \text{ lbs} \]

**LOAD IN TUBE D'E' DUE TO Y_e**: \( P_{D'E'} = \frac{Y_e}{\sin 19.8^\circ} \)

\( = \frac{-76}{0.3387} = 224 \text{ lbs (COMP.)} \)

**MOMENT DUE TO ECCENTRICITY OF 0.06"**

**B.M. = 0.06 (224) = 13.4 in-lb**

**LOAD IN LEG ASSY D'E DUE TO Y_e**: \( P_{D'E} = P_{D'E'} \cos 19.8^\circ = 211 \text{ lbs (TENSION)} \)

**TUBE COLUMN PROPERTIES**

<table>
<thead>
<tr>
<th>OD</th>
<th>ID</th>
<th>C1</th>
<th>L</th>
<th>L</th>
<th>1/L</th>
<th>DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>.50</td>
<td>.37</td>
<td>1.0</td>
<td>22.58</td>
<td>145</td>
<td>776</td>
<td></td>
</tr>
</tbody>
</table>

**TUBE MAT'L**: 6061-T6 AL. ALLOY

\( F_u = 42 \text{ksi} \)

\( F_y = 34 \text{ksi} \)

\( F_{u0} = F_y (1 + \frac{F_{u0}}{F_y}) ) = 34000 \left[1 + \frac{34000}{20000}\right] = 37100 \text{psi} \)

**TRANSITIONAL L'P = 1.346 \text{ti} \left(\frac{F}{F_{u0}}\right)^{1/2} = 62.2 \text{ : COLUMN IS LONG}**

**STRESSES**

\( F_c = \frac{P_{D'E'}}{(145)^2} = 4640 \text{psi} \)

\( F_c = \frac{P_{D'E'}}{A} = 2520 \text{ psi} \)

\( R_c = 0.544 \)

\( M.S. = \frac{1}{R_c + R_b} = 1.75 \)

**REF. NO. 6, PAGE 3.4.2.1**

**REF. NO. 3, PAGE 3.01-1**
**FINAL ANALYSIS**  \textbf{LRRR-300}

**TUBE, DIAGONAL SUPPORT**  \textbf{DWG: 2347345-1}

**BEARING CHECK** - SPRING PIN AGAINST TUBE

**BEARING LOAD**

\[ P_{DE1} = 224 \text{ lbs} \]

**BEARING PROPERTIES**

PIN DIA = 0.1875
TUBE WALL = 0.065
\( A_{br} = 2(0.065) \times 0.1875 = 0.244 \)

**BEARING STRESSES**  \textbf{MAT' L-2014-76 AL ALLOY}  \( F_0 = 65 \text{ KSI} \)

\[ F_{br} = 77 \text{ KSI} \]

\[ f_r = \frac{P_{osi}}{A_{br}} = \frac{224}{0.244} = 918 \text{ KSI} \]

\[ M.S. = \frac{F_{br}}{1.5f_r} = 1 = 4.6 \]

**BEARING FACTOR**

1. REF. PAGE 37
Final Analysis LRRZ-300
Bracket, Diagonal Support

**LOAD**

1. **Bearing Load**
   \[ \bar{P}_{o} = 224 \text{ lbs} \]

2. Assume a 60-40 load distribution:
   \[ P = 0.60 \bar{P}_{o} = 134.5 \text{ lbs} \text{ (one side)} \]

**Bearing Properties**

- PIN DIA = 0.1875
- MIN BRACKET WALL = 0.057
- \( A_{b} = 0.1875 \times 0.057 = 0.0107 \)

**Bearing Stresses**

- **MATERIAL**: 2024-7351 Al. Alloy \( f_{y} = 62 \text{ KSI} \)
- \( f_{b} = \frac{134.5}{0.0107} = 12.9 \text{ KSI} \)
- **M.S.** = \( \frac{f_{b}}{f_{y}} - 1 = 2.33 \)

**Bearing Factor**

1. **REF. PAGE 37**
Final Analysis LRRR-300
Pivot Brace, Front & Rear

DWGS. 2347344 8 2347347

Column Analysis - Array at 60° Attitude

Astronaut Force
Applied at Array Handle
in the (+X) Direction

Front & Rear Pivot Brace Assy

Loads

The most critical condition for the pivot brace Assy
as a long column is when the array is at a 60°
attitude and condition no. 3 with the astronaut
exerting an ultimate force of 45 pounds at the
array handle in the (+X) direction is considered.

Column Load in Pivot Brace Assy (Brace BC)

\[ S_{BC} = \frac{6.30 \times 200 + 45(24.72 \cos 82.5°)}{14.50} = 156.165 \]

\[ P_{BC} = \frac{S_{BC}}{\sin 82.5°} = \frac{156}{\sin 82.5°} = 158.165 \]

Column Moment = \( P_{BC} \) (offset + eccentricity + slop)

\[ = 158 (0.63 + 0.06 + 0.06) = 118.5 \text{ in-lbs} \]

\( \) Assumed
FINAL ANALYSIS LRRR - 300
PIVOT BRACE, FRONT & REAR

COLUMN ANALYSIS (CONT'D)

SECTION PROPERTIES

FRONT PIVOT BRACE

\[ A = 2 \times 12 \times 1.0 + 2 \times 12 \times 1.12 = 4.44 \]
\[ A_2 = 0.24 \times 1.50 + 2 \times 34 \times 0.94 = 3.59 \quad 2 = 0.73 \]
\[ A_{net} = 4.44 - 2 \times 1.12 \times 1.12 = 1.448 \]
\[ I_y = \frac{2 \times (12)(1.0)^3 + 2 \times 12 \times (1.12)^3 + 2 \times 34 \times (2.25)^3 + 2 \times 34 \times (2.21)^3}{12} = 0.0439 \]
\[ I_{12} = \frac{0.0439}{12} = 0.0036 \]
\[ Q_y = 0.12 \times (1.73)^2 = 0.4699 \quad K_y = \frac{2Q_y}{I_{12}} = \frac{2 \times 0.4699}{0.0439} = 10.68 \]
\[ P_y = \left( \frac{I_y}{A} \right)^{\frac{1}{2}} = \left( \frac{0.0439}{4.44} \right)^{\frac{1}{2}} = 0.218 \]

REAR PIVOT BRACE

\[ A = 2 \times 12 \times 1.25 + 1.88 \times 1.25 = 4.01 \]
\[ A_{net} = 4.01 - 2 \times 1.12 \times 1.12 = 1.855 \]
\[ A_2 = 1.66 \times (3.45) + 2.35 \times (0.83) + 2.35 \times (1.12)^2 = 1.1477 \]
\[ I_y = \frac{2 \times (12)(1.65)^3 + 1.66 \times (1.65)^2 + 1.88 \times (1.25)^3 + 2 \times 35 \times (1.12)^3}{12} = 0.0821 \]
\[ I_{12} = \frac{0.0821}{12} = 0.0068 \]
\[ Q_y = 1.66 \times (1.65) + 2.35 \times (1.12) = 0.386 \quad K_y = \frac{2Q_y}{I_{12}} = \frac{2 \times 0.386}{0.0068} = 1.35 \]
\[ P_y = \left( \frac{I_y}{A} \right)^{\frac{1}{2}} = \left( \frac{0.1477}{4.01} \right)^{\frac{1}{2}} = 0.192 \]
FINAL ANALYSIS  LRRR - 300
PIVOT BRACE, FRONT & REAR  DWGS. 2347344 & 2347347

COLUMN ANALYSIS (CONT'D)

STRESSES  MAT'L ALLOY 2024-T351  \( \sigma_u = 62 \text{ ksi} \)

CONSERVATIVELY ASSUME PIVOT BRACE TO HAVE
SECTION PROPERTIES OF THE REAR PIVOT BRACE
FOR THE ENTIRE LENGTH OF THE COLUMN. \( L = 21.88'' \)

\[
F_C = F_y \left( 1 + \frac{L}{1000} \right) \\
= 36000 \left[ 1 + \left( \frac{21.88}{1000} \right) \right] = 42800 \text{ psi}
\]

\[
\frac{L}{L'} = \frac{21.88}{192} = 1.14
\]

\[
F_C = \pi^2 E \left( \frac{\pi}{L'} \right)^2 \\
= \frac{\pi^2 \left( 1.0 \times 10^6 \right)}{114^2} = 7970 \text{ psi}
\]

\[
\frac{f_c}{P_e} = \frac{158}{.355} = 445 \text{ psi}
\]

\[
R_e = .054
\]

\[
R_b = R_b = .022
\]

\[
\frac{1}{R_b + R_e} = 1 = \text{AMPERE}
\]

\[\text{REF. NO. 6, PAGE 3.4.2.1}\]
FINAL ANALYSIS  LRPP-300  
Pivot Brace, Front & Rear  
Dwg's, 2347344 & 2347347  

COLUMN ANALYSIS - ARRAY AT 10° ATTITUDE (REF. SKETCH PAGE 21)  

LOADS  

\[ Z_{Tot} = 171.5 \text{ lbs} \]  
\[ P_{x} = 480 \text{ lbs} \]  
\[ P_{y} = 449 \text{ lbs} \]  

COLUMN MOMENT = \( P_{y} \) (OFFSET + ECCENTRICITY + SLOP)  
\[ = 480 (1.63 + 0.06 + 0.06) = 360 \text{ in.-lbs} \]  

COLUMN SECTION PROPERTIES  

FRONT PIVOT BRACE  
\[ A = 0.444 \quad A_{z} = 0.359 \quad \bar{z} = \frac{A_{z}}{A} = 0.78 \quad A_{net} = 0.448 \]  
\[ I_{y} = 0.0439 \quad I_{x} = 0.1626 \]  
\[ P_{y} = \left( \frac{I_{y}}{A} \right)^{1/2} = \left( \frac{0.0439}{0.444} \right)^{1/2} = 0.298 \]  

REAR PIVOT BRACE  
\[ A = 0.401 \quad A_{z} = 0.205 \quad \bar{z} = \frac{A_{z}}{A} = 0.51 \quad A_{net} = 0.355 \]  
\[ I_{y} = 0.01477 \quad I_{x} = 0.0823 \]  
\[ P_{y} = \left( \frac{I_{y}}{A} \right)^{1/2} \left( \frac{0.01477}{0.401} \right)^{1/2} = 0.192 \]  

1. Ref. Page 25  
2. Ref. Page 40  
3. Assumed  
4. Ref. Page 41 for Analysis
FINAL ANALYSIS  LRRR-300
PIVOT BRACE, FRONT & REAR  DWG'S. 2347344 & 2347347

COLUMN ANALYSIS (CONT'D)

STRESSES  MAT'L ALLOY 2024-T351  \( F_{yw} = 62 \text{ ksi} \)
\( F_{cy} = 36 \text{ ksi} \)

CONSERVATIVELY ASSUME PIVOT BRACE ASY TO HAVE SECTION PROPERTIES OF THE REAR PIVOT BRACE FOR THE ENTIRE LENGTH OF THE COLUMN \( (L = 11.5'' \)

COLUMN YIELD STRESS
\[ F_{co} = F_{cy} \left( 1 + \frac{\sqrt{F_{co}}}{1000} \right) \]
\[ = 36000 \left[ 1 + \frac{\sqrt{36000}}{1000} \right] = 42800 \text{psi} \]

\( L = L' = 11.5'' \)
\( C = 1.0 \)
\( L' = 11.5 \times \frac{10}{10} = 60 \)

TRANSITIONAL
\[ \frac{L'}{L} = 1.732 \pi \left( \frac{L}{F_{co}} \right)^{1/2} \]
\[ = 1.732 \pi \left( \frac{10.5 \times 10^{5}}{42800} \right)^{1/2} = 85.8 \]
\( \text{Column is short} \)

ALLOWABLE COLUMN STRESSES

\[ F_{c} = F_{co} \left[ 1 - \frac{385 (L' / L)}{\pi} \right] \]
\[ = 42800 \left[ 1 - \frac{385 (60)}{\pi \left( \frac{10.5 \times 10^{5}}{42800} \right)^{1/2}} \right] = 22.7 \text{ ksi} \]

\[ f_{c} = \frac{P_{c}}{A_{ntr}} = \frac{480}{355} = 1.35 \text{ ksi} \]
\[ R_{c} = 0.009 \]

\[ F_{b} = F_{co} = 62 \text{ ksi} \]
\[ f_{b} = \frac{360}{0.0881} = 4.38 \text{ ksi} \]
\[ R_{b} = 0.071 \]

\[ M.S. = \frac{1}{R_{c} + R_{b}} = 1 = \text{AMPLE} \]

\( \text{REF. NO. 6, PAGE 3.4.2.1} \)
FINAL ANALYSIS  LR-RE-300
PIVOT BRACE ASSY
PIN ANALYSIS - FRONT BRACE TO REAR BRACE

PIN LOADS

1. \( P_{\text{front}} = 480 \text{ lbs} \)
2. Column moment = 3600 in-lbs

ASSUME A 60-40 DISTRIBUTION BETWEEN THE TWO SETS OF PINS

LOAD PER PIN:

\[
P_{\text{P}} = \left[ (0.30[480])^2 + (0.30\left[\frac{3600}{10.5}\right])^2 \right]^{\frac{1}{2}} = 145 \text{ lbs}
\]

**BENDING IN PIN**

\[
B.M. = \frac{P_{\text{P}}}{2} (0.06 + 0.01 + 0.06) = 145.13 = 18.9 \text{ in-lbs}
\]

**PIN PROPERTIES**

PIN DIA = 0.1875  \( A = 0.02761 \)  \( I = 0.00061 \)  \( I/c = 0.00065 \)

**STRESSES**

\( F_{zu} = 140 \text{ KSI} \)  \( \text{NAS 1003 Bolt} \)

**SHEAR CHECK**

\[ F_{zu} = 87 \text{ KSI} \]
\[ F_{z} = \frac{145}{0.0276} = 53 \text{ KSI} \]
\[
\text{M.S.} = \frac{F_{zu}}{F_{z}} = 1 - \text{AMPT}
\]

**BENDING CHECK**

\[ F_{zu} = F_{zd} = 140 \text{ KSI} \]
\[ f_z = \frac{18.9}{0.00065} = 29.1 \text{ KSI} \]
\[
\text{M.S.} = \frac{F_{zu}}{F_{zd}} = 1 - 43.18
\]
FINAL ANALYSIS  LRRR-300

PIVOT BRACE ASSY

BEARING CHERRY - ATTACH PIN AGAINST BRACE

LOAD

\[ \text{Pin Load} = 145 \text{ lbf} \]

BEARING PROPERTIES

\[ \text{Pin Dia} = 0.1875 \quad t = 0.12 \quad A_b = D t = 0.0225 \]

STRESSES

\[ \text{MATTL 2024-T551 Al Alloy} \quad \sigma_0 = 62 \text{ ksi} \]

\[ \sigma_y = 63 \text{ ksi} \quad \frac{f_{br}}{t_{br}} = \frac{145}{0.0225} = 645 \text{ ksi} \]

\[ M.S. = \frac{\sigma_y}{t_{br}} - 1 = \frac{6.50}{1.5} \]

(2) BEARING FACTOR

(1) REF. PAGE 45
**FINAL ANALYSIS**

**Pivot Brace - Rear**

**Lug Analysis at Brace Slide Attachment**

**Lug Loads**

\[ P_{lug} = P_{c707} = 480 \text{ lbs} \]

Assume load to be transverse to lug 2

**Lug Properties**

\[
\begin{align*}
D &= .25 \\
\alpha &= .20 \\
\omega &= .40 \\
\epsilon &= .25 \\
\Phi &= 21^\circ \\
A_{br} &= 0.0625 \\
\end{align*}
\]

\[ K_e = 1.27 \quad K_y = 1.27 \]

\[ A_{br} = K_e \frac{P_{lw}}{2R} = 0.382 \quad K_{eu} = 0.42 \]

Allowable Lug Load

\[ P_{eu} = K_{eu} A_{br} F_y = 62 \text{ ksi} \]

\[ = 0.42 (0.0625) 42000 = 1620 \text{ lbs} \]

\[ M.S. = \frac{P_{eu}}{1.15 P_{lw}} - 1 = 1.93 \]

---

**Ref. No. 3, Section 2.3**

**Fitting Factor**

**Ref. Sketch on Page 48**

**Conservative, Ref. Page 25**
**Final Analysis: LRRZ-300**

**Slide, Brace**

**Socket Analysis at Pivot Brace Attach**

**Socket Loads**

1. \( P_{C_{0\text{tot}}} = 449 \text{ lbs} \)

- **In Plane of Slide**:
  - \( P_{C_{1}} = 1.51 \frac{P_{C_{0\text{tot}}}}{1.87} \)
  - \( = 1.51(449) = 363 \text{ lbs} \)

- **Normal to Pivot Brace**:
  - \( R_{C_{0\text{GC}}} = \frac{R_{C_{1}}}{\cos 21^\circ} \)
  - \( = \frac{363}{\cos 21^\circ} = 390 \text{ lbs} \)

**Socket Properties**

- \( L = 3.85 \)
- \( D = 1.54 \)
- \( D = 0.25 \)
- \( L_{B} = 0.275 \)
- \( L_{B} = 1.00 \)
- \( a = 0.21 \)
- \( a/D = 0.84 \)
- \( t_{1} = t_{2} = 0.085 \)
- \( d = 0.145 \)
- \( C_{U} = 0.77 \)

**Socket Load**

\[
V_{1} = \frac{R_{C_{0\text{GC}}}}{L} + \frac{R_{C_{1}}}{2} = \frac{390(3.338)}{0.279} + 195 = 667 \text{ lbs}
\]

**Allowable Socket Load**

- **Material AISI 304 Stainless Steel**
  - \( F_{L} = 75 \text{ ksi} \)

\[
V_{L} = C_{0} D L_{B} F_{L} = 0.77(75)(104/75000) = 1580 \text{ lbs}
\]

**M.S.**

\[
\frac{V_{L}}{V_{1}} - 1 = 1.29
\]

---

2. **Ref. No. 3, Section 2.6**

1. **Ref. Page 25**
FINAL ANALYSIS  LRRR-300

SLIDE, BRACE

PAWL STUD TEAROUT ANALYSIS

LOADS & MOMENTS

\[ P_{cd} = 449 \text{ lb} \]

\[ B.M. = 449 (1.3) = 585 \text{ in-lb} \]

ASSUMED TEAROUT SECTION (SIMPLIFIED)

\[ A = 2(0.36)(0.8) + 2(0.15)(0.08) = 1.077 \text{ in}^2 \]

\[ I_c = \frac{1}{12} (z^2 - 2z) = \frac{1}{12} (0.0127^2) = 0.00705 \text{ in}^4 \]

\[ R = \frac{0.3 + 0.114}{2} = 0.465 \text{ in} \]

\[ \lambda = \frac{1.285}{(R/2)^2} = 4.83 \]

STRESSES MAT' L: AISI 304 STAINLESS STEEL \( f_{us} = 75 \text{ ksi} \)

\[ f_b = \frac{58.3}{0.00705} = 8200 \text{ psi} \]

\[ f_o = 0.08(8200) = 661 \text{ psi/in} \]

LOCAL BENDING DUE TO \( f_o \):

\[ f_{bc} = \frac{5f_o}{2(4.83)(0.08)} = \frac{5(661)}{2(4.83)(0.08)} = 53.2 \text{ ksi} \]

TENSION DUE TO \( P_{cd} \):

\[ f_c = \frac{4.49}{0.044} = 100 \text{ ksi} \]

\[ f_{c,max} = f_b + f_c = 63.6 \text{ ksi} \]

1 REF. PAGE 25

2 REF. NO. 4, TABLE VIII, CASE 8 COEFFICIENT INCREASED TO ALLOW FOR FIXED END CONDITION AT BASE OF STUD.

3 STIFFNESS IN SHEAR & TENSION ASSUMED PROPORTIONAL TO RESPECTIVE MODULUS.
Final Analysis \text{ LRRR - 300 }

Attach Pin - Rear Pivot Brace to Brace Slide

\text{ LOAD }

\begin{align*}
1 & \quad P_{Pi} = R_{Pi} = 390 \text{ lbf} \\
2 & \quad B.M. = R_{Pi} (0.125 + 0.06 + 0.06) \\
& \quad = 390 (0.226) = 88.1 \text{ in.-lbf}
\end{align*}

\text{ Pin Properties }

\begin{align*}
\text{Dia} & = 0.25 \quad A = 0.0491 \\
I_c & = 0.00152 \\
\gamma_{c} & = 2.0
\end{align*}

\text{ Stresses }

\text{ Mat'l: AISI 303 Stainless Steel } \quad \sigma_{u} = 75 \text{ ksi}

\text{ AT SHEAR FACE: }

\begin{align*}
F_{su} & = 50 \text{ ksi} \\
\frac{f}{c} & = \frac{390}{0.0491} = 7.95 \text{ ksi}
\end{align*}

\text{ M.S. } = \frac{F_{su}}{f} - 1 = 1.53

\text{ Bending Check }

\begin{align*}
F_{b} & = F_{u} = 25 \text{ ksi} \\
\frac{f}{c} & = \frac{88.1}{0.00152} = 58 \text{ ksi}
\end{align*}

\text{ M.S. } = \frac{F_{b}}{\gamma_{c}/f} - 1 = 1.12

1. \text{ Fitting Factor}
2. \text{ Clearance}
3. \text{ Ref Page 48}
Final Analysis LRRR-300

PAWL

Section A-A Curved Beam Analysis

Loads & Moments

1. \( P_{E0} = 449 \text{ lbs} \)
   B.M. \( A-A = \frac{.25}{.75} P_{E0} = 112 \text{ in-lbs} \)

Section Properties

\( A = .187 (.25) = .0467 \quad K = 1.5 \)

Eccentricity:

\( e = \frac{h c}{2 (3 c^2 - 8)} \)

\( = \frac{.25(2)}{2 [3(2)^2 - 8]} = 0.023 \)

Stress Concentration:

\( K_c = \frac{3c^2 - c - 8}{3c(c + 1)} \)

\( = \frac{3(2)^2 - 2 - 8}{3(2)(2 - 1)} = 1.53 \)

Stresses

Mat'#: 17-4 PH Stainless Steel \( \sigma_{Y} = 190 \text{ ksi} \)

\( \sigma = 190 \text{ ksi} \quad \sigma = \frac{P_{E0}}{A} = \frac{449}{.0467} = 9.60 \text{ ksi} \)

\( R_6 = \frac{1}{R_6 + R_7} = 1 = 1.93 \)

Ref. No. 5, Page 398
Ref. Page 25
Final Analysis LRRZ-300

PAWL

SECTION 8-B (REF SECTION PAGE 51)

LOADS

\[ P_{CP} = 449 \]

SECTION PROPERTIES

\[ A = 0.187(0.23) = 0.43 \]

STRESSES

MATERIAL: 17-4 PH STAINLESS STEEL \( f_y = 190 \text{ KSI} \)

\[ f_y = 190 \text{ KSI} \]

\[ \frac{f_y}{f_c} = \frac{449}{0.43} = 10.45 \text{ KSI} \]

M.S. \( = \frac{F_{wy}}{f_c} - 1 = \text{AMPLE} \)
FINAL ANALYSIS  LRRR-300

KEEPER ASSY

PAWL STUD TENZOUT

1. \( P_{c_{\text{out}}} = 449 \text{ lbs} \)

B.M. = 1.16 \( P_{c_{\text{in}}} = 71.8 \text{ in-lbs} \)

CONSIDER PAWL STUD ACTING ON
A FLAT PLATE WITH EDGES
SUPPORTED AS SHOWN

FLAT PLATE PROPERTIES

\[ a = \frac{474}{2} = 0.237 \quad \gamma = 0.30 \]

\[ r_0 = 0.155 \quad t = 0.08 \]

\[ r_{10} = \frac{0.155}{0.237} = 0.66 \quad \beta = 0.90 \]

STRESSES

MAT'L: AISI 304 STAINLESS STEEL  \( \sigma_0 = 75 \text{ KSI} \)

\( F_{20} = 75 \text{ KSI} \)

MAX RADIAL STRESS:

\[ f_r = \frac{BM}{at^2} \]

\[ = \frac{0.90 (71.8)}{0.237 (0.08)^2} = 42.5 \text{ KSI} \]

M.S. = \( \frac{F_{20}}{f_r} - 1 = 4.76 \)

3. REF. NO. 4, PAGE 216
2. REF. NO. 4, TABLE I, CASE 5
1. REF. PAGE 25
**Final Analysis**

**Lug Analysis**

**Loads**

1. **On Lug Assy**
   - \( P_{cd} = 449 \text{ lb} \)
   - \( R_B = - \frac{1.21 P_{cd}}{1.09} = 449 \text{ lb} \)
   - \( R_A = - \left[ P_{cd} + R_B \right] = -50 \text{ lb} \)

2. **On Leg Assy**
   - \( R_c = \frac{0.85 R_A - 446 R_B}{1.805} = -598 \text{ lb} \)
   - \( R_0 = - \left[ R_A + R_B + R_c \right] = 149 \text{ lb} \)

**Lug Load** = \( R_0 = 499 \text{ lb} \)

**Lug is Axially Loaded**

**Lug Properties**

- \( D = 0.19 \)
- \( A_b = D^2 \frac{\pi}{4} = 0.0304 \)
- \( t = 0.16 \)
- \( A_L = (W \cdot D) t = 0.0304 \)
- \( a = 0.19 \)
- \( a/D = 1.0 \)
- \( K_{bp} = 0.85 \)
- \( W = 0.38 \)
- \( W/D = 2.0 \)
- \( K_L = 0.90 \)

**Lug Allowables**

**Material: AISI 304 Stainless Steel**

- \( F_{eu} = 75 \text{ ksi} \)
- \( F_{tu} = K_L A_L F_{eu} = 0.90(0.0304)(75000) = 2050 \text{ lb} \)

**Tension**

\( M.S. = \frac{P_{tu}}{K_{bp} A_b F_{eu}} = \frac{2050}{0.85(0.0304)} = 2.57 \)

**Shear Bearing**

\( M.S. = \frac{P_{br} \cdot 1}{1.15 P_{tu}} \)

**References**

1. Friction neglected
2. Ref. Page 25
3. Ref. No. 3, Section 2.3
4. Fitting factor
FINAL ANALYSIS  LRRZ - 300

KEEPER ASSY

LOAD

\[ P_{\text{bearing}} = 499 \text{ lb} \]

BEARING PROPERTIES

Bolt Dia = 0.1875
Leg Wall Thickness, \( t = 0.16 \)
\( A_b = D_t = 0.030 \)

BEARING STRESSES  MAT\# A132 304 STAINLESS STEEL

\[ F_{\text{br}} = 50 \text{ ksi} \]
\[ \frac{f}{f_{br}} = \frac{499}{0.03} = 16.6 \text{ ksi} \]

M.S. = \( \frac{F_{\text{br}}}{1.5 f_{br}} \) = 41.01

\( \square \) BEARING FACTOR
\( \Box \) REF. PAGE 54
FINAL ANALYSIS LRRR-300

BOLT, ATTACH KEEPER ASSY TO LEG ASSY

LOAD AND MOMENT

\[ R_B = 499 \text{ lbf} \]

B.M. = 1.16 \[ R_B = 79.8 \text{ in-lbf} \]

BOLT PROPERTIES

\[ \text{Dia} = 0.1875 \]
\[ A = 0.02761 \]
\[ I = 0.000061 \]
\[ J_c = 0.00045 \]
\[ d/l = 2.0 \]

STRESSES

MAT' L NAS 1003 BOLT \[ F_u = 140 \text{ ksi} \]

SHRINK FACE

\[ F_{sv} = 87 \text{ ksi} \]
\[ f_s = \frac{499}{0.02761} = 18.1 \text{ ksi} \]

\[ M.S. = \frac{F_{sv}}{f_s} - 1 = 3.80 \]

BENDING CHECK

\[ F_b = 236 \text{ ksi} \]
\[ f_b = \frac{79.8}{0.00045} = 173 \text{ ksi} \]

\[ M.S. = \frac{F_b}{1.15f_b} - 1 = 4.67 \]

1. REF. PAGE 54
2. FITTING FACTOR
3. REF. NO. 3, PAGE 3.11-12
Final Analysis  LRRZ - 300

CLEVIS, FRONT BRACE

LUG ANALYSIS

1. CLEVIS LOAD, \( P_{\text{clevis}} = 480 \text{ lb} \)
2. \( P_{\text{lug}} = 480 \) \( P_{\text{clevis}} = 288 \text{ lb} \)
3. \( P_{\text{Axial}} = P_{\text{lug}} \sin 45^\circ = 23 \text{ lb} \)
4. \( P_{\text{Trans}} = P_{\text{lug}} \cos 45^\circ = 288 \text{ lb} \)

LUG PROPERTIES

- \( D = 0.19 \)
- \( A_B = D^2 - 0.019 \)
- \( t = 0.10 \)
- \( A_L = (W - D) t = 0.031 \)
- \( G = 0.25 \)
- \( q = 1.32 \)
- \( K_{br} = 1.02 \)
- \( D = 0.50 \)
- \( W_D = 2.44 \)
- \( K_L = 0.93 \)
- \( R = 0.95 \)
- \( E = 0.12 = 1.55 \)
- \( R/E = 0.61 \)
- \( \Theta = 20^\circ \)
- \( K_1 = 1.11 \)

\[ A_{BV} = K_{br} \frac{1.11 (1.55)}{0.19} = 1.90 \]

LUG ALLOWABLES  MAT'L: 2024-7351 AL. ALLOY  \( F_{LU} = 62 \text{ kips} \)

TENSION

\[ P_{LU} = K_{br} A_B F_{LU} = 93 (0.019) 62000 = 1780 \text{ lb} \]

SHEAR-BEARING

\[ P_{bru} = K_{br} A_B F_{LU} = 1.02 (0.19) 62000 = 1280 \text{ lb} \]

TRANSVERSE

\[ P_{tu} = K_{tu} A_B F_{LU} = 0.51 (0.019) 62000 = 600 \text{ lb} \]

\[ U = \left( \frac{P}{P_{LU} / 2} \right)^{1/2.4} = 0.482 \]

M.S. = \( \frac{1}{U} \)

FITTING FACTOR

REF. NO. 3, SECTION 2.3
60-40 LOAD DISTRIBUTION ASSUMED
REF. PAGE 26  TENSION CONSERVATIVELY ASSUMED
FINAL ANALYSIS

CLEVIS, FRONT PIVOT STRUCTURE

LUG ANALYSIS

1. CLEVIS LOAD, \( P_{\text{EXT}} = 480 \) lbs
2. \( P_{\text{LUG}} = 0.60 \cdot P_{\text{EXT}} = 288 \) lbs
3. \( P_{\text{AXIAL}} = P_{\text{LUG}} \sin 32^\circ = 153 \) lbs
4. \( P_{\text{TRANS}} = P_{\text{LUG}} \cos 32^\circ = 244 \) lbs

LUG PROPERTIES

- \( D = 0.19 \)
- \( \frac{A_{\text{br}}}{A_{\ell}} = \frac{D - t}{t} = 0.19 \)
- \( t = 0.10 \)
- \( A_{\ell} = (w - d) \cdot t = 0.31 \)
- \( \alpha = 0.25 \)
- \( a/d = 1.32 \)
- \( K_{\ell} = 1.02 \)
- \( \omega = 0.50 \)
- \( w/d = 2.44 \)
- \( K_{\ell} = 0.93 \)
- \( \gamma = 0.095 \)
- \( e = a - \gamma = 0.155 \)
- \( K_{\omega} = 0.61 \)
- \( \theta = 0^\circ \)
- \( K_{\ell} = 1.11 \)
- \( K_{\omega} = 0.51 \)

LUG ALLOWABLES

- MATL: 2024-T351 AL. ALLOY
- \( F_{\ell} = 62 \) KSI

TENSION

- \( P_{\ell} = K_{\ell} A_{\ell} F_{\ell} = 0.93 \cdot 0.31 \cdot 62000 = 1780 \) lbs

SHEAR/BENDING

- \( P_{\text{BEND}} = K_{\ell} A_{\ell} F_{\ell} = 1.02 \cdot 0.19 \cdot 62000 = 1200 \) lbs
- \( R_{A} = 128 \)

TRANSVERSE

- \( P_{\text{TRANS}} = K_{\omega} A_{\text{br}} F_{\ell} = 0.51 \cdot 0.19 \cdot 62000 = 400 \) lbs
- \( R_{U} = 0.407 \)

\[ U = \left( R_{A} 1.6 + R_{U} 1.6 \right)^{1/6} = 4.46 \]

M.S. = \[ \frac{1}{1.15U} - 1 = 4.95 \]

\[ k_{\text{BR}} \text{ PAGE 25} \]
Final Analysis LRRR-300
Pivot Pin, Front

Load & Moment

1. \( P_{BC} \) = 480 lbf
2. \( \frac{.60 P_{BC}}{P_{BC}} = 288 \) lbf

B.M. = \( 14 \times (288) = 40.3 \) in-lb

Pin Properties

Pin Dia = .1875
\( A = .02761 \), \( I = .000061 \), \( I_C = .000045 \), \( d = 2.0 \)

Stresses

Material: AISI 304 Stainless Steel \( F_b = 75 \) ksi

Shear Check

\( F_{su} = 40 \) ksi
\( f_s = \frac{288}{.02761} = 10.45 \) ksi
\( M.S. = \frac{F_s}{f_s} = 1 = 72.83 \)

Bending Check

\( F_b = 124 \) ksi
\( f_b = \frac{40.3}{.000045} = 62.0 \) ksi
\( M.S. = \frac{F_b}{f_b} = 1 = 1.15 \)

3. Fitting Factor
2. Assume Clevis shifted to one side 60% of \( P_{BC} \) load on most separated set of Clevis
1. Ref Page 25
Lug Analysis

Assumptions:
1. Small array weight = 30 lbf
2. Bracket sees no load in the x-direction
3. Equal load distribution on the tie down brackets and hinges (y and z-directions).

Lug Loads

Small array force at 30 g's

\[ P = 30 \times 30 = 900 \text{ lbf} \]

Bracket load = 0.25(900) = 225 lbf

\[ P_{\text{bracket}} = 225 \text{ lbf} \]

60-40 distribution between lugs:

\[ P_{\text{lug}, 1} = 0.60(225) = 135 \text{ lbf} \]

\[ P_{\text{lug}, 2} = 0.40(225) = 90 \text{ lbf} \]

Lug Properties

\[ D = 0.25 \text{ in} \]
\[ t = 0.04 \text{ in} \]
\[ A_{\text{br}} = Dt = 0.01 \text{ in}^2 \]
\[ A_{\ell} = (\pi - 0.5236) \times t = 0.02 \text{ in}^2 \]
\[ a = 0.38 \text{ in} \]
\[ \alpha/\theta = 1.52 \]
\[ K_{\text{br}} = 1.08 \]
\[ W = 76 \text{ in} \]
\[ W_{\ell} = 3.04 \text{ in} \]
\[ K_{\ell} = 0.92 \]
\[ R = 1.25 \text{ in} \]
\[ \ell = a - R = 0.25 \text{ in} \]
\[ \theta = 0^\circ \]
\[ R_{\ell} = 0.50 \text{ in} \]
\[ K_{\ell} = 1.095 \]
\[ A_{\text{l}} = K_{\text{l}} = 1.095 \]
\[ K_{\text{ew}} = 0.52 \]

Lug Allowables

Matl: 2024-T351 Al Alloy \( F_{\text{ul}} = 62 \text{ ksi} \)

Tension

\[ P_{\text{tu}} = K_{\ell} A_{\ell} F_{\text{ul}} = 0.92(0.02) \times 62000 = 1140 \text{ lbf} \]

Singe-bearing

\[ P_{\text{br}} = K_{\text{br}} A_{\text{br}} F_{\text{ul}} = 1.08(0.01) \times 62000 = 670 \text{ lbf} \]

\[ M.S. = \frac{P_{\text{br}}}{1.15 P_{\text{e}}} = 1 \pm 3.31 \]

Transverse

\[ P_{\text{tr}} = K_{\ell} A_{\text{l}} F_{\text{ul}} = 0.52(0.01) \times 62000 = 322 \text{ lbf} \]

\[ M.S. = \frac{P_{\text{tr}}}{1.15 P_{\text{e}}} = 1 \pm 1.07 \]

Fitting Factor

Ref. No. 3, Section 2.3

Acting separately

This thickness assumed for total tension.
**Final Analysis**

**LR3R-300**

**Bracket, Rear Tie-Down - Large Array**

**Socket Analysis**

For assumptions, refer page 88

Rear Support Rod Reaction:

\[ P_{R.S.E} = 51.4 \text{ 165} \]

**Socket Load**

\[ V_1 = \frac{P (d + 4_t)}{L - L_{br}} + \frac{P}{2} \]

\[ = \frac{51.4 (5.29)}{.69} + \frac{51.4}{2} \]

\[ = 419 \text{ 165} \]

**Socket Properties**

\[ D = .368 \quad L/D = 2.55 \]

\[ L = .94 \quad L_{br} = .24 \quad L_{br} = .226 \]

\[ t = .01 \quad a = .31 \quad a/d = .84 \quad C_u = .67 \]

**Socket Allowables**

\[ \text{Mat'2: 7024-7351 Al Alloy} \quad E = 62 \text{Ksi} \]

\[ V_U = C_u D L_{br} F_u \]

\[ = .67 (.368) .226 (62000) \]

\[ = 3460 \text{ 165} \]

\[ M.S. = \frac{V_u}{1.15 V_1} = 1 + .19 \]

---

1. Ref. No. 3, Section 2.60
2. Based on \( a/d = 1.75 \)
3. Fitting Factor
Final Analysis: LRRZ-300

Bolt Pattern - Rear Tie Down Bracket to Large Array Analysis

Loads

1. Direct Force on Bolts:
   \[ F = \frac{225}{4} = 56.3 \text{ lbs} \]
   
   Constant of Proportionality of Bolt Pattern, \( K \):
   \[ K = \frac{1.54(225)}{4(0.58)^2} = 257 \]

   Moment Force on Bolts:
   \[ F_m = K \cdot 257 \cdot 0.58 = 149 \text{ lbs} \]

   Maximum Force at Bolt (A):
   \[ F_{\text{Bolt}} = F + F_m = 205.3 \text{ lbs} \]

Bolt Designation

A 3 CRES Bolt

Ult. Tensile Strength = 2210 lbs
YLD. Tensile Strength = 1690 lbs
Single Shear Strength = 225 lbs

Bolt Margin of Safety

\[ M.S. = \frac{225}{205.3} - 1 = 4.35 \]

3. Conservatively assume loads acting in line.
2. Ref. No. 5, Page 239
1. Ref. Page 60
**FINAL ANALYSIS LRRR-300**

**BRACKET, HANDLE R.H.**

**LUG ANALYSIS - TIE DOWN LUG**

**COND. 1**

**ASSUMPTIONS:**

1. SMALL ARRAY WEIGHT ≤ 30 lb.
2. EQUAL LOAD DISTRIBUTION ON HANDLE BRACKET & MOUNTS IN THE X-DIRECTION.
3. EQUAL LOAD DISTRIBUTION ON BOTH BRACKETS & MOUNTS IN THE Y & Z DIRECTIONS.

**LUG LOADS**

**SMALL ARRAY FORCE:**

\[ P = 30 \times 30 = 900 \text{ lb} \]

TOTAL Bracket Lug Load:

\[ P_{BRKT} = 25 \times 900 = 225 \text{ lb} \]

60-40 DISTRIBUTION BETWEEN LUGS:

\[ P_{LU1} = 135 \text{ lb} \]

\[ P_{LU2} = 135 \text{ lb} \]

**LUG PROPERTIES:**

- \( D = 1.9 \) in.
- \( t = 0.0228 \) in.
- \( A_t = (W-D)\times t = 0.0684 \) in.
- \( a = 0.38 \) in.
- \( b = 2.0 \) in.
- \( K_{1} = 1.14 \)
- \( K_{2} = 1.29 \)
- \( W = 4.0 \) in.

**LUG ALLOWANCES**

MAP 2: 6061-T651 AL. ALLOY \( F_{LU} = 42 \text{ KSI} \)

**TENSION**

\[ P_{LU} = K_{LU} A_{LU} F_{LU} = 0.24 (0.0684) (0.20) = 0.33 \text{ lb} \]

**Fitting Factor**

\[ M.S. = \frac{P_{LU}}{F_{LU}} - 1 = 4.37 \]

**SHEAR BEARINGS**

\[ P_{BU} = K_{BU} A_{LU} F_{LU} = 0.14 (0.20) = 0.03 \text{ lb} \]

**TRANSVERSE**

\[ P_{BU} = K_{BU} A_{LU} F_{BU} = 1.34 (0.20) = 0.32 \text{ lb} \]

**FITTING FACTOR**

\[ M.S. = \frac{P_{BU}}{1.15 P_{LU}} - 1 = 1.09 \]

**REFERENCES**

3. Ref. No. 3, Section 2.30
1. Acting Separately.
FINAL ANALYSIS LRRR-300

BRACKET, HANDLE R.H.

SECTION A-A

1. LOADS AND MOMENTS

\[ P_{BKT} = \frac{900}{3} = 300 \text{ lbs} \]

\[ P_{BKT} = \frac{900 (1.38)}{22.25} = 56 \text{ lbs} \]

SECTION LOADS & MOMENTS

SHEAR = \left[ P_{BKT}^2 + (P_{BKT} \sin 45^\circ)^2 \right]^{\frac{1}{2}}

\[ = 303 \text{ lbs} \]

COMP. = \frac{P_{BKT} \cos 45^\circ}{22.25} = 39.6 \text{ lbs} \]

\[ M_{x,A-A} = 1.10 \frac{P_{BKT} \sin 45^\circ}{22.25} = 43.5 \text{ in.-lbs} \]

\[ M_{y,A-A} = 1.10 \frac{P_{BKT} \sin 45^\circ}{22.25} = 43.5 \text{ in.-lbs} \]

SECTION PROPERTIES

\[ A = 1.12 (1.19) = 1.31 \text{ in.}^2 \]

\[ I_x = \frac{1.12 (1.19)^3}{12} = 1.022 \text{ in.}^4 \]

\[ I_y = \frac{1.12 (1.19)^3}{12} = 0.0063 \text{ in.}^4 \]

\[ I_{xc} = 0.0386 \text{ in.}^4 \]

\[ K_x = 1.5 \]

\[ K_y = 1.5 \]

STRESSES

\[ F_{by} = 1.45 \frac{330}{0.0066} = 61 \text{ ksi} \]

\[ f_{by} = \frac{330}{0.0066} = 50 \text{ ksi} \]

\[ R_{by} = 0.820 \]

\[ F_{bx} = 61 \text{ ksi} \]

\[ f_{bx} = \frac{43.5}{0.0396} = 1.10 \text{ ksi} \]

\[ R_{bx} = 0.018 \]

\[ F_{cy} = 35 \text{ ksi} \]

\[ f_{c} = \frac{39.6}{2/3} = 1.186 \text{ ksi} \]

\[ R_{c} = 0.005 \]

\[ F_{su} = 27 \text{ ksi} \]

\[ f_{s} = \frac{30.3}{2/3} = 1.42 \text{ ksi} \]

\[ R_{s} = 0.053 \]

\[ U = \left[ (R_{by} + R_{bx} + R_{c} + R_{s})^2 + R_{s}^2 \right]^{\frac{1}{2}} = 0.845 \]

M.S. = \frac{1}{1} = 1 = 1.18

REF. NO. 3, HAGE 3, 3.01-3

REF. HAGE 63
FINAL ANALYSIS  LRRZ-300
BRACKET, HANDLE & H.
Dwg. 2347241

SECTION B-B

1. LOADS AND MOMENTS

\[ \text{SHEAR} = \left( P_{\text{BKT}}^2 + (1.60 P_{\text{BKT}} \sin 45^\circ)^2 \right)^{\frac{1}{2}} = 301.16 \]

\[ \text{COMP.} = 1.60 P_{\text{BKT}} \cos 45^\circ = 24.16 \]

\[ M_{N-B} = 0.44 P_{\text{BKT}} = 134 \text{ in.-lb} \]

\[ M_{A-A} = 0.44 (1.60 P_{\text{BKT}} \sin 45^\circ) = 10.6 \text{ in.-lb} \]

SECTION PROPERTIES

\[ A = 0.13 (0.90) = 0.117 \]

\[ I_x = \frac{13 (9.0)^2}{12} = 0.0079 \quad I_x/6 = 0.0175 \quad K_y = 1.5 \]

\[ I_y = \frac{9.0 (13)^2}{12} = 0.00126 \quad I_y/6 = 0.00246 \quad K_y = 3.5 \]

STRESSES

\[ M_{N-B} = 12 \text{ kips} \]

\[ F_{N-B} = 61 \text{ kips} \quad f_{by} = \frac{134}{0.0246} = 54.5 \text{ kpsi} \quad R_y = 0.892 \]

\[ F_{Bx} = 61 \text{ kips} \quad f_{bx} = \frac{10.6}{0.0175} = 902 \text{ kpsi} \quad R_y = 0.175 \]

\[ F_{Cy} = 35 \text{ kips} \quad f_c = \frac{24}{0.117} = 205 \text{ kpsi} \quad R_y = 0.006 \]

\[ F_{SU} = 27 \text{ kips} \quad f_s = \frac{301}{0.117} = 2.61 \text{ kpsi} \quad R_y = 0.104 \]

\[ U = \left[ \left( \frac{R_y + R_{bx} + R_c}{R_y} \right)^2 + R_s^2 \right]^{\frac{1}{2}} = 0.42 \]

\[ M.S. = \frac{1}{U} - 1 = 4.08 \]
FINAL ANALYSIS LRRZ-300

BRACKET, HANDLE R.H.

DWG. 2347241

SECTION C-C

1. LOADS AND MOMENTS

\[ \text{SHEAR} = 0.60 P_{\text{EXT}} = 33.6 \text{ in-lb} \]

\[ \text{TENSION} = P_{\text{EXT}} = 300 \text{ in-lb} \]

\[ M_{x\text{cc}} = 0.53 (0.60 P_{\text{EXT}} \sin 45^\circ) = 12.6 \text{ in-lb} \]

\[ M_{y\text{cc}} = 0.53 P_{\text{EXT}} + 1.16 (0.60 P_{\text{EXT}} \cos 45^\circ) = 163 \text{ in-lb} \]

\[ M_{z\text{cc}} = 1.16 (0.60 P_{\text{EXT}} \sin 45^\circ) = 6.0 \text{ in-lb} \] (NEGLECT)

2. SECTION PROPERTIES

\[ A = 0.18 (0.90) = 0.162 \]

\[ I_y = \frac{0.90 (0.18)^3}{12} = 0.00043 \]

\[ I_z = 0.0048 \quad K_y' = 1.5 \]

3. CALCULATED SANDING VOLUME:

\[ \text{Vol} = \frac{b^2 (3 a - b)}{12} = \frac{(1.8)^2 (3(0.9) - 1.8)}{12} = 0.0068 \text{ in}^3 \]

4. STRESSES

\[ \text{MATERIAL: GO61-T651 AL. ALLOY} \quad f_y = 42 \text{ ksi} \]

\[ f_y = 61 \text{ ksi} \quad f_y = \frac{163}{0.0048} = 34 \text{ ksi} \quad R_{by} = 0.557 \]

\[ f_y = 42 \text{ ksi} \quad f_y = \frac{300}{0.162} = 185 \text{ ksi} \quad R_{by} = 0.444 \]

\[ f_y = 27 \text{ ksi} \quad f_y = \frac{33.6}{0.162} = 208 \text{ ksi} \quad R_{by} = 0.088 \]

\[ \tau_{\text{all}} = 2 V f_{y} \]

\[ = 2(0.0068) 27000 = 367 \text{ in-lb} \quad M_{x\text{cc}} = 12.6 \text{ in-lb} \quad R_{fy} = 0.034 \]

\[ U = \left[ \left( R_{by} + R_{fy} \right)^2 + \left( R_{by} + R_{fy} \right) \right]^{\frac{1}{2}} = 0.032 \]

\[ M.S. = \frac{1}{U} = 46 \]

\[ \text{REF NO. 3, PAGE 240-1} \]

\[ \text{REF PAGE 64} \]
SECTION 'D-D' LOADS AND MOMENTS

1. \[ W = 2(100) = 200 \text{ lb} \]
2. \[ M_{D-D} = \frac{W l}{8} = \frac{200(6.38)}{8} = 159.5 \text{ in-lb} \]
   Tension = \( \frac{W}{2} = 100 \text{ lb} \)

SECTION PROPERTIES

\[ A = 2(.43) .06 + 2(1.19) .06 = .0744 \]
\[ A_{y} = .0516 (.25) + .0228 (.05) = .0118 \]
\[ \gamma = \frac{A_{y}}{A} = .16 \]
\[ I_{P} = 2 \left[ .06 (93.9)^3 + .0516 (0.55)^2 + .19 (06)^2 + .0228 (12)^2 \right] = 0.0087 \]
\[ I_{Pc} = \frac{.0087}{.16} = .0117 \]
\[ Q_{2} = .12 (.27)^2 = .0044 \]
\[ K_{e} = \frac{2Q_{2}}{I_{Pc}} = \frac{2(.0044)}{.0117} = .75 \text{ USE 1.0} \]

STRESSES

M40: .6001 Ti6Al-4V AL. ALLOY

\[ f_{b} = \frac{159.5}{.0117} = 13420 \text{ psi} \]
\[ f_{t} = \frac{100}{.0744} = 1350 \text{ psi} \]

\[ M.S. = \frac{f_{t} - 1}{f_{b} + f_{t}} = \frac{17000}{14970} - 1 = .13 \]

REFERENCES

1. Ref. Page 72
2. Ref. No. 4, Table III, Case 31
3. Reduced Ref. Near Mid of Well, Ref. Page 76
FINAL ANALYSIS LRRK-300

SECTION A-A

LOADS & MOMENTS

Astronaut force (ult.) = 45 1/8

Conservatively assume the handle transfers no load to the right hand bracket and section A-A resists the total torque induced by 45% astronaut force being applied at the U.M.T. handle:

\[ T = 27.12 \times (45) = 1220 \text{ 1/8} \]

Assume the torque is taken out as flange shear with no help from the web:

\[ P_{\text{flange shear}} = \frac{1220}{2.44} + \frac{45}{2} = 523 \text{ 1/8} \]
FINAL ANALYSIS--LRR-300
BRACKET, HANDLE--L.H.

SECTION A-A (CONT'D)

SECTION PROPERTIES

\[ A_{\text{FLANGE}} = 0.06 (1.50) = 0.03 \]

STRESSES

\[ \text{MAT' L: G061-T65} \]

\[ F_{u} = 42 \text{ KSI} \]

\[ F_{s} = 27 \text{ KSI} \]

\[ \sigma = \frac{523}{0.8} = 17.5 \text{ KSI} \]

\[ M.S. = \frac{F_{u}}{F_{s}} - 1 = 4.54 \]
FINAL ANALYSIS LRRZ-300

BRACKET, HANDLE L.H.

BEARING CHECK

LOAD AT ADJUSTMENT HOLE

\[ P_{br} = \frac{127.0}{1.25} = 975 \text{ lbs} \]

BEARING PROPERTIES

\[ d = 0.188 \]
\[ t = 0.19 \]
\[ d_{cr} = D_t = 0.188(0.19) = 0.0357 \]

BEARING STRESS

\[ M.S. = \frac{F_{br}}{1.5t_{cr}} = 7.22 \]

\[ t_{cr} = \frac{975}{0.0357} = 27.3 \text{ KSI} \]

\[ F_{br} = 50 \text{ KSI} \]

MAT L: 6061 - T651  \[ F_{u} = 42 \text{ KSI} \]

ADJUSTMENT PIN AGAINST BRACKET

CONC. 2

1. BEARING LOCUS
2. BEARING FACTOR

REF: PAGE 68
FINAL ANALYSIS LRRZ-300

ADJUSTMENT PIN - BRACKET, HANDLE L.H. & TOOL SOCKET

LOADS

1. SHEAR LOAD = 975 lbf

PIN DESIGNATION

AN 3 CHES BOLT

BOLT ALLOWABLES

SINGE SHEAR LOAD = 2125 lbf

M.S. = $\frac{2125}{975} - 1 = 1.18$

PIVOT PIN

LOADS

1. SHEAR LOAD = 975 + 45 = 1020 lbf

PIN DESIGNATION

AN 4 CHES BOLT

BOLT ALLOWABLES

SINGE SHEAR LOAD = 3680 lbf

M.S. = $\frac{3680}{1020} - 1 = 2.61$

(1) REFER PAGE 70
FINAL ANALYSIS LRRR-300

HANDLE

SECTION E-E

LOADS & MOMENTS

1. \[ W = 2 \times 100 = 200 \]

2. \[ M_{E.E} = \frac{W \cdot L}{8} = \frac{200 \times 6.38}{8} = 159.5 \text{ in.-ft} \]

SWAY BAR: \[ \frac{W}{2} = 100 \times 1.45 \]

SECTION PROPERTIES

\[ A = 0.50 (1.25) - 1.062 (3.125) = 0.294 \]

\[ I_z = \frac{1.25 (0.50)^3 - 1.062 (3.125)^3}{12} = 0.0103 \]

\[ I_{EC} = 0.0412 \]

\[ Q_z = \frac{1.25 (0.75)^2 - 1.062 (2.062)^2}{2} = 0.0262 \]

\[ K_z = \frac{2.062}{0.412} = 4.99 \]

STRESSES

MATERIAL: 6061-T6 ALUMINUM \[ \sigma_0 = 24 \text{ ksi} \]

\[ \sigma_0 = 29.8 \text{ ksi} \]

\[ \sigma_5 = \frac{159.5}{0.0412} = 3.87 \text{ ksi} \]

\[ R_b = 0.130 \]

\[ R_s = 0.022 \]

\[ U = \left[ 2 \left( \sigma_0^2 + \sigma_b^2 \right) \right]^{1/2} = 1.32 \]

\[ M.S. = \frac{1}{U} - 1 = \text{Ample} \]

3. REDUCE ACCURACY DUE TO SUSPICION. SEE PAGE 76.

2. REF. NO. 4, TABLE III, CASE 31

1. WEIGHT OF LRRR-300 ASSUMED TO BE 100 LBS.
FINAL ANALYSIS LRRR-300

TOOL SOCKET, ADJUSTABLE

Dwg. 2347242

SOCKET ANALYSIS

The socket configuration is identical to the socket used on LRRK. Since the loads are the same, this analysis for the socket that is included in Report ATM 871 covers the socket to be used on the LRRR-500. Therefore, no further analysis was deemed necessary.

BEARING CHECK

ADJUSTMENT PIN AGAINST TOOL SOCKET

BEARING LOAD

1. \( P_{br} = 975 \text{ lbs} \)

BEARING PROPERTIES

PIN DIA = 0.188
\( T = 0.12 \)
\( A_{br} = D T = 0.188 \times 0.12 = 0.0226 \)

BEARING STRESSES

MATERIAL: 17-4 PH STAINLESS STEEL
\( F_{tu} = 190 \text{ KSI} \)

\( S_{br} = \frac{975}{0.0226} = 43.10 \text{ KSI} \)

M.S. = \( \frac{F_{br}}{1.5 S_{br}} = 1 \)

BEARING FACTOR

1. KES: HAGI-70
**Final Analysis - LERR-300**

**Bracket, FWD Tie Down - Small Array**

**Dwg. 2547237**

**Cond. 1**

**Lug Analysis - Lug A**

**Lug Load:** \( P_{lug} = P_a = \frac{P_e}{E} = 225 \text{ lbs} \)

**Lug Properties:**

\[
\begin{align*}
A & = 0.38 \\
A_D & = 1.52 \\
D & = 2.5 \\
\varepsilon & = 0.186 \\
W & = 0.76 \\
W_D & = 3.00 \\
K_\theta & = 1.08 \\
\theta & = 15^\circ \\
\tau & = 0.125 \\
E & = 2.55 \\
\rho & = 0.49 \\
K_i & = 1.085 \\
A & = \frac{K_i E}{2k} \\
M & = \frac{Dk}{0.0465} \\
K & = (W-D) \varepsilon = 0.093 \\
k & = 0.53
\end{align*}
\]

**Lug Allowables**

**Material:** Al. Alloy 6061-T651

**Tension**

\[
P_{tu} = 1.15 P_e = 1.15(24000) = 27000 \text{ lbs}
\]

**Sneak Bearing**

\[
P_{tu} = K_a A_k P_e = 1.08(24000) = 26000 \text{ lbs}
\]

**Transverse**

\[
P_{tu} = K_a A_k P_e = 0.53(24000) = 12900 \text{ lbs}
\]

**M.S.**

\[
\text{M.S.} = \frac{P_{tu}}{1.15} = 23000 \text{ lbs}
\]

**Fitting Factor**

\[
\text{Fitting Factor} = 1 + 0.025
\]

**Ref. Page 600**

**Ref. No. 3, Section 2.6**

**Acting Separately**
FINAL ANALYSIS LRRIC-300

BRACKET, FWD TIE DOWN - SMALL ARRAY

Dwg. 2347237

SECTION A-A

1 LOADS AND MOMENTS

\[ P_{X\text{BKT}} = 300 \text{ 1bs} \]
\[ P_{Z\text{BKT}} = 54 \text{ 1bs} \]
\[ \text{SHEAR} = \left[ P_{X\text{BKT}} - \left( P_{Z\text{BKT}} \sin 15^\circ \right) \right]^{1/2} = 300 \text{ 1bs} \]
\[ \text{COMP} = P_{Z\text{BKT}} \cos 15^\circ = 54.1 \text{ 1bs} \]
\[ M_{4A} = 40 P_{Z\text{BKT}} = 120 \text{ in-1bs} \]
\[ M_{6A} = 40 \left( P_{Z\text{BKT}} \sin 15^\circ \right) = 5.8 \text{ in-1bs} \]

SECTION PROPERTIES

\[ A = 0.186 (94) = 0.174 \]
\[ I_x = \frac{0.186 (94)^3}{12} = 0.0129 \]
\[ I_{I/C} = 0.0274 \]
\[ K_x = 1.5 \]
\[ I_y = 0.0058 \]
\[ I_{I/C} = 0.0054 \]
\[ K_y = 1.5 \]

STRESSES

MAT'L 6061-T651 AL. ALLOY \( F_{yu} = 42 \text{ KSI} \)

2 AS WELDED \( F_{yu} = 24 \text{ KSI} \) \( F_{uy} = 17 \text{ KSI} \)

\( F_{uy} = 1.45 F_{yu} = 61 \text{ KSI} \)
\( f_{uy} = \frac{120}{0.0054} = 22.2 \text{ KSI} \)
\( R_{by} = 0.364 \)
\( F_{ox} = 61 \text{ KSI} \)
\( f_{ox} = \frac{5.8}{0.0274} = 0.21 \text{ KSI} \)
\( R_{bx} = 0.004 \)
\( F_{cy} = 35 \left( \frac{12}{35} \right) = 17 \text{ KSI} \)
\( f_c = \frac{54.1}{0.174} = 0.31 \text{ KSI} \)
\( R_c = 0.018 \)
\( F_s = \frac{24}{13} = 18.8 \text{ KSI} \)
\( f_s = \frac{300}{0.174} = 1.73 \text{ KSI} \)
\( R_s = 0.125 \)

\[ U = \left[ \left( R_{by} + F_{by} + R_c \right)^2 + R_s^2 \right]^{1/2} = 4.06 \]
\[ \text{M.S.} = \frac{1}{1} = 1.46 \]
FINAL ANALYSIS - LRRR-300

Bracket, FWD Tie Down - Small Array DWG. 2347237

SECTION 8-B

CONSERVATIVELY ASSUME SECTION SHAPE & LOCATION AS SHOWN

Loads & Moments on Section

\[ \begin{align*}
\text{Tension} & = 45 \text{ kips} \\
\text{Moment} & = 45 (1.09) = 49 \text{ in-kips}
\end{align*} \]

Section Properties

\[ A = .186 (1.00) = .186 \]
\[ I = \frac{1.00 (.186)^3}{12} = .00053 \]
\[ \frac{I}{c} = .0057 \]

Stresses

\[ \text{M.T.L.: Al. Alloy 6061-T651: } F_y = 42 \text{ kips} \]
\[ F_x = \frac{49.0}{.0057} = 8600 \text{ psi} \]
\[ F_c = \frac{45}{.186} = 242 \text{ psi} \]
\[ F_x' F_c = 8892 \text{ psi} \]

\[ F_y' \text{ of Al. Alloy (Parent Metal) Near WELD is } 24000 \text{ psi} \]
\[ F_y' \text{ of other Al. Alloy near WELD is } 17000 \text{ psi} \]

\[ M.S. = \frac{F_y}{F_x + F_c} - 1 = +.92 \]

PART WILL NOT YIELD UNDER ASTRONAUT HANDLING

\[ \text{REF No. 7, PAGE 18, TABLE 64.35} \]
FINAL ANALYSIS - LRRR-500

SECTION C-C - THRU HANDLE

Cond. 2

Moment = 1.0 (45.0) = 45.0 in.-lbs

Section Properties

\[ \begin{align*}
D_C &= 0.75 \\
A &= 0.079 \\
I_C &= 0.005 \\
I_D &= 0.035 \\
D_H &= 21.4 \\
F_b / F_y &= 1.80
\end{align*} \]

Stresses

\[ \begin{align*}
F_b &= 1.8 F_y \\
F_b &= \frac{45.0}{0.0133} = 3380 \text{ psi} \\
F_b &= 0.78
\end{align*} \]

\[ \begin{align*}
F_{sv} &= 2700 \times \left( \frac{24}{42} \right) \\
F_s &= \frac{45.0}{0.079} = 570 \text{ psi} \\
F_s &= 0.086
\end{align*} \]

\[ M.S. = \frac{1}{U} = \text{AMPERE} \]

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\( \text{Ref. No. 2, Page 78} \)

\( \text{Ref. No. 3, Page 3.01-1} \)
FINAL ANALYSIS

BRACKET, FWD TIE DOWN - SMALL ARRAY

DREV 2547237

TEAR OUT AT BOLT HOLE

ASSUME BOLT HOLE ACTS AS A LUG WITH 352 IBS APPLIED
AS SHOWN

LUG LOADS

1. \[ F_{\text{bolt}} = 352 \text{ Ibs} \]
2. \[ F_a = F_{\text{bolt}} \cos 31^\circ = 302 \text{ Ibs} \]
3. \[ F_b = F_{\text{bolt}} \sin 31^\circ = 181 \text{ Ibs} \]

LUG PROPERTIES

\[ D = 0.19 \quad A_{br} = D^2 = 0.0152 \quad \theta = 45^\circ \text{ use } 30^\circ \]
\[ t = 0.08 \quad A_L = (\pi - 0.6) t = 0.034 \]
\[ a = 0.31 \quad A_D = 1.63 \quad K_{br} = 1.11 \]
\[ W = 0.62 \quad W_D = 3.26 \quad K_L = 0.89 \]
\[ R = 0.095 \quad E = a - R = 0.215 \quad R_{\text{le}} = 0.44 \quad K = 1.41 \]
\[ A_{\text{av}} = \frac{K_{\text{le}}}{2R} = \frac{1.41(0.215)}{0.19} = 1.59 \]

LUG ALLOWABLES

MAT' L: 6061-T651 AL. ALLOY \[ F_{\text{u}} = 42 \text{ KSI} \]
AS WELDED \[ F_{\text{w}} = 24 \text{ KSI} \]

TENSION

\[ F_{\text{w}} = K_{\text{le}} A_{\text{w}} F_{\text{u}} = 0.69(0.034)24000 = 570 \text{ Ibs} \]

SHEAR BEARING

\[ F_{\text{br}} = K_{\text{br}} A_{\text{br}} F_{\text{u}} = 1.11(0.0152)24000 = 405 \text{ Ibs} \]

TRANSVERSE

\[ F_r = \frac{F_b A_c}{A} = \frac{34800(0.0152)}{0.095} = 571 \text{ Ibs} \]

\[ T_r = 1.45 F_r = 34800 \text{ ft-lb} \]

\[ T_r = 571 \text{ ft-lb} \]

\[ T_{\text{le}} = 0.89 (34800)^{2} = 0.00156 \]

\[ F_{\text{le}} = 1.45 F_{\text{u}} = 34800 \text{ ft-lb} \]

\[ P_{\text{r}} = 0.716 \]

\[ M_S = \frac{1}{115} = 0.008 \]

\[ F_r = 11 = 4.89 \]

\[ 110 \left[ F_{\text{r}} + P_{\text{r}} \right] = 11 \]

\[ 0.65 U \]

\[ \text{(Refer to Section 23)} \]

\[ \text{Ref. No. 3, Page 79} \]

\[ \text{Ref. No. 7, Page 69, ARN 64.30} \]
FINAL ANALYSIS - LRRR-300

BOLT PATTERN ANALYSIS  - FORWARD TIIE DOWN BRACKET (2347257)
   TO SMALL ARRAY

LOADS

1. 
   \[ P_{\text{bracket lug}} = 225 \text{ lbs} \]

2. DIRECT FORCE ON BOLTS (A) and (B)
   \[ F = \frac{75(225)}{2} = 84.5 \text{ lbs} \]

3. CONSTANT OF PROPORTIONALITY OF BOLT PATTERN, \( K \):
   \[ K = \frac{1.52(169)}{2(1.375)^2} = 914 \]

MOMENT FORCE ON BOLTS:

3. \[ F_m = Kt = 914(1.375) = 342 \text{ lbs} \]

MAXIMUM FORCE ON BOLTS:

\[ F_{\text{bolt}} = (F^2 + F_m^2)^{1/2} = 352 \text{ lbs} \]

BOLT DESIGNATION

AN 3 CREB BOLT

BOLT MARGIN OF SAFETY

SINGLE SHEAR STRENGTH = 2125 lbs

\[ M.S. = \frac{2125}{352} - 1 = 4.504 \]

5. REF. No. 5, PAGE 63
6. CONSERVATIVELY ASSUME BOLT M.S. (5), MAX. 8% OF BOLTED LOAD
7. REF. PAGE 63
FINAL ANALYSIS  LRRR-300
BRACKET, REAR TIE DOWN - SMALL ARRAY  DWG. 234-723B

LUG ANALYSIS

ASSUMPTIONS:
1. SMALL ARRAY WEIGHT 30 lbs
2. BRACKET SEES NO LOAD IN THE X-DIRECTION
3. EQUAL LOAD DISTRIBUTION ON THE DOWN BRACKETS & HINGES (Y & Z-DIRECTIONS)

LUG LOADS

SMALL ARRAY FORCE AT 30 g's
P = 30 (30) = 900 lbs
BRACKET LOAD = .25 (900) = 225 lbs

\[ P_{\text{axial}} = P_{\text{transverse}} = P_{\text{bracket}} = 225 \text{ lbs} \]

LUG PROPERTIES

\[ D = .25 \quad a/d = 1.52 \]
\[ t = .10 \quad w/d = 3.01 \]
\[ a = .38 \quad A_{br} = Dt = .025 \quad K_{br} = 1.06 \]
\[ w = .76 \quad A_{l} = (w-d) t = .051 \quad K_{l} = .80 \]
\[ r = .125 \quad \theta = 0 \quad \theta = 0^\circ \]
\[ R_{l/E} = .49 \quad K_{l} = 1.09 \quad A_{av} = K_{E} E = 1.09 \quad K_{E} = .52 \]

ALLOWABLE LUG LOAD
MAT'L: 6061-T651 AL. ALLOY  \( F_{tu} = 42 \text{ KSI} \)

TENSION
\[ P_{tu} = K_{l} A_{l} F_{tu} = .80 (0.051) 42000 = 1710 \text{ lbs} \]

SHEAR - BENDING
\[ P_{br} = K_{br} A_{br} F_{tu} = 1.06 (0.025) 42000 = 1110 \text{ lbs} \]

TRANSVERSE
\[ P_{E} = K_{l/E} A_{E} F_{tu} = .52 (0.025) 42000 = 545 \text{ lbs} \]

M.S. = \[ \frac{P_{tu}}{1.15} + \frac{1}{1.04} \]

M.S. = \[ \frac{P_{br}}{1.15} + \frac{1}{1.04} \]

[1] FITTING FACTOR
[2] REF No. 3, SECTION 2.3

(1) \textit{Acting separately}
**FINAL ANALYSIS**

**BRACKET, REAR TIE DOWN - SMALL ARRAY**

**BEARING CHECK - AT BOLT HOLE (A)**

**ASSUMPTIONS:**
1. **BRACKET PIVOTS ABOUT BOLT (B)**
2. **BRACKET LVG LOAD TAKEN OUT AT BOLT (A)**
3. **BRACKET LOAD APPLIED AT LVG:**

   **REACTION AT (A)**
   \[ P_A = \frac{2.88(225)}{0.025} = 1040 \text{lbs} \]

   **BEARING LOAD AT (B)**
   \[ P_{AB} = P_A + 225 \cos 28.7 = 1040 + 197 = 1237 \text{lbs} \]

**BEARING PROPERTIES**

- **Dia = 0.188**
- **e = 0.10**
- **Aw = 0.0188**

**BEARING STRESS**

**MAT' L: 6061-T651 AL ALLOY**

\[ f_b = 42 \text{ ksi}, \]

\[ f_b = \frac{1237}{0.0188} = 65.8 \text{ ksi}, \]

\[ M.S. = \frac{F_{br}}{f_b} - 1 = +0.01 \]

---

3. NO BENDING FACTOR INCLUDED DUE TO CONSERVATIVE ASSUMPTIONS USED.

2. REF. PAGE 80

1. CONSERVATIVELY ASSUME NO HELP FROM BOLTS OF OTHER FLANGE.
FINAL ANALYSIS LRRR-300

BRACKET, REAR TIE DOWN - SMALL ARRAY

SECTION A-A

LOADS & MOMENTS

\[ P_{\text{Bracket}} = 225/16 \]

8.M. = 2.36 (225) = 530 in-lb

\[ \text{Shear} = \frac{P_{\text{Bracket}}}{2} = 225/16 \]

SECTION PROPERTIES

\[ A = 0.44 (10) + 106 (10) = 20 \]

\[ A_{y'} = 0.94 (0.05) + 1.06 (0.53) = 0.606 \]

\[ \frac{y'}{y} = \frac{A_{y'}}{A} = 30 \]

\[ I_x = \frac{0.44 (10)^3 + 0.044 (25)^2 + 0.10 (106)^3 + 0.106 (23)^2}{12} = 0.0215 \]

\[ I_{y/C} = 0.0283 \]

\[ Q_x = \frac{10 (76)^2}{2} = 0.289 \]

\[ K_x = \frac{2Q_x}{I_{y/C}} = 20 \]

STRESSES

MAT'1: 6061-T651 AL. ALLOY \( \sigma_u = 42 \) KSI

\[ F_b = \sigma_u = 42 \text{ KSI} \]

\[ f_b = \frac{530}{0.0283} = 18.7 \text{ KSI} \]

\[ R_b = 0.445 \]

\[ F_{sv} = 27 \text{ KSI} \]

\[ f_s = \frac{225}{0.20} = 1.13 \text{ KSI} \]

\[ R_s = 0.012 \]

\[ u = \left( R_b^2 + R_s^2 \right)^{1/2} = 0.450 \]

\[ M.S. = \frac{1}{1} + 1.22 \]

SHEAR CENTER OF SECTION UNDERWROD ZERO

REF PAGE 80
FINAL ANALYSIS  LRRR - 500

BOLT PATTERN - REAR TIE DOWN BRACKET TO SMALL ARRAY

ANALYSIS

LOAD (REF SKETCH PAGE 81 )                      Cond. 1

BOLT IN SHEAR :

CONSERVATIVELY ASSUME BOLT TAKES BEARING LOAD AT (B), \( P_{db} \), IN SHEAR.

\[
P_{shear} = P_{db} = 1237 \text{ lbf}
\]

BOLT IN TENSION :

ASSUME BRACKET PILOTS ABOUT BOLT (C) AND THE REACTION OF THE LUG LOAD IS TAKEN OUT BY BOLT (D) AS TENSION. NO HELP IS ASSUMED FROM BOLTS AT (A) & (B), LUG LOAD APPLIED IN Y-DIRECTION.

\[
P_{tension} = \frac{2.94 (225)}{.625} = 1060 \text{ lbf}
\]

BOLT PROPERTIES

A3 CRES BOLT \( F_u = 125 \text{ ksi} \)

ALLOWABLE BOLT LOADS

SHEAR

\[
P_{allowable} = 2125 \text{ lbf}  \quad P_{shear} = 1237 \text{ lbf}
\]

M.S. = 4.72

TENSION

\[
P_{allowable} = 2210 \text{ lbf}  \quad P_{tension} = 1060 \text{ lbf}
\]

M.S. = 4.04

(1) REF PAGE 81
**Final Analysis**

**Lug Analysis**

**Assumptions:**
Ref. Page 63

**Lug Loads**

**Hinge Load:**
- **P_{hinge} = 225 LBS**
- **60-40 Distribution**
- **Between Lugs:**
  - \( P_{l_1}/P_{l_2} = 135/165 \)

**Lug Properties**

- \( D = .19 \)
- \( t = .25 \)
- \( \alpha = .22 \)
- \( W = .44 \)
- \( \alpha/D = 1.16 \)
- \( K_z = .94 \)
- \( R = .045 \)
- \( E = 0.76 \)
- \( K_x = 1.14 \)
- \( A_{ax} = K_x E = .744 \)
- \( K_{p0} = .50 \)

**Lug Allowables**

**Material:** 2024-T351 Al. Alloy 
- **\( P_{lu} = 62 \) KSI**

**Tension**

\[ P_{lu} \times K_z A_{lu} P_{lu} = .94(0.0475)62000 = 2770 \text{ KBS} \]

\[ M_S = \frac{P_{lu}}{0.15 P_{lu}} = 1 \text{ AMPLE} \]

**Shear Bending**

\[ P_{sb} = K_x A_{sb} P_{lu} = .744(0.0475)62000 = 2300 \text{ KBS} \]

**Transverse**

\[ P_{tr} = K_x A_{tr} P_{lu} = .744(0.0475)62000 = 2300 \text{ KBS} \]

\[ M_S = \frac{P_{tr}}{0.15 P_{tr}} = 1 \text{ AMPLE} \]

---

**References**

- No. 3, Section 2.30

---

**Note:** This analysis covers the top hinge (234726C) also.
FINAL ANALYSIS LRRZ-300
HINGE, BOTTOM

SECTION A-A

1. LOADS AND MOMENTS

\[ P_{\text{Hinge}} = 300 \text{ lfs} \]

\[ M_{y_{AA}} = 0.42 \times P_{\text{Hinge}} = 126 \text{ in-lbs} \]

SECTION PROPERTIES

\[ A = 0.25 \times (4.4) = 1.11 \]

\[ I_{y1} = \frac{44 \times (25)^3}{12} = 0.00057 \]

\[ I_{y1/c} = 0.00456 \]

\[ K_y = 1.5 \]

\[ I_{x} = \frac{25 \times (4.4)^3}{12} = 0.00177 \]

\[ I_{c} = 0.00804 \]

\[ K_x = 1.5 \]

STRESSES

MAT'L: 2024-T351 AL. ALLOY \[ \bar{f}_0 = 62 \text{ ksi} \]

\[ f_x = \frac{F_x}{\bar{f}_0} = 62 \text{ ksi} \]

\[ f_2 = \frac{126}{0.00456} = 27.6 \text{ ksi} \]

\[ R_b = 0.445 \]

\[ F_x = 37 \text{ ksi} \]

\[ f_3 = \frac{300}{1.11} = 27.5 \text{ ksi} \]

\[ R_s = 0.074 \]

\[ U = (R_b^2 + R_s^2)^{1/2} = 0.451 \]

\[ M.S. = \frac{1 - 1}{2J} = 4.72 \]

1. REF. PAGE 63
FINAL ANALYSIS LRRZ-300

PIN, HINGE

LOADS AND MOMENTS

1. \( P_{\text{hinge}} = 225 \text{ lbs} \)
   \( P_{\text{lug}} = 100 \text{ lbs} \)
   \( B.M. = 26 \text{ lbs} \cdot \text{in} \)

PIN PROPERTIES

\( DIA = 0.1875 \text{ in} \)
\( A = 0.0276 \text{ in}^2 \)
\( I = 0.00065 \text{ in}^4 \)
\( F_c = 0.00065 \)
\( d/c = 2.0 \)

STRESSES

MAT'L: AISI 304 STAINLESS STEEL \( F_t = 75 \text{ ksi} \)

SHEAR FACE

\( F_s = 40 \text{ ksi} \)
\( t_s = \frac{135}{0.0276} = 4.90 \text{ kips} \)
\( M.S. = \frac{F_s}{t_s} = 7.16 \)

BENDING CHECK

\( F_b = 124 \text{ ksi} \)
\( t_b = \frac{35.1}{0.00065} = 54 \text{ kips} \)
\( M.S. = \frac{F_b}{t_b} = 2.99 \)

\[ 2 \] FITTING FACTOR
\[ 1 \] REF. PAGE 63
FINAL ANALYSIS  LRRZ - 300

BOLT PATTERN ANALYSIS  - HINGE TO ARRAY

LOADS

1. Hinge Load = 300 165
   Direct Force on Bolts:
   \[ F = \frac{300}{4} = 75 \text{ 165} \]

2. Constant of Proportionality of
   Bolt Pattern, \( K \):
   \[ K = 0.47 \left( \frac{300}{4(0.94)} \right) = 82.5 \]

3. Moment Force on Bolts:
   \( F_M = K_f = 82.5(0.94) = 77.5 \text{ 165} \)

4. Maximum Force at Bolts:
   \( F_{\text{bolt}} = F + F_M = 152.5 \text{ 165} \)

BOLT DESIGNATION

An 3 CRES Bolt

Ult. Tensile Strength = 2210 165

Yield = 1690 165

Single Shear Strength = 2125 165

BOLT MARGIN OF SAFETY

\[ M.S. = \frac{2125}{152.5} - 1 = \text{Ample} \]

4. Analysis covers both top and bottom hinges.
3. Conservatively assume loads acting in line.
2. Ref. No. 5, Page 239
1. Ref. Page 63
FINAL Analysis LR3-300

REAR SUPPORT ROD

ASSUMPTIONS:
1. WEIGHT OF LR3 WITHOUT SMALL ARRAY = 70 lbs
2. ZG CONDITION ON 15° SLOPE
3. LR3 PIVOTS ABOUT MIDPOINT OF BOTTOM RESTING PLATE
4. 60-40 LOAD DISTRIBUTION ON SUPPORT HOOP LEGS
5. AMBient LUNAR TEMP. = +250° F

LOADS

\[ W = 2(70) = 140 \text{ lbs} \]

REACTION AT SUPPORT HOOP END, \( R \):
\[ R = \frac{140(4.01)}{6.70} = 84 \text{ lbs} \]
\[ 0.60 R = 51.4 \text{ lbs} \]

MOMENT AT BASE OF LEG:
\[ \text{Moment} = 4.82(51.4) = 243 \text{ in-lbs} \]

SECTION PROPERTIES (SECTION A-A)

O.D. = 0.375
I.D. = 0.195
\( A = 0.0805 \)
\( \ell_c = 0.0048 \)
\( t = 0.009 \)
\( d_t = 0.17 \)
\( F_{1/2} = 1.57 \)

STRESSES

MAT'L: 2024 AL. ALLOY TUBING
OD = 0.375
\( t_{\text{wall}} = 0.09 \)

\[ F_{x} = 60 \text{ ksi} \]
\( F_{y} = 42 \text{ ksi} \)
\( F_{z}^{\text{ELEV. TEMP}} = 38.2 \text{ ksi} \)

\[ F_{x} = 157 \frac{F_{y}}{F_{z}} = 60.0 \text{ ksi} \]
\[ F_{z} = \frac{243}{0.0048} = 50.6 \text{ ksi} \]
\( R_{z} = 0.844 \)

\[ F_{x} = 22.0 \text{ ksi} \]
\( F_{y} = 0.0514 \frac{F_{z}}{0.085} \]
\( R_{y} = 0.029 \)

\[ U = \left( \frac{R_{z}^2 + R_{y}^2}{F_{x}} \right)^{1/2} = 0.844 \]

M.S. = \( \frac{1}{1} = 0.18 \)

\( \text{REF. NO. 3, PAGE 3.01-1} \)
\( \text{REF. NO. 6, FIGURE 3.2.3.1.1} \)
FINAL ANALYSIS LRPR-300

REAR SUPPORT ROD

SUPPORT HOOP DEFLECTION ON 15° SLOPE

ASSUME SUPPORT HOOP LEG ACTS AS A SIMPLE CANTILEVER

\[ S = \frac{WA^3}{3EI} \]

WHERE:
\[ W = 0.60 \text{ in.} \]
\[ A = 5.50 \text{ in.}^2 \]
\[ L = 4.82 \text{ ft} \]
\[ E = 10.5 \times 10^6 \text{ psi} \]
\[ I = 0.009 \text{ in.}^4 \]

\[ S = 0.202 \text{ in. (EARTH CONDITIONS)} \]

FOR LUNAR SURFACE CONDITIONS:

\[ N = \frac{51.4}{6} = 8.57 \text{ in.} \]

\[ S = \frac{WA^3}{3EI} = \frac{8.55(4.82)^3}{3(10.5 \times 10^6)(0.009)} = 0.035 \text{ in.} \]

THE ABOVE DEFLECTIONS ASSUME A HARD SURFACE AND

CONSIDERS NO SURFACE IMPRESSION. NO SUPPORT IS

CONSIDERED FROM OTHER LEG.

---

1. REF. NO. 4, TABLE III CASE 1
2. REF. NO. 6, FIGURE 3.2.3.1.4.
FINAL ANALYSIS - LRRR-300

SUN COMPASS SPRING

DWG. 2342269

SPRING PROPERTIES

SPRING MEAN DIA, D = 0.356
WIRE DIA., d = 0.048
E = 30 x 10^6
LENGTH OF ACTIVE WIRE, L = 0.472
NUMBER OF ACTIVE WIRE, N = 13
MINIMUM TENSILE STRENGTH, S_m = 262 KSI

TORSIONAL MOMENT AT FINAL LOCATION = 1.5 in.-lb

TORSIONAL MOMENT REQUIRED TO DEFLECT SPRING ONE TURN:

\[ M = \frac{E d^4 T}{10.8 N D} = \frac{30 \times 10^6 (0.048)^4}{10.8 (13) \cdot 356} \]

WIRE STRESS DUE TO 1.5 IN.-LB TORQUE:

\[ S = \frac{32 M}{\pi d^3} = \frac{32 (1.5)}{\pi (0.048)^3} = 141.2 \text{ KSI} \]

\[ M.S. = \frac{S_m}{S} - 1 = \frac{262}{141.2} - 1 = 1.85 \]

TORSIONAL MOMENT REQUIRED FOR DEFLECTION OF 165°:

\[ 3.185 \left( \frac{165}{360} \right) = 1.46 \text{ IN.-LB} \]

THIS FALLS WITHIN THE LIMITS SPECIFIED ON THE DRAWING.
**Final Analysis** LRR7-300

**Rivet Connection Investigation**

The following connections are attached with 4 .125 dia rivets made of 2117 Al. Alloy:

<table>
<thead>
<tr>
<th>Connection</th>
<th>Max. Connection Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Pivot Brace (2347344) &amp; Front Pivot Structure Clevis (2347349)</td>
<td>480 lbs (1)</td>
</tr>
<tr>
<td>Foot (2347340) &amp; Foot Bracket (2347338)</td>
<td>211 lbs (2)</td>
</tr>
<tr>
<td>Foot (2347340) &amp; Diagonal Support Bracket (2347336)</td>
<td>224 lbs (2)</td>
</tr>
</tbody>
</table>

Ultimate shear allowable for 2117-T4 Al. Alloy:

\[ F_{su} = 28 \text{ ksi} \]

Cross-sectional area of .125 dia rivet:

\[ A = 0.01227 \text{ in}^2 \]

1. Max single shear load of rivet:

\[ P_{single \ shear} = A F_{su} \]

\[ = 0.01227 \times 28000 = 344 \text{ lbs} \]

Since each connection has 4 rivets and the maximum connection load is 480 lbs, all connections have ample strength.

(2) Ref. Page 37
(1) Ref. Page 57
FINAL ANALYSIS  LRRZ-300

SLOTTED SPRING PIN INVESTIGATION

The following connections are attached with an NAS 561-G slotted spring pin:

<table>
<thead>
<tr>
<th>Connection</th>
<th>Max. Connection Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEG &amp; FOOT ASSY (2347346)</td>
<td>211 165</td>
</tr>
<tr>
<td>DIAGONAL SUPPORT ASSY (2347345)</td>
<td>224 165</td>
</tr>
<tr>
<td>DIAGONAL SUPPORT TUBE (2347345-1) &amp; REAR SUPPORT BRACKET (2347348)</td>
<td>224 165</td>
</tr>
</tbody>
</table>

Allowable double shear load of an NAS 561-G slotted spring pin:

\[ P_{\text{double shear}} = 4400 \text{ 165} \]

*The above connections have ample strength*