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Produced by the NASA Center for Aerospace Information (CASI)
MATERIAL PROPERTIES, LOADS, AND STRESS ANALYSIS - SPARTAN REM

Appendix A

19 June 1984

Contract NAS8-35599

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER, AL 35812

by

Donna S. Marlowe
Erik J. West

Lockheed

Research & Development Division
Huntsville Research & Engineering Center

Cummings Research Park
4800 Bradford Drive,
Huntsville, AL 35807

(NASA-CR-171092) MATERIALS PROPERTIES, LOADS, AND STRESS ANALYSIS, SPARTAN REM: APPENDIX A (Lockheed Missiles and Space Co.)
124 p HC A05/MF A01
CSCL 20K
N85-11375
Unclas
G3/39 00964
Fig. A-1  Spartan REM
Fig. A-2 Latching Mechanism
LOADS
LOIDS (for ED23-84-24
FEB 16, 1984)

LOW FREQUENCY ACCELERATIONS

\[
\begin{align*}
\hat{x} & \pm 4.3 \\
\hat{y} & \pm 2.0 \\
\hat{z} & +7.1/-3.8
\end{align*}
\]

ORIGINAL PAGE IS
OR POOR QUALITY.

LOAD COMBINATIONS

<table>
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<th>\hat{y}</th>
<th>\hat{z}</th>
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<td>2.0</td>
<td>7.1</td>
</tr>
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<td>-3.8</td>
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SPARTAN REM

WEIGHT

ADAPTER = 167 LB
BASE ASSY. = 420 LB

TOTAL = 587 LB

CALCULATED CYCLES

BERTHING LOAD 4000 N-m lb TORQUE

LIMIT CYCLES = 100
LIFE FACTOR = 4

TOTAL REQUIRED DESIGN CYCLE LIFE = 100 x 4 = 400 CYCLES

MAJOR FLIGHT LOADING CYCLE LIFE

TIME = 50 SEC. + 20 SEC./MISSION
FOUR MISSION DESIGN TIME = 50 + 80 SEC. = 130 SEC.
LIFE FACTOR = 4
USE 50 Hz = NATURAL FREQUENCY

TOTAL REQUIRED DESIGN CYCLE LIFE = 130 x 4 x 50 = 26,000 CYCLES
FIGURE 1
MASS PROPERTIES COORDINATE SYSTEM
(BASE)
FIGURE 2. ADAPTIVE SYSTEM (ADAPTER)

MASS PROPERTIES:

Y = 2.5
X = 0.0

Z = 5.681

ORIGINAL PAGE IS OF POOR QUALITY.
<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY</th>
<th>WEIGHT</th>
<th>X (STATION-INCHES)</th>
<th>Y (STATION-INCHES)</th>
<th>Z (INCHES)</th>
<th>IX (POUND-INCHES)</th>
<th>IY (POUND-INCHES)</th>
<th>IZ (POUND-INCHES)</th>
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</thead>
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<td>2692</td>
<td>5/16-24 X2.13 CAP</td>
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<td>43.66</td>
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<td>43.66</td>
<td>6.77</td>
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<td>2694</td>
<td>5/16 WASHER, FLAT</td>
<td>2</td>
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<td>43.66</td>
<td>6.77</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td></td>
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<td>30.99</td>
<td>23.67</td>
<td>6.18</td>
<td>102099.7</td>
<td>116854.9</td>
<td>216842.6</td>
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</tbody>
</table>

**NOTE:**
- The table above summarizes the weight and dimensions of various parts in an assembly.
- The total weight and dimensions are calculated for each part and summed up for the total assembly.
- The assembly includes parts with varying weights and dimensions, contributing to the total calculated values.

**Comment:**
- The comment at the top right indicates a note or instruction, possibly regarding the assembly or its components.
### TABLE IV

<table>
<thead>
<tr>
<th>Item</th>
<th>Part No.</th>
<th>CR</th>
<th>X Station-Inches</th>
<th>Y Station-Inches</th>
<th>Z Station-Inches</th>
<th>IX Pound-Inches Squared</th>
<th>IZ</th>
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<td>4.12</td>
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<td>E</td>
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<td>18.92</td>
<td>45.00</td>
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<td>0.02</td>
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<td>0.01</td>
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<td>4586 CABLE UI</td>
<td>30A60752-1</td>
<td>E</td>
<td>0.50</td>
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<td></td>
<td><strong>382.01</strong></td>
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<td><strong>22.07</strong></td>
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9-17 SEP 7, 1983
MATERIAL PROPERTIES

3.1 2219 AL
3.3 Inconel 718
3.5 4340 STFSL

MP35N
416 STAINLESS

ORIGINAl PAGe IS
OF POOR QUALITY.
2219 ALUMINUM ALLOY SHEET AND PLATE (BARE)
Specifications QQ-A-250/30
SUMMARY OF ROOM TEMPERATURE PROPERTIES

<table>
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<th>Condition</th>
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<th>Prelim&lt;sup&gt;a&lt;/sup&gt;</th>
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<td>3.001-4.000</td>
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<td>F&lt;sub&gt;c&lt;/sub&gt; (ksi)</td>
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<td>L</td>
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<td>54</td>
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<td>-</td>
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<tr>
<td></td>
<td>F&lt;sub&gt;u&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
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<td></td>
<td>b&lt;sub&gt;r&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
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</tr>
<tr>
<td></td>
<td>e/0 = 1.5</td>
<td>91</td>
<td>91</td>
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<td></td>
<td>e/0 = 2.0</td>
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<tr>
<td></td>
<td>F&lt;sub&gt;b&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>e/0 = 1.5</td>
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<td>e/0 = 2.0</td>
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<td>e (% percent)</td>
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<td>L</td>
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<td>6</td>
</tr>
<tr>
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<td>LT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Physical Properties (average)**

- E ($10^6$ psi): 10.5
- E<sub>c</sub> ($10^6$ psi): 10.8
- G ($10^6$ psi): 4.0
- u: 0.33
- K (BTU-in./hr-sq in.-°F): 6.2
- a ($10^{-6}$ in./in.-°F): 12.4 (70°F to 212°F, see p. 02.24.02.01)
- C (BTU/lb-°F): 0.23 (at 212°F)
- b (lb/cu.in.): 0.102

<sup>a</sup> Properties shown for 5.001-6.000 inches thick are preliminary, pending negotiation with suppliers.

<sup>b</sup> Bearing allowables include the lubricated pin reduction factor. When the hole axis is parallel with the plane of the plate, F<sub>b</sub> values must be adjusted per p. 01.00.00.11.
2219-T67 Aluminum Alloy Sheet and Plate, 0.10 to 1.5 Inch Thick TL Orientation

CYCLIC CRACK GROWTH RATE AT ROOM TEMPERATURE

\[ K_c = 35 - 60 \]
\[ \Delta K_0 = 3.5 \]
\[ n = 3.30 \]
\[ C = 2.19 \times 10^{-3} \]

VARIATION OF \( K_c \) WITH THICKNESS

Nomenclature for growth rate constants is given on page 01 00 00 00

REF. LOCKHED MALL MANUAL
Inconel 718 Sheet, Plate, Bar, and Forgings Specifications HB0170-071, -074, -075, 076, and MA011-303 AMS 5596, 5597, 5663

SUMMARY OF ROOM TEMPERATURE PROPERTIES

99 Percent Probability Minimum Values

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<th>Material</th>
<th>Condition</th>
<th>Sheet and Plate</th>
<th>Bar and Forgings</th>
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<td>F_tu (ksi)</td>
<td>LT</td>
<td>110</td>
<td>180</td>
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<tr>
<td>F_ty (ksi)</td>
<td>LT</td>
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<td>150</td>
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<tr>
<td>F_cy (ksi)</td>
<td>LT</td>
<td>50</td>
<td>150</td>
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<tr>
<td>F_s (ksi)</td>
<td>LT</td>
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<td>113</td>
</tr>
<tr>
<td>F_br (ksi)</td>
<td>e/0 = 1.5</td>
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<td>248</td>
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<tr>
<td>F_bry (ksi)</td>
<td>e/0 = 1.5</td>
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<tr>
<td>e (percent)</td>
<td>LT</td>
<td>30</td>
<td>12</td>
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</tbody>
</table>

Physical Properties (average)

- E (10^6 psi) = 29.5
- E (10^6 psi) = 29.5
- G (10^6 psi) = 11.4
- μ = 0.29
- K (BTU/hr/ft^2°F) = 0.53 (STA, 68°F)
- ρ (10^-6 in/10^-6°F) = 7.2 (68°F to 200°F)
- C (BTU/lb*°F) = 0.104
- ρ (lb/cu.in.) = 0.297
Cyclical Crack Growth Rate Data

Material: 403 INCONEL 718 S, LTS AND TLS ORIENATIONS

YS (0.2% 0.5%) KSI 150.0

Growth Rate Constants:

\[ n = 2.7 \]
\[ C = 0.0004 \]
\[ \Delta K_c = 15.0 \]
\[ K_c = 115.0 \]

Cyclical Growth Rate, \( \Delta a/\Delta N \), Microinches per Cycle
**Fracture Mechanics Data**

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<td>180</td>
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<td>Inconel 786</td>
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<td>MP35N</td>
<td>260</td>
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<td>120</td>
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</table>

**NPR = Viotto-Priest Equation Parameters**

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<th>i_p</th>
<th>i_c</th>
<th>i_p</th>
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**Crack Growth Rate**

\[
\frac{da}{dn} = c (\Delta K)^n
\]
SPARTAN REM
STRESS ANALYSIS
### Margin Summary

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<tr>
<td>BASE</td>
<td>+1/1</td>
<td>1.29</td>
<td>45</td>
<td>TENSION</td>
</tr>
<tr>
<td>ADAPTER/PM INTERFACE</td>
<td>+1/1</td>
<td>1.798</td>
<td>25</td>
<td>SHEAR TEAROUT</td>
</tr>
<tr>
<td>Pin Bearing</td>
<td>+1/1</td>
<td>7.28</td>
<td>49</td>
<td>TENSION</td>
</tr>
<tr>
<td>HM TO BE DRILLED IN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADAPTER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOCATOR ROD</td>
<td>-1560 lb</td>
<td>0.015</td>
<td>88.1</td>
<td></td>
</tr>
<tr>
<td>(30400647)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LATCHING MECHANISM

PAYLOADER FRAME (GT = 2500 lb)
2.0 G - Y AXIS ACC.

LATCH MECHANISM REACTS TOTAL Y AXIS LOAD

MAX P = 5.19 kips (Ref. P. 51 PIN REACTION SUMMARY)

LINEAGE FORCES

\[ F_T = \frac{p \times 2.70}{2.45} = 5.72 \, \text{kips} \]

\[ R_y = -F_T \sin 105^\circ \]

\[ F_T = \text{TURNBUCKLE FORCE} \]

\[ = F / \cos 105^\circ \]

\[ = 5.72 / \cos 105^\circ \]

\[ = 5.72 \, \text{kips} \]

\[ R_y = -5.19 + 5.72 \sin 105^\circ \]

\[ = -5.19 + 0.305 \]

\[ = -5.09 \, \text{kips} \]
LATCHING MECHANISM

SECTION A-A

TOGGLE LINK LUG (30A60694)
(LOADING FROM NASTRAN RUN NO0511 - APP. I
SUMMARY P. 51)

MAY Y AXIS PIN REACTION - R_y = 5.19 kips

Resulting REACTION - from p 1.0

\[ R_x = 5.72 \text{ kip} \]
\[ R_y = 5.09 \text{ kip} \]

EFFECTIVE LUG WIDTH @ HOLE = 2 (.65") = 1.30 in

MATL: INC 718
\[ F_{tu} = 180 \text{ ksi} \]
\[ F_{su} = 113 \text{ ksi} \]
LATCHING MECHANISM - TOSLE LINK LUG
TRANSVERSE LOADS

Ref. fig p2

\[ Y = (\cos 45^\circ) \cdot 31.25 = 22.1 \]
\[ X = \tan 45^\circ \Rightarrow X = Y = 22.1 \]
\[ X' = 1.14 - X = .919'' \]
\[ Y' = X' + \tan 30^\circ = .919(\sqrt{3}) = .531'' \]
\[ D_1 = D_4 = 1.4 - Y - Y' = 1.4 - .221 - .531 \]
\[ = .648'' \]

\[ t = .375'' \]

\[ A_1 = D_1 t = .648(.375) = .243 \text{ in}^2 \]
\[ A_2 = A_3 = D_2(t) = .3375(.375) = .1266 \text{ in}^2 \]
\[ A_4 = D_4 t = D_1 t = .243 \text{ in}^2 \]

\[ A_V = \frac{6}{\frac{3}{A_1} + \frac{1}{A_2} + \frac{1}{A_3} + \frac{1}{A_4}} = \frac{6}{\frac{A_4}{A_1} + \frac{2}{A_2}} = .186 \]

\[ \frac{A_4}{A_1} = \frac{.186}{.795} \]

\[ D_1 = .625'' \]
\[ D_3 = \frac{.655 - .625}{2} = .375'' \]
\[ D_2 - D_3 = .3375'' \]
\[ A_{br} = D_t = .625(.375) = .234 \]
**LATCHING MECHANISM (cont.)**

**TOGGLE LINK LUG (3D462634)**

From p. 2.0

\[
\frac{\text{Area}}{A_{\text{cr}}} = 0.795 \text{ in.}^2, \quad A_{\text{cr}} = 2.234 \text{ in.}^2
\]

Shear Breaking

\[
P_{\text{tu}} = K_{\text{tu}} \frac{A_{\text{tu}}}{t}
\]

From graph on p. 4.1

\[K_{\text{tu}} = 0.59\]

\[P_{\text{tu}} = 0.59 \times (234)(180,000) = 24.85 \text{ kips}\]

Axial

\[
\frac{e_{\text{b}}}{d} = 1.14, \quad \frac{w}{d} = 1.3 = 2.08, \quad \frac{D}{t} = \frac{625}{375} = 1.67, \quad A_t = \frac{w-d}{t}
\]

From graph on p. 4.2

\[K_{\text{br}} = 0.84\]

Shear Breaking

\[P_{\text{tu}} = K_{\text{br}} \frac{A_{\text{tu}}}{t} = 0.84 \times (234)(180,000) = 36.22 \text{ kips}\]

**COMBINED AXIAL & TRANVERSE LOADING**

**LOADING ON LUG**

\[K_x' = 5.72 / 2 = 2.86 \text{ kips}\]

\[K_y' = 5.05 / 2 = 2.55 \text{ kips}\]

\[R_A = \frac{2.86(2)}{36.22} = 0.158, \quad R_{kr} = \frac{2.55(2)}{24.85} = 0.21\]

\[M.S. = \frac{1}{(R_{k1} + R_{k2})} - 1 = \frac{1}{0.0522 + 0.082} = 2.51 \text{ ULT SHEAR BEARING}\]
<table>
<thead>
<tr>
<th>Material</th>
<th>Curve No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-5PH Steel H1150, Ftu = 135 KSI, eu = .11 (T)</td>
<td>1</td>
</tr>
<tr>
<td>15-5PH Steel H1100, Ftu = 140 KSI, eu = .10 (T)</td>
<td>2</td>
</tr>
<tr>
<td>15-5PH Steel H1025, Ftu = 155 KSI, eu = .08 (T)</td>
<td>4</td>
</tr>
<tr>
<td>Inconel 718 B&amp;F Sta, Ftu= 180 KSI, eu = .10 (L)</td>
<td>3</td>
</tr>
<tr>
<td>Inconel 718 B&amp;F Sta, Ftu= 180 KSI, eu = .06 (T)</td>
<td>5</td>
</tr>
</tbody>
</table>

Curve (A) - Approximate Strength. If Ktru is below this curve, see text (VI:C)

\[ e_u = \text{Ultimate Elongation} \]

L, T, & ST indicate grain in direction 'F' in sketch:

L = Longitudinal, T = Long Transverse, ST = Short Transverse.

**Figure 7e** EFFICIENCY FACTORS OF LUGS FOR TRANSVERSE LOADING, ALLOY STEEL AND HEAT RESISTANT ALLOYS
LATCHING MECHANISM (cont.)

FROM P. 51, 110 TOGGLE LINK LUG INTERFACE (NASTRAN RUN NOCSM11)

\[ R_y = 809 \text{ kip} \]
\[ R_x = 5.72 \text{ kip} \]

@BASE INTERFACE

\[ P_{S1} = P_{S2} = \frac{5.72}{2} = 2.86 \text{ kip} \]
\[ P_2 = \frac{5.72 \times (2.54) + 5.09}{1.5} \]
\[ P_2 = 12.23 \text{ kip} \]
\[ P_1 = -5.72 \times \frac{2.54}{1.5} + \frac{5.29}{2} \]
\[ P_1 = -7.14 \text{ kip} \]

ORIGINAL PAGE IS OF POOR QUALITY.
LATCHING MECHANISM  (cont.)

LUG BENDING @ BASE

SECTION A - A

\[ A = 2.8 \times (3.8) = 1.064 \text{ in}^2 \]
\[ I_1 = \frac{b h^3}{12} = 2.8 \times (3.8)^3 = 0.0128 \text{ in}^4 \]
\[ I_2 = \frac{1}{12} \left( 2.8 \times (3.8)^3 \right) = 0.195 \text{ in}^4 \]
\[ I_{1/c} = \frac{0.25}{0.19} = 1.32 \text{ in}^3 \]
\[ I_{2/c} = \frac{0.25}{0.14} = 1.79 \text{ in}^3 \]

\[ R_x = 5.72 \text{ kip} \]
\[ R_y = 5.09 \text{ kip} \]

\[ M_{11} = R_y \left[ (1.0) - \frac{38}{2} \right] = 5.09 \times (1.81) = 4.12 \text{ in}-\text{kip} \]

\[ M_{12} = R_{xx} (2.54) = 14.53 \text{ in}-\text{kip} \]

\[ S_{b1} = \frac{M_{11}}{I_{1/c}} = \frac{4.12}{1.32} = 3.11 \text{ ksi} \]

\[ S_{b2} = \frac{M_{12}}{I_{2/c}} = \frac{14.53}{1.79} = 29.29 \text{ ksi} \]

\[ S_{b_{max}} = 61.49 + 29.29 = 90.78 \text{ ksi} \]

\[ S_t = \frac{R_y}{A} = \frac{5.09}{1.064} = 4.78 \text{ ksi} \]

\[ F_{du} = 270 \text{ ksi} \]

\[ R_b = \frac{2 \times (90.78)}{270} = 0.67 \]

\[ R_t = \frac{2 (4.78)}{180} = 0.053 \]

\[ M.S. \ u = \frac{1}{R_b + R_t} = 0.38 \]
LATCHING MECHANISM (cont.)

\[
\begin{align*}
N_1 & = \frac{A \tau_y A_y A_y^2 T_w}{3.8} \\
N_2 & = \frac{92 \times 1.05}{1.191} = 1.48, 0.42 \\
\gamma & = \frac{3.42}{1.191} = 0.771 \text{ in}^3 \\
x & = \frac{1.348}{1.252} \\
J_\theta & = \frac{1.350}{11} \\
\frac{1}{\gamma_{c}} & = 0.2771 \text{ in}^3
\end{align*}
\]

\[M_{\text{A}} = (P_2 - P_1) \times 1.345 = 5.07 (1.345)\]

\[S_b = \frac{6.85}{2.79} = 24.55 \text{ KSI}\]

\[S_{bu} = 1.5 \times 63 = 94.5 \text{ KSI}\]

\[\frac{S_a}{2(24.55)} - 1 = 0.92\]

MOUNTING BOLT LOADS

From NASTRAN RUN NO003/11, \( P_1 \):

\[R_x = 5.72 \text{ KIP}\]

\[R_y = 5.01 \text{ KIP}\]

Due to Rx load:

\[P_2 (2.15) + 1.65 P_1 = 5.72 (2.54)\]

\[P_1 = \frac{1.65 P_2}{2.15}\]

\[2.15 P_2 + 1.65^2 P_2 = 14.53 \text{ K}\]
LATCHING MECHANISM (cont.)

LUG MOUNTING BOLTS (cont.)

\[ 2 \cdot 3.46 \, P_2 = 14.53 \]
\[ P_2 = 6.19 \, \text{kip} \]
\[ P_{1*} = \frac{0.65}{2.15} (6.19) = 1.87 \, \text{kip} \]

Due to Roy condition (ref. pg. on previous pg.)

\[ P_1 - P_2 = \frac{6.19}{2} = 2.545 \, \text{kip} \]

\[ P_{2t} = 2.545 + 6.19 = 8.735 \, \text{kip} \]
\[ P_{1t} = 2.545 + 1.87 = 4.415 \, \text{kip} \]

BOLTS

\[ \frac{\text{DIA}}{\text{N.A.}} = \frac{0.397}{1.93} = 0.20 \, \text{kip} \]
\[ P_{du} = 28.2 \, \text{kip} \]
\[ P_{s, su} = 16.25 \, \text{kip} \]

Since bolts are tested items, F. S. = 1.4

\[ \text{M.S. u.} = \frac{23.2}{1.4 (8.735)} - 1 = 0.897 \, \text{TENSION} \]

Bolt shears:

\[ \frac{5.72}{2} = 2.86 \, \text{kip/bolt} \]

\[ \text{M.S. u.} = \frac{16.25}{1.4 (2.86)} - 1 = 3.05 \, \text{SHEAR} \]
LATCHING MECHANISMS (cont.)

TOGGLE LINK LUG INTERFACE (cont.)

BOLT INTERACTION -

\[
R_t = 1.4 \left( \frac{8.735}{23.2} \right) = 0.527
\]

\[
R_s = 1.4 \left( \frac{8.76}{16.25} \right) = 0.246
\]

\[
M.S.t = \frac{1}{15.27} - 1 = 0.71 \\
\text{(ULT INTERACTION)}
\]
\[ R_s^2 + R_5^2 = 1 \]

BOLT INTERACTION

\[ R_5 = \frac{\text{ACTUAL} \times \text{Gross}}{\text{ALL}} \]
LATCHING MECHANISM

TOGGLE LINK (30A60673)

FROM NASTRAN SUMMARY

\[ F_t = \frac{5.19 (2.7)}{2.45} = 5.72 \text{ kips} \]

\[ \text{LOAD/LUG} = \frac{5.72}{2} = 2.86 \text{ kips} \]

\[ A_{brg} = 0.438 \cdot 0.343 = 0.15 \text{ in}^2 \]

\[ A_2 = (1.3 - 0.348)t = 0.296 \text{ in}^2 \]

MATL 43K VOD STL

\[ F_{tu} = 180 \text{ ksi} \]

REF P 3 FOR PROCEDURE

\[ A_1 = A_4 = 0.343 (0.61^2) = 0.21 \text{ in}^2 \]

\[ A_3 = A_2 = (0.65 - 0.21^2)t = 0.148 \text{ in}^2 \]

\[ \text{Avg} = \frac{6}{\frac{1}{A_1} + \frac{1}{A_2} + \frac{1}{A_3} + \frac{1}{A_4}} = \frac{0.184}{A_{brg}} = \frac{0.184}{0.15} = 1.23 \]
LOW ALLOY STEELS
4340, 4140, 300M & Others
Ftu £ 300 ksi

Curve A - Approximate
Strength. If Ktru is below
this curve, see text (VI:C)
L, T, & ST indicate grain
in direction 'F' in sketch:
L = Longitudinal, T = Long
Transverse, ST = Short
Transverse.

\[ e_u = \text{Ultimate Elongation} \]

\[ K_{tru} \]

\[ 0.06 \leq e_u \leq 0.03 \]

FIGURE 7d
EFFICIENCY FACTORS OF LUGS FOR TRANSVERSE LOAD
LOW-ALLOY STEELS
IDGLEF LINK (CONT.)

TRANSVERSE LOADS - SHEARBEARINGS

\[ P_{IRU} = K_{TRU} A B R \text{ ft} \text{ lb} \]

From graph on p. 11 \( K_{TRU} = 1.07 \)

\[ P_{IRU} = 1.07 (1.15)(150) = 24.10 \text{ kips} \]

\[ M.S_u = \frac{24.10}{2(2.86)} = 1 = 3.21 \text{ ULT} \]

LUG DIA. (3.860698) SHEAR

From p. 1.0 \( R_x = 5.72 \text{ kip} \)

\( R_y = 5.09 \text{ kip} \)

\[ P_{IN DIA} = 0.625'' \]

\[ A = 0.306 \text{ in}^2 \]

\[ P_s = \sqrt{5.72^2 + 5.09^2} = 7.66 \text{ kips} \]

\[ S_s = \frac{4/3 P_s}{2A} = \frac{4}{3} \frac{7.66}{2(0.306)} = 2.66 \text{ kips} \]

\[ M.S_{su} = \frac{113}{2(16.69)} = 2.39 \text{ ULT SHEAR} \]
LATCHING MECHANISM (cont.)

TOGGLE LINK PIN (30x160700)

SHEAR

\[ F_S = \frac{F_{SS}}{2.15} \]

\[ F_{SS} = 113 \text{ kips} \]

\[ F_S = \frac{113}{2.15} = 53.0 \text{ kips} \]

\[ \frac{F_S}{D} = \frac{53.0}{0.433} = 122.7 \text{ kips/in} \]

\[ N_S = \frac{113}{25.1} = 4.5 \text{ kips/in} \]

\[ \frac{N_S}{F_S} = \frac{4.5}{53.0} = 0.084 \]

ULTIMATE SHEAR
LATCHING MECHANISM (CONT.)
TOGGLE LINK PIN (30A60700)

BENDING - REF MSFC STRUCTURES MANUAL, 82

\[
P_{or} = \frac{e}{t_2} \frac{D}{t_2}, \text{ for inner leg} = \frac{156.25}{4.41} \cdot \frac{4.138}{2} \cdot 0.47 = 1.04
\]

\[
P_{ub} = \frac{204}{1.50} = 130
\]

REDUCTION FACTOR - FROM FIG. B2.11.0-6 \[ f = 0.525 \]

\[
b = t_2 + \frac{t}{2} + t_2 = \frac{343}{2} + 0.47 + 0.525(0.47)
\]

\[
M = P (\frac{b}{2}) = P (1.1405)
\]

from p 14 \[ P = 5.72 \text{kips} \]

\[
M = 18.04 \text{kips-in}
\]

\[
S_b = \frac{M_y}{I} = \frac{1804(2.11)}{0.0018} = 97,82 \text{kips}
\]

\[
I = 0.0018 \text{m}^4
\]

\[
y = \frac{4.38}{2} = 2.19
\]

\[
M.S. = \frac{300}{2 \cdot (97.82)} - 1 = -0.53
\]
**LATCHING MECHANISM** cont.

**TOGGLE LINK** (cont.) (30A60 695)

BENDING OF LATCH PIN -
THIS IS THE PIN THAT ENGAGES WITH THE LATCH HOOK

![Diagram of toggle link and latch mechanism]

BENDING NOT CRITICAL DUE TO SHORT LENGTH .435"

**Shear in a pin**

\[ A = \left(\frac{1.82}{2}\right)^2 = 1.528 \text{ in}^2 \]

\[ P = 5.72 \text{ kips (p.110)} \]

\[ \sigma_{min} = \frac{4}{3} \frac{P}{A} = \frac{4}{3} \frac{(5.72)}{1.528} = 14.44 \text{ ksi} \]

\[ \lambda_{s, u} = \frac{85.5}{2(14.44)} - 1 = 1.95 \text{ ultimate shear} \]
LATCHING MECHANISM (S0NY)

TOGGLE LINK
LUG PIN HOLE (.625")

SET P. 3 FOR PROCEDURE

\[
\begin{align*}
D_1 &= D_2 = 1.3375 \\
D_3 &= 1.3375 \\
A &= 1.817 (1.3375) = 0.613 \text{ m}^2
\end{align*}
\]

\[
A_{AV} = \frac{b}{6/A^*} = A = 0.613
\]

\[
A_{br} = Dt = .625(1.817) = 1.14 \text{ m}^2
\]

\[
\frac{H_V}{A_{br}} = 0.54 \quad K_{eu} = 0.52
\]

TRANSVERSE

\[
P_{eu} = K_{eu} A_{br} F_{eu} = 0.52 (1.14) (150) = 88.92 \text{ kips}
\]

AXIAL

\[
\frac{W}{D} = \frac{1.3}{6.25} \quad \frac{D}{D} = \frac{1.3}{6.25} \quad \frac{t}{t} = \frac{1.3}{1.817} \quad A_e = (1.3 - 1.625) (1.817)
\]

\[
A_e = 1.23 \text{ m}^2
\]

From graph on p. 153, \( K_t = 0.74 \)

\[
P_{eu} = K_t A_e P_{eu} = 0.74 (1.23 \times 150) = 173.4
\]
LATCHING MECHANISM (cont.)

TOGGLE LINK - LUG PIN HOLE (cont.)

COMBINED AXIAL & TRANSVERSE LOADS

\[
R_x = 5.72\text{ kips}
\]

\[
R_y = 5.09\text{ kips}
\]

\[
P_A = \frac{2(5.72)}{173.4} = 0.07
\]

\[
P_{12} = \frac{5.62(2)}{88.92} = 0.114
\]

\[
M.S.O = \frac{1}{(10^{14} + 0.114^{12})} = 5.9\text{ mil}
\]
LATCHING MECHANISM cont.

LOG PIN (30A60678)

**BENDING**

\[ \begin{align*}
\varepsilon_1 &= 0.35 \times 10^{-6} \\
\varepsilon_2 &= 1.817 \\
g &= g_{49} = 1.896 - 1.817 = 0.08 \\
P_{trm} &= 28.89 \\
\end{align*} \]

Ref MSFC STRUCT. MANUAL p B2.5

\[ r = \left[ \frac{g}{2} - \frac{1}{2} \right] \frac{0}{t_2} = \frac{\left(\frac{65}{625} - \frac{1}{2}\right) \cdot 625}{1.817} = 0.27 \]

from graph B2.1.1-6

from p. \( P_u = 88.72 \text{kips} \)

\[ \frac{P_u}{\text{for Flu}} = 0.52 \]

from graph B2.1.1-6

MSFC STRUCT. MANUAL
\[ n = 0.52 \]

\[ \begin{align*}
\theta &= \frac{0.35 + 0.047 + 0.52 \left(\frac{1.817}{4}\right)}{2} \\
M &= \frac{Pb \cdot \theta}{2} = \frac{7.0 \times (4.58)}{2} = 17.5 \text{ kN-kips} \\
S_b &= \frac{M}{1.7} = \frac{17.5 \times (3.125)}{1.7} = 72.9 \text{ ksi} \\
\end{align*} \]

\[ k = 1.7 \quad \text{F \( \text{bu} = 300 \text{ ksi} \)} \]

PLASTIC BENDING

\[ M.S.u = \frac{300}{72.9(2)} - 1 = 1.05 \quad \text{ULT} \]
<table>
<thead>
<tr>
<th>Material</th>
<th>Curve No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4130 &amp; 8630 Steel, Ftu ≤ 200 KSI (L,T)</td>
<td>1</td>
</tr>
<tr>
<td>4340 Steel Ftu = 260 KSI (L)</td>
<td>2</td>
</tr>
<tr>
<td>H-11 Steel Ftu = 260 KSI (L)</td>
<td>3</td>
</tr>
<tr>
<td>18-8 Stainless Steel, Ann.</td>
<td>4</td>
</tr>
<tr>
<td>18-8 Stainless Steel, Full hard</td>
<td>5</td>
</tr>
<tr>
<td>(Note: for 1/4, 1/2, &amp; 3/4 hard, interpolate between curve no. 4 and 5)</td>
<td></td>
</tr>
<tr>
<td>300 M Steel Ftu = 270 KSI A &lt; 100 sq.in. (T)</td>
<td>6</td>
</tr>
<tr>
<td>300 M Steel Ftu = 270 KSI 100 ≤ A ≤ 225 sq.in. (T)</td>
<td>7</td>
</tr>
<tr>
<td>300 M Steel Ftu = 270 KSI A &gt; 225 sq.in. (T)</td>
<td>8</td>
</tr>
<tr>
<td>4340 Steel Ftu = 260 KSI (T)</td>
<td>9</td>
</tr>
</tbody>
</table>

L, T & ST indicate grain in direction "F" in sketch:
L = Longitudinal, T = Long Transverse, ST = Short Transverse.

**FIGURE 5c** TENSION EFFICIENCY FACTORS OF LUGS FOR AXIAL LOADING

STEEL
LATCHING MECHANISM (cont.)

TURNBUCKLE, ROD END

From: P. J.R.
MATT 4340 STEEL
Ftu = 150 ksi

MAX TENSION LOAD
ASSUMES LOAD REVERSAL IN LATCH

\[
\frac{D}{t} = \frac{5.625}{.47} = 1.28'' \quad \frac{D}{t} = \frac{.438}{.47} = .93 \quad \frac{D}{t} = .47
\]

\[
\omega = \frac{1.125}{.438} = 2.57^\circ
\]

\[
A_{BR} = .438 (1.125) = 206 \text{ in}^2 \quad A_L = (1.125 - .438)(.97) = 1.323 \text{ in}^2
\]

SHEAR BEARING -

\[
P_{BRu} = K_B R_A H_T F_{tu} = 18H_T (.323)(150000)
\]

\[
P_{BRu} = 32,134 \text{ lb}
\]

TENSION -

\[
P_{tu} = K_T A_T F_{tu} = .915 (.323)(150000)
\]

\[
P_{tu} = 44,332 \text{ lb}
\]

\[
\frac{M.S. u}{2} = \frac{32,14}{(2)(5.72)} = 1.81 \text{ ULT SHEAR BEARING}
\]

TURNBUCKLE BARREL ADEQUATE BY INSPECTION
LATCHING MECHANISM (cont.)

THREADED SECTION

\[ 5/8 - 18 \text{ THDS} \quad A_t = 1.24 \text{ in}^2 \]

\[ f_t = \frac{5.72}{.24} = 23.83 \text{ ksi} \]

\[ M.S. = \frac{150}{(2)(23.83)} - 1 = 2.15 \]
# Latching Mechanism (cont.)

**Bell Crank**  
(30Al60696)

\[ T = 1521 \text{ in.-lb} \]

![Diagram of a bell crank mechanism]

## Spline Stresses

Shear Stress & Pitch Dia of Teeth:  
Ref. Machinery’s Handbook p 1023

\[
\begin{align*}
S_s &= \frac{4T K_a K_m}{D N L e t K_f} \\
K_a &= 1.2, K_m &= 1.0, K_f &= 1.0 \\
L_e &= .70, t &= 1.86 \\
&\text{(Assumes } 1/2 \text{ of teeth reaching } T) \\
S_s &= 4 \left(\frac{1521}{.75}\right) \left(\frac{1.2 \times 1.0}{6 \times .70 \times (.186) \times 1.0}\right) \\
S_s &= 12460 \text{ psi} \\
&\text{Fsu} = 40 \text{ ksi (Ref. Machinery’s Handbook tables)} \\
\end{align*}
\]

\[
M.S.u = \frac{40}{2(12.46)} - 1 = .60 \text{ ULT}
\]
LATCHING MECHANISM (cont.)

MAXIMUM SPLINE TORQUE CAPABILITY

\[
\text{MATERIAL: } 4340 \text{ STEEL} \\
F_{tu} = 180 \text{ ksi} \\
F_{su} = 108 \text{ ksi} \\
F_{cy} = 173 \text{ ksi}
\]

\[
L = 0.75 \text{ in}, \quad h = 0.094 \text{ in} \\
W = 0.188 \text{ in}
\]

FOR SHEAR FAILURE

\[
T_s = F \frac{d}{N}, \quad N = 3 \text{ SETS OF TEETH ON SPLINE}
\]

\[
F_s = \frac{1.5F}{N_s} = \frac{1.5}{0.75(0.188)} F
\]

\[
F = \frac{0.75(0.188)(108000)}{1.5} = 10150 \text{ lb}
\]

\[
T_s = 10150 (0.75)(3) = 22840 \text{ in-lb}
\]

ASSUMING 1/2 OF SPLINE TEETH TRANSMIT TORQUE

\[
T_s' = \frac{T_s \times F_s}{F_s(2)} = \frac{22840}{2(2)} = 5710 \text{ in-lb}
\]

COMPRESSION FAILURE

\[
T_c = F \frac{d}{N}, \quad S_c = F/A_c \Rightarrow F = A_c F_c = 0.75 (0.094)(173,000)
\]

\[
F = 12196 \text{ lb}
\]

\[
T_c = 12196 (0.75)(3) = 27440 \text{ in-lb}
\]

\[
T_c' = \frac{27440}{2(2)} = 6860 \text{ in-lb}
\]
LATCHING MECHANISM (cont.)

SHAFT DESIGN TORQUE

\[ T = 4000 \text{ in}-\text{lb} \quad \text{(REF: ED23-82-166, 12/6/82)} \]

From PII, LIMIT TORQUE = 5710 in-lb

\[ M.S. = \frac{5710}{4000} - 1 = 0.42 \]

TORSION ON MINIMUM SHAFT SECTION

\[ \sigma_{\text{max}} = \frac{16T}{\pi d^3} = \frac{16(4000)}{\pi (0.7499)^3} \]

\[ d = 0.7499 \text{ in} \]

\[ = 48,300 \text{ psi} \]

SHAFT = 1/286 CRES

\[ F_{\text{lu}} = 140 \text{ksi} \]
\[ F_{\text{su}} = 91 \text{ksi} \]

\[ M.S. = \frac{71}{48.3} - 1 = 1.88 \]
LATCHING MECHANISM (cont.)

BELLOWS SPLINE CONT.

Compressive stress on sides of teeth -

\[ \sigma_c = \frac{2Tkm k_m}{9DNLe h k_f} \]

\[ = \frac{2(1521X1.7)(1.0)}{9(1.75)(6X1.70)(0.094)(1.0)} \]

\[ = 1370 \text{ psi} \]

\[ F_{cu} = 3 \text{ ksi} \quad \text{ref: Machinery's Handbook p 1024} \]

\[ M_{Su} = \frac{3.0}{2(1.37)} - 1 = 0.09 \]

TENSILE STRESS IN SPLINE \[ \text{ref: Machinery's Handbook p 1024} \]

RADIAL TENSILE STRESS \[ \sigma_t = \frac{T \tan \theta}{\pi D^2 w} \]

\[ \theta = \text{pressure} \Delta = 30^\circ \]
\[ D = 1.75 \text{ in}, \quad L = 1.75 \text{ in} \]
\[ t = 0.562 \text{ in} \]

\[ \sigma_t = \frac{1521(1100)30^\circ}{\pi(1.75)(0.562X0.75)} = 884 \text{ psi} \]
LATCHING MECHANISM (cont.)

BELLCORP SPINE (cont.)

BEAM LOADING TENSILE STRESS

\[ S_{t_3} = \frac{4T}{D^2 L e} \]

\[ L e = 0.70, \; Y = 1.5 \quad \Rightarrow \quad S_{t_3} = \frac{4 \left( 1521 \right)}{0.70^2 \left( 0.70 \right)^{1.5}} = 10300 \text{ psi} \]

TOTAL TENSILE STRESS

\[ S_{t_1} = \frac{L}{K_m} \left( S_t + S_{t_3} \right), \; K_a = 1.2, \; K_f = 1.0 \]

(from p. 13 \[ S_{t_1} = 884 \text{ psi} \]

\[ S_T = \frac{1.2 \left( 884 \right)}{1.0} \left( 884 + 10300 \right) = 13420 \text{ psi} \]

\[ F_{tu} = 45 \text{ ksi} \] (Ref TBL 7, Machinery's Handbook)

\[ M.S. u = \frac{45}{2(13.42)} - 1 = 0.67 \]
LOCKHEED MISSILES & SPACE COMPANY, INC.

Prepared by: DSM Date: 5/84

Checked by: EJW Date: 6/84

Approved by: 

Title: SPARTAN REM

LATCHING MECHANISM (CLAY)

BELLCRANK LUGS

MAX TENSION LOAD - CONSERVATIVELY

Assuming load reversal from p. 4

\[ \text{partial} = 5.72 \text{ kbf} \]

\[ \text{load} = 2.86 \text{ kbf/deg} \]

\[ \theta = \frac{75}{438} = 0.17 \text{ degrees} \]

\[ \Delta = \frac{225}{438} = 0.51 \text{ degrees} \]

\[ t = 0.438 \text{ in} \]

\[ \text{Material} = 4340 \text{ steel} \]

\[\text{tension} = 0.438 (0.468) = 0.205 \text{ in}^2 \]

\[ A_t = (1.5 - 0.438 \times 0.468) = 0.50 \text{ in}^2 \]

HIGH BEARING

\[ k_{BR} = 1.10 \]

\[ P_{BRU} = k_{BR} A_{BR} F_{tu} = 1.60 (0.205 \times 150000) = 49.2 \text{ kips} \]

TENSION

\[ k_t = 0.53 \]

\[ P_{tu} = k_t A_t F_{tu} = 0.93 (0.50) (150000) = 69.75 \text{ kips} \]

\[ \frac{111.5 + 111.5}{2} = 3.30 \]

LUG BENDING @ JOGGL BEND: ADEQUATE BY INSPECTION!
LATCHING MECHANISM (cont.)

ROUND PIN - (30A60642)

\[ \text{SHFAR PIN DIA} = 1.875 \text{IN (SHANK)} \]

\( \text{From NAS1354 Rev A000011) Ref p. 51} \)

\[ \begin{align*}
F_x &= 11.78 \text{ kip} \\
F_y &= 7.41 \text{ kip} \\
R &= \sqrt{11.78^2 + 7.41^2} = 14.15 \text{ kips} \\
A &= \frac{\pi (1.875)^2}{4} = 1.60 \text{ in}^2 \\
S_{\text{max}} &= \frac{4}{3} \frac{R}{A} = \frac{4}{3} \frac{14.15}{1.60} = 31.44 \text{ kips} \\
F_{\text{su}} &= 113 \text{ kips} \\
M_{\text{su}} &= \frac{113}{(31.44)} = 3.78 \text{, UCT SHFAR} \\
\end{align*} \]

SQUARE PIN (SAME SHANK AS ROUND PIN)

\[ \text{SAME M.S.} \]
LATCHING MECHANISM (cont.)

ADAPTER/PIN INTERFACE

(from NASTRAN RUN ND003/1)

LOAD CASE 7

\[ P_{FIN} = 9.47 \text{kips} \]

SHEAR TEAR OUT

\[ A_s = 1.0(1.69)^2 \]

\[ = 1.35 \text{ in}^2 \]

\[ S_{max} = \frac{3}{2} \frac{P_t}{A_s} \]

\[ = \frac{3}{2} \left( \frac{9.47}{1.38} \right) \]

\[ = 10.27 \text{ ksi} \]

\[ 2219-787 \text{ AL} \]

\[ F_{tu} = 63 \text{ ksi} \]

\[ F_{su} = 37 \text{ ksi} \]

\[ M_{S.U.} = \frac{37}{2 \times (10.27)} - 1 = 0.798 \text{ ULT SHEAR} \]
ADAPTER / PINS (cont.)

Ref p. 51 for pin reactions

\[ P_H = 5.15 \text{ kip} \]
\[ P_V = 11.73 \text{ kip} \]
\[ I/C = .3 \text{ in}^3 \]

\[ M_{min} = 1.0 P_H - P_V (1,1) \]
\[ = 5.19 - 12.9 \]
\[ = 7.713 \text{ in-kip} \]

\[ S_b = \frac{P_V}{A} = 25.7 \text{ ksi} \]

\[ S_t = \frac{P_V}{A} = 11.73 \text{ ksi} = 3.26 \text{ ksi} \]

PLASTIC BENDING

\[ F_{bu} = 97 \text{ ksi (see graph) next page} \]

\[ R_0 = \frac{2(25)}{11} = .53 \]

\[ R_t = \frac{2(8.26)}{62} = .11 \]

\[ M.S. = \frac{1}{.53 + .11} = .56 \text{ ULT} \]
ORIGINAL PAGE IS
DE POOR QUALITY
LATCHING MECHANISM (CON'T)

BEARING ON CONICAL START

\[ P_{\text{min}} = 5.19 \text{ kip} \]

\[ \text{Avg DIA} = 1.55 \text{ in} \]

\[ \text{CIR} = \pi (1.55) = 4.869^\circ \]

\[ A_{\text{reg}} = \frac{3}{1.707} (4.869) = 2.066 \text{ in}^2 \]

\[ f_{\text{reg}} = \frac{5.19}{2.066} = 2.51 \text{ ksi} \]

\[ M_{\text{ult}} = 2219 \quad \text{T87 AL} \]

\[ F_{B\text{ult}} = 99 \text{ ksi} \]

\[ M_{S,\text{ult}} = \frac{99}{2(2.51)} - 1 = \text{LARGE} \]
ADAPTOR / BASE PINS

From p. 54 - MAX PIN REACTIONS -

\[
P_V = 11.73 \text{ kip} \\
P_H = -5.19 \text{ kip}
\]

\[
\theta = 1.63^\circ
\]

\[
(D0A06A15)
\]

\[
\frac{7}{8} - 14 \text{ UNF - 2A THREADS} \\
K. H. THREADS
\]

\[
1.250 \text{ DIA THRU} \\
\frac{4}{5} \text{ THRU MIND - ASSEMBLY}
\]

\[
\text{AREA } "A" \\
1.250 \times 0.000 \text{ DIA}
\]
LATCH MECHANISM ASSY

DRAWN PAGE IS OF POOR QUALITY.
ADAPTEC BASE PINS (CONT.)

SHEAR ON MOUNTING BOLTS

\[
P_s = \sqrt{11.73^2 + 7.97^2} = 14.14 \text{ kip}
\]

\[
P_s / \text{BOLT} = 14.14 / 4 = 3.54 \text{ kip/BOLT}
\]

\[
M. S_u = \frac{16.24}{2 (3.54)} - 1 = 1.30 \text{ ULT. SHEAR}
\]

BEARING

\[
A_BERG = .437 (.5) = .2185 \text{ in}^2
\]

\[
\sigma_{BF} = \frac{3.54}{.2185} = 16.2 \text{ ksi (LOW)}
\]

SHEAR TEAR OUT IN PLATE

PLATE MATERIAL: INC 718

\[
F_{tu} = 180 \text{ ksi}
\]

\[
F_{su} = 113.4 \text{ ksi}
\]

\[
A_5 = 2 \times t = (2 \times .50) (0.56) = 0.56
\]

\[
2X = (5 - \frac{.44}{2}) (0.28)^2 = .56
\]

\[
S_5 = \frac{3}{2} \frac{11.73}{.56} = 31.42 \text{ ksi}
\]

\[
M. S_u = \frac{113.4}{(2)(31.42)} - 1 = .80
\]
EAST DUAL PLATE (cont.)

(FROM NASTRAN RUN NCOO-3111)

14. P. 55) LOAD CASE 2

\[ P_H = -7.91 \text{ kip} \]
\[ P_V = 11.73 \text{ kip} \]

Refer drawings to p. 24.

\[ A_s = \left[ \frac{1.625 \times 2.16}{36} \right] = 0.70 \]

\[ \text{MATT} = \text{INCONEL 718} \]
\[ F_{u} = 180 \text{ ksi} \]
\[ F_{s} = 113 \text{ ksi} \]

\[ S_{s} \text{ min} = \frac{2}{1} \left( \frac{11.73}{0.70} \right) = 25.14 \text{ ksi} \]

\[ N \cdot S_u = \frac{113}{2(25.14)} - 1 = 1.25 \]
Launching Mechanism  (cont.)

Round Pin/Adapter Bearing

\[ F_{brg} = 0.875 (1.0) = 0.875 \text{ M}^2 \quad \text{(ref. fig. p. 48)} \]

\[ s_{brg} = \frac{14.15}{0.875} = 16.17 \text{ kSI} \]

\[ F_{bru} = 94.5 \text{ kSI} \]

\[ M_{S,bru} = \frac{94.5}{2 (16.17)} = 1.92 \text{ U.T. BRAPINS} \]

Square Pin Plate (30AG0044)

Shear Tearout

(from NASA-WP-1104-51)

\[ \text{Ref p. 51} \]

Max Vert Shear = 11.69 kip

\[ A_s = (1.075 - 0.625)(0.625) \]

\[ = 0.5625 \text{ in}^2 \]

\[ S_{s,\text{MAX}} = 11.69 \left( \frac{3}{2} \right) = 31.17 \text{ kSI} \]

\[ F_{su} = 113 \text{ kSI} \]

\[ M_{S,\text{u}} = \frac{113}{2 (31.17)} = 81 \text{ U.L. SHAPR} \]
CATCHING MECHANISM cont. ORIGINAL PAGE IS DE POOR QUALITY.

**SO PIN PLATE - BENDING**

\[ I_{AA} = \frac{0.45^3 (0.625)}{12} = 0.009746 \text{ in}^4 \]

\[ I/c = \frac{0.009746}{0.45/2} = 0.0211 \text{ in}^3 \]

**USING PT LOAD @ CENTER**

\[ \text{Load} = \frac{11.67 \text{ kip}}{8} \]

\[ = 1.459 \text{ kip} \]

\[ S_0 = \frac{2.358}{0.0211} = 111.75 \text{ ksi} \]

\[ \tau_d = 180 \text{ ksi} \]

\[ \tau_{1_{th}} = 180 (1.17) = 306 \text{ ksi} \]

\[ \tau_{1_{th}} = 111.75 \frac{206}{2 (111.75)} - 1 = 0.37 \]

**SHEAR**

\[ R = 11.67 \]

\[ S_S = \frac{5.845 \text{ kip}}{0.625 (0.45)} = 31.17 \text{ ksi} \]

\[ \tau_S = \frac{113.4}{2 (31.17)} - 1 = 0.82 \]
SPARTAN REMI

RODS POSITION HOLDER, 4

SECTION A-A

MOUNTING BASE

1/8 RAD TYP 4 PL

1/4-28 UNF x 625 DP (2 PLCS)
DRILL & TAP FOR LOCKING HELICOIL

SINGLE ROD HOLDER
BASE ROD POSITIONS 2 & 3

DOUBLE ROD BASE
LOCATOR ROD BASE FIG. (SEE POOR QUALITY)

**SINGLE ROD BASE (30A68047 MOUNTING FASTENERS -**

(4) 5/16-24 SCREWS MS57940-106

\[
P_{tu} = 4.64 \text{ kip} \\
P_{su} = 4.96 \text{ kip}(\text{based on 53 ksi CRES STEEL})
\]

MAX ROD LOAD - 1560 lb (REF: ED23-88-42 3/20/83)

Moment @ BASE - (SEE FIG P34)

\[
M = 1560 (3 + 1.6) = 7.176 \text{ kip-ft}
\]

**TENSION**

\[
P/\text{FASTENER} = \frac{7.176}{2.34(2)} = 1.6 \text{ kip}
\]

Shear

\[
P_s = 1560/4 = 390 \text{ kip}
\]

**INTERACTION** (REF P 4.9.1)

\[
R_t = \frac{2(1.6)}{4.64} = 69 \quad R_s = \frac{2(1.37)}{4.06} = 27
\]

\[
M/S = \frac{96}{1.69} = 59 \quad \text{INTERACTION}
\]
LOCATOR PUD BASE FIG. (cont.)

MOUNTING FASTENERS

DOUBLE PUD BASE - 301660648

ASSUME BOTH RODS STRIKE "Y" FIGS @ THE SAME TIME. (REF. P. 17)

ULT. SHEAR

\[ P_s = \frac{1560 \times 2}{4} = 780 \text{ lb/FASTENER} \]

\[ P = \sqrt{5.0^2 + (3.47)^2} = 2.52 \text{ in.} \]

\[ P_{sl} = \frac{1560 \times 3.7}{4 \times 2.52} = 835.7 \text{ lb/Fastener} \]

\[ \tan \gamma = \frac{1.535}{2.10} = 0.7375 \]

\[ \gamma = 37.5^\circ \]

\[ P_{sv} = 835.7 \cos (37.5^\circ) = 663.0 \text{ lb} \]

\[ P_{sh} = 835.7 \sin (37.5^\circ) = 508.7 \text{ lb} \]

RESULTANT SHEAR

\[ P_{sr} = \left[ (P_{sv} + P_{sv})^2 + P_{sh}^2 \right]^{1/2} = \left[ (663 + 780)^2 + (508.7)^2 \right]^{1/2} \]

\[ = 1530.0 \text{ lb} \]
LOCATOR ROD BASE FIG. (cont.)

MOUNTING FASTENERS

DOUBLE ROD BASE (cont.)

From p. 19, \( P_{sa} = 1,530 \text{kips} \)

\( \frac{1}{16} \) - 24 fasteners \( P_{tu} = 4,164 \text{ kip} \)
\( P_{su} = 4,096 \text{ kip} \)

\[ M_S = \frac{4,096}{2 (1.53)} - 1 = 0.33, \text{ ult shear} \]
GUIDE RODS (301160649)  ORIGINAL PAGE IS
OE POOR QUALITY

MATERIAL 2219-T87 AL  \( F_{tu} = 63 \text{ ksi} \), \( F_{su} = 38 \text{ ksi} \)

LOAD = 1560 lb  \( \text{(ref p. 4.26)} \)

at 5" from base

\( 
I = \frac{\pi (1.5)^4}{64} = 0.049 \text{ in}^4
\)

\[ f_0 = \frac{1560(3)(5)}{0.049} = 47.76 \text{ ksi} \]

Plastic bending \( \text{(ref p. 4.27)} \)

\( F_{bu} = 97 \text{ ksi} \)

\[ 
I_xI_y = \frac{17}{2(47.76)} - 0.015 \text{ PLASTIC BENDING}
\]
**SPARTAN REM**

**REM BASE MOUNTING BOLTS**

Original page is of poor quality

**From p. 51**

\[ P_x = +5.07 \text{ kips} \]
\[ P_y = 5.79 \text{ kips} \]
\[ P_z = -10.64 \text{ kips} \]
\[ M_y = 14.4 \text{ in.-kips} \]

\[ P_t = P_x + \frac{M_y}{2.5} = 10.64 + \frac{14.4}{2} = 11.08 \text{ kips/bolt} \]

**Shear**

\[ P_s = \left[ \left( \frac{P_x}{2} \right)^2 + \left( \frac{P_y}{2} \right)^2 \right]^{1/2} = \left[ \left( \frac{5.07}{2} \right)^2 + \left( \frac{5.79}{2} \right)^2 \right]^{1/2} = 3.85 \text{ kips/bolt} \]

\[ R_s = \frac{2 \times 3.85}{33.15} = 0.23 \]

\[ R_t = \frac{2 \times 11.08}{49} = 0.45 \]

**Interaction**

\[ M_S = \frac{0.88}{0.45} - 1 = 0.96 \]
REIN BASE / POM FASTENS

NAS1960C BOLT 5/8" DIA  \( P_{tu} = 49000 \text{ lb} \)
\( P_{tu} = 49000 \text{ lb} \)
\( P_{tu} = 33150 \text{ lb} \)

FROM P51, MAX TENSION LOAD IS \( P_t = 10.66 \text{ lb} \)
\( P_t = 10.66 \text{ lb} \)
\( P_t = 5.69 \text{ lb} \)
\[ P_s = \sqrt{4.26^2 + 5.69^2} = 7.11 \text{ lb} \]

\[ R_t = \frac{(2)(10.66)}{49.0} = 0.435 \]
\[ R_s = \frac{(2)(7.11)}{33.5} = 0.43 \]

\[ \text{ULT INTERACTION} \]

for NUT - MS21045C 5/8-18UNF SB
(per M. Lieberman)
\( P_{cu} = 34130 \text{ lb} \)

\[ \text{ULT TENSION} \]

\[ \text{ULT TENSION} \]

\[ \text{ULT TENSION} \]
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<th>MAX</th>
<th>MIN</th>
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<tbody>
<tr>
<td>1</td>
<td>4.14</td>
<td>-1.94</td>
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<td>2</td>
<td>6.64</td>
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<td>3</td>
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<td>9</td>
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Note: The table shows stress values in ksi (kilo-pound per square inch) for various loads with corresponding maximum and minimum values.
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<tr>
<th>LOAD</th>
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**SPARTAN REM**
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Stresses in Ele 157, 158, 163 are due to concentrated forces on base at grid 132 representing the base mass. Therefore these are not realistic stresses and will not be considered.
REM ADAPTER STRESSES

FROM STRESS SUMMARY P. 41 & 42
LOAD CASE 4, ELE 3

\[ \Delta_{\text{max}} = 9.83 \text{ ksi} \]

\[ \mu = 7074-187 \text{ AL} \]

\[ F_{tu} = 62 \text{ ksi} \]

\[ M.S._u = \frac{62}{2 (9.83)} - 1 = 2.15 \]

REM BASE STRESSES

FROM SUMMARY P. 43 & 44
LOAD CASE 1, ELE 128

\[ \Delta_{\text{max}} = 13.51 \text{ ksi} \]

\[ M.S._u = \frac{62}{2 (13.51)} - 1 = 1.29 \]
CHECK STRESSES AROUND HOLE TO BE DRILLED

FROM NASTRAN MODEL ELEMENT 48
STRESSES @ PTS

\[ \sigma_{B}^{c'} = \left( \frac{-1453.8 - 265.3}{5.5} \right)x + 265.3 = -312.4x + 265.3 \]
\[ \sigma_{B}^{c'} = 5.5 - 3.625 = 1.875 \]
\[ \sigma_{B}^{c'} = -320.8 \text{ psi} \]

ASSUME A LINEAR STRESS DISTRIBUTION FROM POINT TO POINT.

BENDING = \[ \sigma_{\text{AXIAL}} = 793.2 \text{ psi} \]

ORIGINAL PAGE IS OF POOR QUALITY
ADAPTER HOLE STRESSES (cont.)

STRESS IN SECTION C'-D

\[ \sigma_B^{C'-D} = \left( \frac{320.8 + 1403.7}{3.4} \right) X - 320.8 = 507.2 X - 320.8 \]

STRESS IN SECTION F-E

\[ \sigma_B^{F-E} = \left( \frac{1453.8 + 623.3}{5.75} \right) X - 1453.8 \]
\[ = 361.2 X - 1453.8 \]

\[ \sigma_{\text{TOTAL}} = \sigma_B + \sigma_{\text{AXIAL}} \]

FOR STRESSES @ HOLE EDGE, \( X = 1.875 - R \)

\[ \sigma_B^{C'-D} = 507.2 (1.875) - 320.8 \]
\[ = 376.6 \text{ psi} \]

\[ \sigma_B^{F-E} = 361.2 (1.875) - 1453.8 \]
\[ = -957.15 \text{ psi} \]

TOTAL STRESS

\[ \sigma_T^{C'-D} = 376.6 + 793.2 = 1166.8 \text{ psi} \]  \( \text{(C'-D)} \)

\[ \sigma_T^{E-F} = -957.15 + 793.2 = -163.95 \text{ psi} \]  \( \text{(E-F)} \)
ADAPTER HOLE STRESSES (cont.)

![Diagram of adapter hole stresses]

DIAMETER = 1"

FOR SECTION C'-D (INNERWALL)

\[ e = 1.875" \]
\[ c = 3.4 - 1.875 = 1.525" \]
\[ A - B = c - \frac{1}{2} = 1.375" \]

\[ \frac{e}{c} = \frac{1.875}{1.525} = 1.23 \]
\[ \frac{f}{c} = \frac{0.5}{1.875} = 0.2667 \]

FROM GRAPH P,

\[ \frac{f_{\text{max}}}{f} = 3.26 \]

FOR SECTION E-F (OUTERWALL)

\[ c = 1.875" \]
\[ e = 5.75 - 1.875 = 3.875" \]
\[ A - B = 1.375" \]

\[ \frac{e}{c} = \frac{3.875}{1.875} = 2.067 \]
\[ \frac{f}{c} = \frac{1.5}{1.875} = 0.8267 \]

FROM GRAPH P,

\[ \frac{f_{\text{max}}}{f} = 3.24 \]
ADAPTER HOLE STRESSES (CONT.)

USING STRESS CONCENTRATIONS:

SECTION C - D

\[ \sigma_{C'D} = 1166.8 \]
\[ \sigma_{T} = 3.26/5 \]
\[ \therefore \sigma_{\text{max}} = 3.26(1166.8) = 3803.8 \text{psi} \]

SECTION E - F

\[ \sigma_{\text{max}} = 3.24/5 \]
\[ \sigma_{TEF} = 163.95 \text{psi} \]
\[ \therefore \sigma_{\text{max}} = 3.24(163.95) = 531.20 \text{psi} \]

\[ M, S, u = \frac{63000}{(2)(3803.8)} - 1 = 7.28 \]
STRESS CONCENTRATION FACTOR, $K_t$
FOR TENSION CASE
OF A
FLAT BAR WITH A CIRCULAR HOLE
DISPLACED FROM CENTER LINE
(BASED ON MATHEMATICAL ANALYSIS OF SJÖSTRÖM)
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REMARKS: NAstran Run Nnodos1142/18981

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**F** load factors applied to payload, adapter & base cases. 
- **F** indicates tension in fasteners. 

*From NASTRAN run, N003111 (4/18/84)*

*ORIGINAL PAGE 13
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* NO CRACK GROWTH
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MP - MAGNETIC PARTICLE
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* NOT DONE.
FRAC TURE ANALYSIS
BELLOWS LUG, (304 SS)

\[ F_t = 5.72 \text{ kips} \quad \text{(REF 4.1)} \]
\[ \text{or} \quad 2.86 \text{ kip/lug} \]

ASSUME \( F_{\text{MIN}} = 0 \text{ kip} \) (CONSERVATIVE)

LOADED 26,000 CYCLES
(4 MISSIONS WITH SF = 4)

CHECKING FOR CRACKS OR HOLE

MODEL

WORST CASE DEL CRACKS

FROM COMPUTER ANALYSIS:
\[ CF = 0.415 \text{ in} \]

INSPECTION - MAGNETIC PARTICLE
LIMITS - 0.25 in

\[ CF > \text{INSPECTION LIMIT} \]
\[ 0.415 > 0.25 \]

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FR ActURE ANALYSIS

TIGHT LINK (32A60698)

\[ t = 0.373'' \]

\[ d = 0.05'' \]

\[ 1.3 = \frac{1.3}{d} \]

LUG AREA

MATERIAL 4340 S7C
LOADED 26,000 CYCLES
4 MISSIONS (1,141)
S.F. = 4

Front Stress Analysis:

From p.4.10, \( F_T = 5.72 \) kips \( \rightarrow \) LOAD/LUG = 2.86 kips

Assume \( P_{\text{min}} = 0 \) (Conservative)

MODEL

CHECK - CRACK OFF HOLE

\[ t = 0.219'' \]

\[ 0.5 = 0.05'' \]

\[ 1.3 = \frac{1.3}{d} \]

FROM COMPUTER ANALYSIS

\( CF = 0.230 \) in.

INSPECTION - EDDY CURRENT

MINIMUM SIZE - 0.05 IN

\( CF > \) INSPECTION LIMIT

0.23 > 0.05

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Fracture Analysis

Toggle Link Pin (30A60700)

DIA = .438"        MATL - INCONEL 718

From Stress Analysis -
(ref p. 4.14) TMAX = 92.78 kpsi
ASSUME TMIN = 0 kpsi (Conservative)

Loaded 26,000 cycles (Includes 4 Miss/Dias)

Model

Assume Rod in Tension
Check for surface flaws

From Computer Analysis
CF = 0.052
or CF = 1.04

Inspection - Eddy Current
Limits - .1 in Minimum

1.04 > .1
FRAC TURE ANALYSIS

TOGGLE LUG (30A40694)

MATL - INC 718
(CONSERVATIVELY LET ONE LUG)
CARRY FULL REACTION
F_{max} = 7.66 kips (p 4.4)
ASSUME F_{min} = 0 (CONSERVATIVE)

LOADED 26,000 CYCLES -
4 MISSIONS WITH S.F. = 4

CHECK FOR CRACKS
OFF HOLE

FROM COMPUTER ANALYSIS -
CF = .165 in

INSPECTION - EDDY CURRENT
MIN SIZE = .05 in

CF > INSPECT. LIMIT
.165 > .05

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FRACTURE ANALYSIS
LUG PIN (301403698)

.625 DIA

4.64 in

LOADING IS FOR 4 MISSIONS @ 50 Hz WITH SF = 4) OR 26000 CYCLES

\( \sigma_{\text{max}} = 72,8 \text{ ksi} \)

ASSUME \( \sigma_{\text{min}} = 0 \text{ ksi} \)
(CONSERVATIVE)

MODEL -

ASSUME ROD IN TENSION

CHECK FOR SURFACE FLAWS

FROM COMPUTER ANALYSIS

\( \sigma_{\text{OF}} = 0.073 \)

OR .146

INSPECTION DONE WITH EDDY CURRENT

MIN LIMITS ARE .1 IN

.146 > .1

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PROJ. SITE ANALYSIS

ROUND PIN (30AG0042)

SHAFT AREA = \((8.75)^2 \pi / 4\) = 115.27 in.\(^2\)

Tangential Analysis:

\[ T_{\text{max}} = \frac{P_{\text{max}}}{f} = \frac{5.19}{.601} = 8.63 \text{ KSI} \]

Assume \(\sigma_{\text{min}} = 0\) KSI (Conservative)

ASSUME ROD IN TENSION

LOADED 26,000 CYCLES

FOR 4 Missions

AND 5.5 F.4
Fracture Analysis

Round Pin (cont.)

Inspection - Fddy Current Limits - .1 in

From Computer Analysis -

With initial flaws of 80% of the pin diameter there was no crack growth after 200,000 cycles.
ROUND PIN PLATE (30460645)

\[ \frac{r}{a} = 0.25 \quad \text{MATL \- TNA 715} \]
\[ \frac{r}{a} = 0.25 \quad \text{LOADED 20.800 lb} \]
\[ (\text{MISSIONS WITH S.F.} = 4) \]

FROM STRESS ANALYSIS -
\[ P_{\text{V, max}} = 11.73 \text{ kips} \quad (\text{ref. p. 4.28}) \]
\[ A_t = (4.0 - 1.25)(0.25) = 1.71 \text{ in}^2 \]
\[ T = \frac{P_{\text{V, max}}}{A_t} = 6.86 \text{ kips/in} \]

Assume \( \sigma_{\text{min}} = 0 \) (conservative)

FROM COMPUTER ANALYSIS -
\[ c_f = 1.0625 \text{ in.} \]

INFORMATION - INDY CURRENT
MINIMUM SIZE = .05 in

\[ c_f \text{ 7 INS MIN.} \]
\[ 1.0625 > .05 \]

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FRACTURE ANALYSIS

SQUARE PIN  (30A60643)

\[ A_5 = 0.785 \times 0.75 = 0.765^2 \]\n
FROM STRESS ANALYSIS
MAX LOAD = 5.19 kips (0.42)

\[ A_5 = 0.785^2 = 0.762 \text{ in}^2 \]

\[ T_{\text{max}} = 5.19 \times 1000 = 5.19 \text{ ksi} \]

ASSUME \( T_{\text{min}} = 0 \).

CHECKING FOR SURFACE FLAWS ON SHANK

WITH INITIAL FLAWS SIZES OF 80% OF
THE SHANK AREA THERE WAS NO CRACK GROWTH
AFTER 260,000 CYCLES
FRACTURE ANALYSIS

MATERIAL: 4130 VIT (35A6C44)

MINI: INC 7/8

LOADED 26000 CYCLES
(4 MILLION WITH
S. F. = 4)

FROM STRES ANALYSIS -
TENSION

\[ P_{weld} = 11.69 \text{kips} \quad (A.51) \]

\[ A_2 = (4 - 1.6)(1.625) = 1.5 \text{ in}^2 \]

\[ S = \frac{P_{weld}}{A_2} = 7.79 \text{kips} \quad \text{ASSUME} \quad S_{min} = 0 \quad \text{(CONSERVATIVE)} \]

MODEL

CHECK SQUARE HOLE
CORRECT FOR CRACKS

FROM COMPUTER ANALYSIS:

\[ CF = 0.98 \]

FDDY CURRENT INSPECTION

MIN SIZE = 0.05

\[ CF > \text{INSPECTION MIN.} \]

\[ 0.98 > 0.05 \]
FRACUTRE ANALYSIS.

RED HOLD DOWN (304AL: 647, 648)

SECTION AA

CRACK OFF RED HOLE - CHECK LOAD - BERTHING LOADS

TORSION STRESS ANALYSIS - MAX LOAD = 1560/16 ASSUME P MIN = 0 (CONSERVATIVE)
30A600648
BASE RCD
POSITIONS 2 & 3

DOUBLE AID BASE
FILM HOLDERS - (CONT)

AS SHOWN THE LOADED LUG

FROM COMPUTER ANALYSIS -

\[ t = 1.6 \text{ in} \]

\[ \text{DIA} = 1.0 \]

\[ 1.07'' \]

\[ 2.02'' \]

\[ \text{INITIAL CRACKS OF 20% OF LUG AREA SHOWN NO GROWTH} \]

\[ P = 1560 \text{ lb} \]

\[ \text{ref p 4.36} \]

SAME AS (30460647) SINGLE ROD HOLDER

NO GROWTH

NOTE - NO INSPECTION CURRENTLY DONE

NONE RECOMMENDED
THE TYPICAL ANALYSIS

LOAD - PTD (CON-36.42)
MAXI 2077-787 FL

\[ \text{DIA} = 1.0 \text{ in.} \]
\[ t = 0.02 \text{ in.} \]

FROM STRESS ANALYSIS - MAX LOAD = 1560 lb

\[ m - 3p = 4680 \text{ in.-lb} \]

\[ F_{max} = 4680 \left( \frac{1}{0.02} \right) = 468 \text{ kips} \]

\[ \tau_{max} = 100 \text{ ksi} \]

ASSUME \( \tau_{min} = 0 \)

MODEL

ASSUME ROD

FROM COMPUTER ANALYSIS -

\[ m CF = 0.90 \]

\[ \text{max} CF = 0.18 \text{ in.} \]

INSPECTION - Eddy Current

LIMITS - 0.1 in.

\[ 0.18 > 0.1 \]
MAIL - 4/6 CRCS

From Stress Analysis

$F_{\text{max}} = \frac{F}{A} = 66.78 \text{ ksi}$ (from previous analysis)

Conservatively let

$F_{\text{min}} = 0$

Life Factor = 4

Design Life = 1000 cycles x LF

= 100 x 4 = 400 cycles

Check crack on yoth surface

MODEL

Critical flaw size from computer analysis:

$2CF = 0.05 \text{ in.}$

or $CF = 0.1 \text{ in.}$

Eddy current inspection

Min size = 0.1

$CF = \text{ min size} = 0.1$

*From earlier analysis - loads unchanged*
FRACTURE ANALYSIS

LOCATE GEAR PIN (30A60043)

.25 dia

MATL - MA85N SIL

FROM STRESS ANALYSIS -

\( \sigma_{\text{max}} = 145.3 \text{ ksi} \)

ASSUME \( \sigma_{\text{max}} = 0 \) (CONSERVATIVE)

LOAD CYCLES = 100 X SF

= 100 X 4 = 400

ASSUME ROD IN TENSION

CHECK FOR SURFACE FLAW

FROM COMPUTER ANALYSIS

\( 20F = 1053 \text{ in} \)

\( 10F = 106 \text{ in} \)

Eddy current inspection limit = .1 in

\( \frac{106}{7.1} = \)

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* FROM PREVIOUS SPARTAN M1 ANALYSIS LOADS CHANGED
Worm Gear Pin (304900043)
Surface Flaw
TRAXIEL ANALYSIS

DIN (30460021)

.1241 DIA

NiAl-L-MP35N ST

From stress analysis:
\[ \sigma_{\text{max}} = 92.8 \, \text{ksi} \]
Let \[ \sigma_{\text{min}} = 0 \] (conservative)

Loaded 400 cycles including a life factor of 4.

MODEL

Assume it rods in tension

From computer analysis:
\[ \frac{1}{2} CF = 0.45 \, \text{in} \]
\[ CF = 0.9 \, \text{in} \]

Eddy current inspection (unit) \[ .1 \, \text{in} \]

\[ CF < \text{inspect limit} \]

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* From previous Spartan REM analysis, loads unchanged
FRACUTURE ANALYSIS

WORM SHAFT (304160127)

.80 DIA

MATEL: 416 OX

From STRESS ANALYSIS

F MAX = (62,78 KSI)

Conservatively let F MIN = 0

LOADED 4000 LBS

400 = 1000 psi

LIFT FACTOR = Y

Assume: Red in Tension

With SURFACE FLOW

From computer analysis

\[
\frac{1}{2} CF = 0.0625 \text{ in}
\]

OR \( CF = 0.125 \text{ in} \)

INSPECTION - FDBY CURRENT

MIN INSPECTION SIZE = .1 IN

\( CF > \text{INS SIZE} \)

.125 > .1

Y FROM PREVIOUS SPARTAN RFM ANALYSIS

LOADS UNCHANGED
HALF CRACK LENGTH - 2c (cm)

HALF CRITICAL FLAW SIZE .0625

HALF INSPECTION LIMIT

Cycles

WORM SHAFT (3DA60102) - SURFACE FLAWS

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