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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
LOMDS (FOR ED 23-84-24
FEB 16, 1984)

LOW FREQUENCY ACCELERATIONS

\[
\begin{align*}
\dot{X} & \quad \dot{Y} & \quad \ddot{Z} \\
\pm 4.3 & \quad \pm 2.0 & \quad \pm 7.1/ -3.8
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\]

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LOAD COMBINATIONS

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SPARTAN REM

WEIGHT

ADAPTER = 167 LB
BASE ASSY. = 420 LB

TOTAL 587 LB

CALCULATED CYCLES

BERTHING LOAD 4000 N·m-camb 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
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FIGURE 2: MASS PROPERTIES OF ADAPTOR SYSTEM

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**TABLE II**

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9/16 SEP 7, 1983

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**Unit**: POUND-INCHES-SQUARED
MATERIAL PROPERTIES

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3.3 Inconel 718
3.5 4340 STFFL
  MP35N
  416 STAINLESS

ORIGINAL PAGE 18
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# 2219 Aluminum Alloy Sheet and Plate (Bare)

Specifications QQ-A-250/30

## Summary of Room Temperature Properties

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<td>55</td>
</tr>
<tr>
<td></td>
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<tr>
<td>F&lt;sub&gt;su&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>L</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>LT</td>
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<tr>
<td></td>
<td>ST</td>
<td></td>
</tr>
<tr>
<td>F&lt;sub&gt;b&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>L</td>
<td>113</td>
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<td></td>
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<td>91</td>
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<tr>
<td></td>
<td>ST</td>
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<tr>
<td>F&lt;sub&gt;bry&lt;/sub&gt; (ksi)&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>E (Percent)</td>
<td>L</td>
<td>5</td>
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<tr>
<td></td>
<td>LT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ST</td>
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</table>

### Physical Properties (average)

- E (10<sup>6</sup> psi) = 10.5
- E<sub>c</sub> (10<sup>6</sup> psi) = 10.8
- G (10<sup>6</sup> psi) = 4.0
- u = 0.33
- K (BTU-in./hr-sq in.-°F) = 6.2
- a (10<sup>-6</sup> 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>bry</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

\[ K_c = 35 - 60 \]
\[ \Delta K_o = 3.5 \]
\[ n = 3.30 \]
\[ C = 2.19E-3 \]

VARIATION OF \( K_c \) WITH THICKNESS

Nomenclature for growth rate constants is given on page 01. See LMC LMC 000.
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

<table>
<thead>
<tr>
<th>Form</th>
<th>Condition</th>
<th>All</th>
<th>Sheet and Plate</th>
<th>Bar and Forgings</th>
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<tbody>
<tr>
<td></td>
<td>Material</td>
<td>0.500 Inch</td>
<td></td>
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<tr>
<td>Thickness (in.)</td>
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<td></td>
<td></td>
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<tr>
<td>(F_{tu}) (ksi)</td>
<td>L</td>
<td>110</td>
<td>180</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>LT</td>
<td>110</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>(F_{ty}) (ksi)</td>
<td>L</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>LT</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>(F_{cy}) (ksi)</td>
<td>L</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>LT</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>(F_{su}) (ksi)</td>
<td></td>
<td>70</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>(F_{bru}) (ksi)</td>
<td>e/0 = 1.5</td>
<td>200</td>
<td>248</td>
<td>248</td>
</tr>
<tr>
<td></td>
<td>e/0 = 2.0</td>
<td></td>
<td>248</td>
<td>248</td>
</tr>
<tr>
<td>(F_{bry}) (ksi)</td>
<td>e/0 = 1.5</td>
<td>85</td>
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<td>210</td>
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<tr>
<td></td>
<td>e/0 = 2.0</td>
<td></td>
<td>240</td>
<td>240</td>
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<tr>
<td>e (percent)</td>
<td>L</td>
<td>30</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>LT</td>
<td></td>
<td>12</td>
<td>6 (Bar); 10 (Forgings)</td>
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</tbody>
</table>

Physical Properties (average)

- \(E \times 10^6\) psi: 29.5
- \(G \times 10^6\) psi: 29.5
- \(u \times 10^6\) psi: 11.4
- \(\mu\): 0.29
- \(K \text{ (BTU-in./hr-sq in.-°F)}\): 0.53 (STA, 68°F)
- \(a \times 10^{-6}\) in./in.-°F: 7.2 (68°F to 200°F)
- \(C \text{ (BTU/°F)}\): 0.104
- \(\rho \text{ (lb/cu.in.)}\): 0.297
CYCLIC CRACK GROWTH RATE DATA

MATERIAL: 403 INCONEL 718 STA, LTS AND TLS ORIENTATIONS

YS (0.2% 0.5%) KSI 150.0

GROWTH RATE CONSTANTS:

- \( n = 2.7 \)
- \( C = 0.0004 \)
- \( \Delta K_0 = 15.0 \)
- \( K_C = 115.0 \)
**Fracture Mechanics Data**

1. **4340 Plate** 180 ksi min
2. **Inconel 76 Plate** 180 ksi min
3. **MP35N Stainless Rod** 160 ksi min
4. **416 Stainless** 120 ksi

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<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>E(d)</th>
<th>Kc</th>
<th>Dk</th>
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<td>4340</td>
<td>6.3</td>
<td>7.2</td>
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<td>MP35N</td>
<td>5.5</td>
<td>5.5</td>
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<tr>
<td>416 SS</td>
<td>4.00</td>
<td>4.00</td>
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<td></td>
<td>3.40</td>
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<table>
<thead>
<tr>
<th>Material</th>
<th>Dk</th>
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<td>MP35N</td>
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<td>416 SS</td>
<td>40</td>
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\[
\frac{da}{dn} = C(\Delta K)^N
\]

*Report (N5PC)*

11/22/83
<table>
<thead>
<tr>
<th>Title</th>
<th>SPARTAN REM STRESS ANALYSIS</th>
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<td>Dsm</td>
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### MARGIN SUMMARY

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<th>M.S.</th>
<th>PAGE (SEC.)</th>
<th>COMMENTS</th>
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<td>TOGGLE LINK (304606915)</td>
<td>+/−/+</td>
<td>3.21</td>
<td>12</td>
<td>TRANSVERSE LOAD ON LUG (TURNBUCKLE CONNECTION)</td>
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<td>1.95</td>
<td>14.1</td>
<td>SHEAR ON LATCHING POST</td>
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<td>5.9</td>
<td>15.1</td>
<td>TRANSVERSE LOAD ON LUG (G SUPPORT)</td>
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<tr>
<td>TOGGLE LINK (30460694)</td>
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<td>2.51</td>
<td>4.0</td>
<td>TRANSVERSE LOAD ON LUG BENDING</td>
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<td></td>
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<td>.38</td>
<td>5.1</td>
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<td>SHEAR</td>
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<td>1.05</td>
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<td>BELLCRANK (30460696)</td>
<td>TORSION 1521 in-lb</td>
<td>.16</td>
<td>18</td>
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<td>.82</td>
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<td>TORSION ON SHAFT</td>
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<td>COMPRESSIVE STRESSES ON SPLINE</td>
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<td>23</td>
<td>LUG TENSION</td>
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<td>ROUND PIN (30460642)</td>
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<td>SHANK SHEAR</td>
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<td>1.25</td>
<td>31</td>
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<td>1.92</td>
<td>32</td>
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<td>1.3D</td>
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<td>BOLT SHEAR</td>
</tr>
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<td>+/-</td>
<td>.81</td>
<td>32</td>
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<td>33</td>
<td>BENDING</td>
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### Table: Load Case Analysis

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<th>PAGE</th>
<th>COMMENTS</th>
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<tr>
<td>ROD HOLDER SCREWS</td>
<td>+1/-1</td>
<td>1.37</td>
<td>36</td>
<td>INTERACTION</td>
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<td>+1/-1</td>
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<td>38</td>
<td>SHEAR</td>
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<tr>
<td>ADAPTER</td>
<td>-1/-1</td>
<td>2.15</td>
<td>45</td>
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<td>BASE/FILTER INTERFACE</td>
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<td>PIN BUSHING ON ADAPTER</td>
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<td>LOCATOR KEEPD (3040067)</td>
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</table>
LATCHING MECHANISM

PAYLOAD + FRAME (CT = 2500 lb)
2.0 G - Y AXIS ACC.

LATCH MECHANISM REACTS TOTAL Y AXIS LOAD

\[ \text{MAX } P = 5.19 \text{ kips} \] (Ref. p 51 PWN REACTION SUMMARY

**LINEAGE FORCES**

\[ F_T = \frac{P \cdot 2.70}{2.45} = 5.72 \text{ kip} \]

\[ R_y = -F_T \sin 105^\circ = -5.72 \text{ kip} \]

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

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

\[ = \frac{F}{\cos 105^\circ} \]

\[ = 5.72 \text{ kips} \]

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

\[ = -5.19 + .105 \]

\[ R_y = -5.09 \text{ kip} \]
LATCHING MECHANISM

ORIGINAL PAGE IS DE POOR QUALITY

SECTION A-A

MATERIAL : INC. 718

\( F_{tu} = 180 \text{ ksi} \)
\( F_{sa} = 113 \text{ ksi} \)

TOGGLE LINK LUG (30A60694)
(LOADING FROM NASTRAN RUN NOO85111 - APP.I)
SUMMARY P. 51.

MAY Y AXIS PIN REACTION - \( R_y = 5.19 \text{ kips} \)

RESULTING REACTION - FROM P. 1.0

\( R_x = 5.72 \text{ kip} \)
\( R_y = 5.09 \text{ kip} \)

EFFECTIVE LUG WIDTH @ HOLE = \( 2(\beta.65^-) = 1.30 \text{ in} \)
LATCHING MECHANISM - TOGGLE LINK LUG TRANSVERSE LOADS

Ref. fig p2

\[
\begin{align*}
Y &= (\cos 45^\circ) \times 1.25 = 1.221 \\
X &= \tan 45^\circ \Rightarrow X = Y = 1.221 \\
X' &= 1.14 - X = 0.919'' \\
y' &= X' + \tan 30^\circ = 0.919(0.577) = 0.531'' \\
D_1 &= D_4 = 1.4 - Y = 0.221 - 0.531 = 0.648'' \\
\theta &= 0.375'' \\
A_1 &= D_1 \cdot \theta = 0.648(0.375) = 0.243 \text{ in}^2 \\
A_2 &= A_3 = D_2(t) = 0.3375(0.375) = 0.1266 \text{ in}^2 \\
A_4 &= D_4 \cdot t = D_1 \cdot \theta = 0.243 \text{ in}^2 \\
A_V &= \frac{6}{\frac{3}{A_1} + \frac{1}{A_2} + \frac{1}{A_3} + \frac{1}{A_4}} = \frac{6}{\frac{4}{A_1} + \frac{2}{A_2}} = 0.186 \\
A_{br} &= 0.186 \\
A_{br} &= 0.234 \\
\end{align*}
\]
LATCHING MECHANISM (cont.)

TOGGLE LINK LUG (30460674)

From p. 3.0

\[ \frac{A_{tu}}{A_{fg}} = 0.795 \] \[ A_{fg} = 2.03 \text{ in}^2 \]

Shear Breaking

\[ P_{tu} = k_{fu} A_{tu} f_{tu} \]

From graph on p. 3.1 \[ k_{fu} = 0.59 \]

\[ P_{tu} = 0.59 \times 2.03 \times 180,000 = 24.85 \text{ kips} \]

Axial

\[ C/D = 1.44 \]
\[ W/D = 1.3 \]
\[ D = 1.23 \]
\[ A_t = \frac{w-D}{2} = 1.67 \]

From graph on p. 4.2 \[ k_{br} = 0.84 \]

Shear Breaking

\[ P_{tu} = k_{br} A_{br} f_{tu} \]

\[ P_{tu} = 0.84 \times 2.03 \times 180,000 = 36.22 \text{ kips} \]

COMBINED AXIAL & TRANSVERSE LOADING

LOADING ON LUG - (p. 2.0)

\[ R_x = 5.72 \times 2 = 2.86 \text{ kips} \]
\[ R_y = 5.05 \times 2 = 2.55 \text{ kips} \]

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

\[ M.S. u = \frac{1}{R_{A} + R_{br}} - 1 \]
\[ = \frac{1}{0.0522 + 0.082} - 1 = 2.51 \text{ UTL SHEAR BEARING} \]
Material	 Curve No.
15-5PH Steel H150, Ftu = 135 KSI, eu = .11 (T) 1
15-5PH Steel H100, Ftu = 140 KSI, eu = .10 (T) 2
15-5PH Steel H1025, Ftu = 155 KSI, eu = .08 (T) 4
Inconel 718 B&P Sta, Ftu = 180 KSI, eu = .10 (L) 3
Inconel 718 B&P Sta, Ftu = 180 KSI, eu = .06 (T) 5

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, 10 TOGGLE LINK LUG INTERFACE
(NASTRAN RUN NOC0311)

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

BASE INTERFACE

\[ P_{S_1} = P_{S_2} = \frac{5.72}{2} = 2.86 \text{ kip} \]
\[ P_L = \frac{5.72 (2.54) + 5.09}{1.5} \]
\[ P_L = 12.23 \text{ kip} \]
\[ P_1 = -5.72 \left( \frac{2.54}{1.5} + \frac{5.29}{2} \right) \]
\[ P_1 = -7.14 \text{ kip} \]

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**LATCHING MECHANISM**  (cont.)

**LUG BENDING @ BASE**

**SECTION A - A**

\[
A = 2.8 \times 1.38 = 1.064 \text{ in}^2
\]

\[
I_1 = \frac{bh^3}{12} = \frac{2.8 \times (1.38)^3}{12} = 0.0128 \text{ in}^4
\]

\[
I_2 = \frac{3h}{12} = \frac{3}{12} \times 1.38 = 0.593 \text{ in}^4
\]

\[
I/c = \frac{0.125}{0.19} = 0.657 \text{ in}^3
\]

\[
I_2/c = \frac{0.593}{0.657} = 0.91 \text{ in}^3
\]

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

\[
M_{11} = R_y \left[ (1.0) - \frac{38}{2} \right] = 5.09 \times (0.81) = 4.12 \text{ in-kip}
\]

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

\[
S_{b1} = \frac{M_{11}}{I/c} = \frac{4.12}{0.657} = 6.24 \text{ ksi}
\]

\[
S_{b2} = \frac{M_{12}}{I_2/c} = \frac{14.53}{0.91} = 15.89 \text{ ksi}
\]

\[
S_{b1max} = 61.49 + 29.29 = 90.78 \text{ ksi}
\]

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

\[
F_{bu} = 270 \text{ ksi} \\
R_b = \frac{(2)(90.78)}{270} = 0.67 \\
R_t = \frac{2(4.78)}{180} = 0.053
\]

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

No  A  V  Ax  Ay  Ay²  Ty
1  3.0  25  .037  .187  1.062
2  4.2  105  .471  .482  .042

Σ = 1.348 in
Cmax = 1.252

Jy = 1.350 in²

\[ \frac{1}{C_{max}} = 0.777 \text{ in}^{-3} \]

\[ M_{HA} = (P_2 - P_1) \cdot 1.345 = 5.07(1.345) \]

\[ \delta_b = \frac{6.85}{2.79} = 2.4155 \text{ KSI} \]

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

\[ S_a = \frac{74.5}{2(24.55)} - 1 = 0.92 \]

MOUNTING BOLT LOADS

From NASTRAN RUN NCC00311
\[ R_x = 5.72 \text{ KIP} \]
\[ R_y = 5.01 \text{ KIP} \]

Due to Ry LOAD
\[ P_2(2.15) + 0.65P_1 = 5.72(2.54) \]
\[ P_1 = 0.65P_2 \]

\[ 2.15P_2 + 0.65^2P_2 = 14.53 \text{ K} \]
LATCHING MECHANISM (cont.)

LUG MOUNTING BOLTS (cont.)

\[
\begin{align*}
2.346 P_2 &= 14.53 \\
2 P_2 &= 6.19 \text{ kip} \\

P_1 &= \frac{6.5}{2.15} (6.19) = 1.87 \text{ kip} \\
\end{align*}
\]

Due to Lg. tolerance (ref. fig. on previous page)

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

\[
\begin{align*}
P_2 &= 2.545 + 6.19 = 8.735 \text{ kip} \\
P_1 &= 2.545 + 1.87 = 4.415 \text{ kip}
\end{align*}
\]

BOLTS

\[
\text{4/16 DIA: } N_{A} = 173.72 \\
N_{u} = 25.2 \text{ kip} \\
f_{s_{us}} = 16.25 \text{ kip}
\]

Since bolts are tested items: \( F_S = 1.4 \)

\[
\begin{align*}
\text{II} & \text{S.}\text{s.} = \frac{23.2}{1.4 (8.735)} - 1 = 0.897 \text{ Tension} \\
\text{Bolt shear} &= \frac{5.72}{2} = 2.86 \text{ kip/bolt} \\
\text{II} & \text{S.}\text{s.} = \frac{16.25}{1.4 (2.86)} - 1 = 3.05 \text{ Shear}
\end{align*}
\]
LATCHING MECHANISM (cont.)

TOGGLE LINK LUG INTERFACE (cont.)

BOLT INTERACTION

\[ R_t = \frac{1.4 (8.76)}{2.3.2} = 1.527 \]

\[ R_s = \frac{1.4 (2.86)}{16.25} = 0.246 \]

\[ M.S_{ult} = \frac{1}{0.71} = 1.316 \]
LATCHING MECHANISM

TOGGLE LINK (30A60695)

FROM NASTRAN SUMMARY

\[ F_t = \frac{5.19 (2.2)}{2.45} = 5.72 \text{kips} \]

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

\[ \text{MATL 4340 STL} \]

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

\[ A_{brg} = 0.433 (0.313) = 0.15 \text{in}^2 \]

\[ A_{t} = (1.3 - 0.438)t = 0.296 \text{in}^2 \]

Ref p 3 for procedure

\[ A_1 \geq A_4 = 3.43 (0.61)^2 = 2.1 \text{in}^2 \]

\[ A_3 \geq A_2 = (1.65 - 0.219)t = 0.148 \text{in}^2 \]

\[ A_{avg} = \frac{6}{\frac{1}{A_1} + \frac{1}{A_2} + \frac{1}{A_3} + \frac{1}{A_4}} = \frac{0.184}{A_{brg}} \]

\[ = 1.23 \]
LOW ALLOY STEELS
4340, 4140, 300M & Others
Ftu > 300 ksi

Curve (A) - Approximate Strength. If $K_{tru}$ 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.

$e_u = \text{Ultimate Elongation}$

$e_u \geq 0.06$

$K_{tru} = 0.6$

300M Only

Other Low Alloy Steels

$0.06 > e_u \geq 0.03$

$A_{av}/A_{br}$

FIGURE 7d EFFICIENCY FACTORS OF LUGS FOR TRANSVERSE LOAD
LOW-ALLOY STEELS
TRANVERSE LOADS - SHEARBEARINGS

\[ T_{RU} = k_{RU} A_b R_b \text{ ft-lb} \]

From graph on p. 11, \( k_{RU} = 1.07 \)

\[ T_{RU} = 1.07 (1.15)(150) = 24.10 \text{ kip} \]

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

LUG DIA. (1.860698) SHEAR

From p. 110, \( R_x = 5.72 \text{ kip} \)

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

\[ D_{IN} \text{ DIA} = 1.625'' \]

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

\[ P_s = \sqrt{(5.72^2 + 5.09^2)} = 7.66 \text{ kip} \]

\[ S_s = \frac{4/3 P_s}{2(A)} = \frac{4}{3} \frac{7.66}{2(0.306)} = 16.69 \text{ ksi} \]

\[ M.S_{su} = \frac{113}{2(16.69)} = 1 = 2.37 \text{ ULT SHEAR} \]
LATCHING MECHANISM (cont.)

TOGGLE LINK PIN (30160700)

**SHEAR**

\[ F_{t} = 5.72 \text{ kN} \]

\[ P_{in} = 0.038 \text{ in} \]

\[ d = 0.038 \text{ in} \]

\[ F_{min} = \frac{3(5.72)}{2(0.038)} = 25.42 \]

\[ M_{S,U} = \frac{113}{(25.42)} = 1.22 \text{ ULT SHEAR} \]
BENDING - ref MSFC STRUCTURES MANUAL, 1B2

\[ \text{from p. 14} \]
\[ P = 5.72 \text{kips} \]
\[ M = 1804 \text{kips-in} \]
\[ S_{1b} = \frac{Ml_y}{I} = \frac{1804 \times (2.219)}{1.0018} = 97.82 \text{kips-ft} \]
\[ I = 0.0018 \text{ in}^4 \]
\[ y = \frac{438}{2} = 219 \]
\[ MS = \frac{300}{2(97.82)} - 1 = -5.3 \]
LATCHING MECHANISM cont.

TOGGLE LINK (cont.) (30A60 695)

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

\[ A = \frac{1.82}{2} = 0.91 \text{ in}^2 \]
\[ I = 0.528 \text{ in}^2 \]

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

\[ \sigma_{\text{min}} = \frac{4 \times P}{3 \times A} = \frac{4 \times 5.72}{3 \times 0.91} = 14.44 \text{ ksi} \]

\[ \text{ULT SHEAR} = \frac{85.5}{2 \times 14.44} - 1 = 1.95 \text{ kips} \]
LATCHING MECHANISM (only)

**TOGGLE LINK**

**LUG PIN HOLE (.625")**

SET P. 3 for procedure

assumed \( D_1 = D_2 = D_3 = 0.3375 \)

\[ A = 1.817 (0.3375) = 0.613 \text{ in}^2 \]

\[ \frac{A_{AV}}{A_{BR}} = \frac{A}{A_{BR}} = \frac{1.613}{1.14} \approx 1.41 \]

\[ A_{BR} = A_{AV} (1 - 0.52) = 1.14 \text{ in}^2 \]

\[ P_{Tu} = k_{tu} A_{BR} P_{Tu} = 1.52 (1.14) (150) = 88.92 \text{ kips} \]

**AXIAL**

\[ \frac{P}{D} = \frac{0.5}{0.625} = 0.8 \]

\[ \frac{W}{D} = \frac{1.3}{0.625} = 2.08 \]

\[ \frac{t}{D} = \frac{0.325}{1.14} = 0.283 \]

\[ A_e = (1.3 - 0.625) (1.817) = 1.23 \text{ in}^2 \]

from graph on P. 153 \( k_t = 0.74 \)

\[ P_{Tu} = k_t A_e P_{Tu} = 0.74 (1.23) (150) = 173.4 \text{ kips} \]
LATCHING MECHANISM (cont.)

TOGGLE LINK - LUG PIN HOLE (cont.)

COMBINED AXIAL & TRANSVERSE LOADS

\[
P = 4 \\
R_x = 5.72 \text{ kips} \\
R_y = 5.09 \text{ kips} \\
\frac{P}{A} = \frac{2(5.72)}{113.4} = 0.07 \\
R_{12} = \frac{5.02(2)}{88.92} = 0.114 \\
M.S. = 1 \left( \frac{1}{(0.16 + 0.114)^{6.25}} \right) - 1 = 5.9 \text{ ud}
\]
LATCHING MECHANISM cont.

LUG PIN (30A60678)

BENDING

\[ t_1 = 0.35^- 1.817 \]

\[ g = 9.4 \times (1.896 - 1.817) = 5.04 \]

\[ P_{tr} = 28.89 \]

Ref MSFC STRUCT. MANUAL p B2.5

\[ \mu = \left[ \frac{8 - \frac{1}{2}}{\frac{1}{2}} \right] \frac{0}{t_2} = \left( \frac{6.25 - \frac{1}{2}}{6.25} \right) \frac{1.817}{1.817} = 0.27 \]

From graph B2.1.0-6

from p.

\[ P_u = 88.7 \text{ psi} \]

\[ \frac{P_u}{\mu} = 52 \]

From graph B2.1.0-6

MSFC STRUCT. MANUAL
\[ n = 0.52 \]

\[ b = 0.35 + 0.47 + 0.52 \left( \frac{1.817}{4} \right) - 1.458 \]

\[ M = \frac{P_u b}{2} = 7.16 \left( 0.458 \right) = 1.75 \text{ IN-KIPS} \]

\[ S_b = 20 \left( 0.3125 \right) = 72.9 \text{ KSI} \]

\[ K = 1.7 \]

\[ F_{bu} = 300 \text{ KSI} \]

PLASTIC BENDING

\[ M.S.u = \frac{300}{72.9(2)} - 1 = 1.05 \]

ULT
Material | Curve No.  
---|---
4130 & 8630 Steel Ftu ≤ 200 KSI (L,T) | 1
4340 Steel Ftu = 260 KSI (L) | 2
H-11 Steel Ftu = 260 KSI (L) | 3
18-8 Stainless Steel, Full hard | 4
18-8 Stainless Steel, Full hard | 5
(Note: for 1/4, 1/2, & 3/4 hard, interpolate between curve no. 4 and 5)
300 M Steel Ftu = 270 KSI A<100 sq.in. (T) | 6
300 M Steel Ftu = 270 KSI 100 ≤ A ≤ 225 sq.in. (T) | 7
300 M Steel Ftu = 270 KSI A>225 sq.in. (T) | 8
4340 Steel Ftu = 260 KSI (T) | 9

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

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

**MAX TENSION LOAD**

- Assumes load reversal in latch

\[ \frac{Q}{t} = \frac{5.625}{.47} = 1.28'' \]
\[ D = \frac{.438}{.47} = .93'' \]
\[ \omega = \frac{1.125}{.47} = 2.57'' \]

**Shear Bearing**

\[ P_{BRU} = \frac{K_{BRU}}{K_{BE}} A_t F_{tu} \]
\[ = 184 (0.306)(150000) \]
\[ = 32,134 \text{ lb} \]

**Tension**

\[ P_{tu} = K_t A_t F_{tu} \]
\[ = 1.125 (0.323)(150000) \]
\[ = 44,332 \text{ lb} \]

\[ M.S. = \frac{32,134}{(2)(5.72)} - 1 = 1.81 \text{ ULT SHEAR BEARING} \]

TURNBUCKLE BARREL ADEQUATE BY INSPECTION.

*Measured off assembly 30A60679*

*Ref MSFC STRUCT. MANUAL B2*
LATCHING MECHANISM (cont.)

THREADED SECTION

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

\[ M.S. u = \frac{150}{(2)(23.83)} - 1 = 2.15 \]
**LATCHING MECHANISM (cont.)**

**BELL CRANK**  
(30A60696)

\[ T = 152 \text{ in.-lb} \]

**SPLINE STRESSES**

Shear stress & pitch dia of teeth:  
Ref. Machinery's HDBK p.1023

\[ f_s = \frac{4TK_aK_m}{DNL_e}tK_f \]

\[ K_a = 1.2, \quad K_m = 1.0, \quad K_f = 1.0 \]

\[ L_e = 0.70, \quad t = 0.186 \]

(Assumes \( \frac{1}{2} \) of teeth reaching \( T \))

\[ f_s = \frac{4(152)(1.2\times1.0)}{.75(6\times.70)(.186\times1.0)} \]

\[ f_s = 12460 \text{ psi} \]

\[ f_{su} = 40 \text{ ksi} \]  
(Ref. Machinery's HDBK TABLES)

\[ M . S . u = \frac{40}{2(12.46)} - 1 = 0.60 \text{ ULT} \]
LATCHING MECHANISM (cont.)

MAXIMUM SPLINE TORQUE CAPABILITY

**MATL - 4340 STEEL**

- $F_{tu} = 180$ ksi
- $F_{su} = 108$ ksi
- $F_{cy} = 173$ ksi

$L = .75$ in, $h = .094$ in

$W = .188$ in

**FOR SHEAR FAILURE**

$$T_s = F_d N, \quad N = 3 \text{ SETS OF TEETH ON SPLINE}$$

$$S_s = \frac{1.5 F}{A_s} = \frac{1.5}{.75(1.188)} F$$

$$F = \frac{.75(1.188)(108000)}{1.5} = 10,150 \text{ lb}$$

$$T_s = 10,150 (.75)(3) = 22,840 \text{ in-lb}$$

**ASSUMING 1/2 OF SPLINE TEETH TRANSMIT TORQUE**

$$T_s' = \frac{T_s}{F_s (2)} = \frac{22,840}{2(2)} = 5,710 \text{ in-lb}$$

**COMPRESSION FAILURE**

$$T_c = F_d N, \quad S_c = \frac{F}{A_c} \Rightarrow F = A_c F_c = .75 (.094)(173,000)$$

$$F = 12,196 \text{ lb}$$

$$T_c = 12,196 (.75)(3) = 27,440 \text{ in-lb}$$

$$T_c' = \frac{27,440}{2(2)} = 6,860 \text{ in-lb}$$
SHAFT DESIGN TORQUE

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

From \( \text{Eq} \), LIMIT TORQUE = 5710 in-lb

\[ M.S. = \frac{5710}{4000} - 1 = 1.42 \]

TORSION ON MINIMUM SHAFT SECTION

\[ S_{\text{max}} = \frac{16T}{\pi d^3} = \frac{16(4000)}{\pi (1.7499)^3} \]

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

SHAFT - 1/28" CRES.
\[ F_{u} = 140 \text{ ksi} \]
\[ F_{s} = 91 \text{ ksi} \]

\[ M.S. u = \frac{11}{48.3} - 1 = 0.88 \]
LATCHING MECHANISM (cont.)

BELLCRANK SPLINE cont.

Compressive stress on sides of teeth:

\[ f_c = \frac{2T \cdot K_{m} \cdot K_{a}}{9 \cdot D \cdot N \cdot L \cdot h \cdot K_{f}} \]

\[ = \frac{2(1521)(1.7)(1.0)}{9(1.75)(6)(1.0)(0.94)(1.0)} \]

\[ f_c = 1370 \text{ psi} \]

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

\[ M_{Su} = \frac{3.0}{2(1.87)} - 1 = 0.09 \]

TENSILE STRESS IN SPLINE \ref: Machinery's Handbook p 1024

RADIAL TENSILE STRESS \[ \sigma_r = \frac{T \cdot \tan \theta}{\pi \cdot D \cdot W} \]

\[ \theta = \text{PRESSURE} \Delta = 30^\circ \]
\[ D = 1.75 \text{ in}, \quad L = 1.75 \text{ in}. \]
\[ z = 0.562 \text{ in}. \]

\[ \sigma_r = \frac{1521(1.00)(30^\circ)}{\pi(1.75)(0.562)(1.75)} = 884 \text{ psi} \]
LATCHING MECHANISM (cont.)

BELLOWS SPLINE (cont.)

BEAM LOADING TENSILE STRESS

\[ S_{t3} = \frac{4T}{D^2 Le Y} \]

\[ Le = 0.70, Y = 1.5 \implies S_{t3} = \frac{4(1521)}{0.75^2(0.70)(1.5)} = 10300 \text{ psi} \]

TOTAL TENSILE STRESS

\[ S_t = \frac{L_1 K_{m1} (S_t + S_{t1})}{K_p} \]

\[ K_a = 1.2, K_p = 1.0, K_m = 0.7 \]

From p. 13 \[ S_t = 884 \text{ psi} \]

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

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

\[ M.S. n = \frac{45}{2(13.42)} - 1 = 0.167 \]
LATCHING MECHANISM (CAT. )

BELLCRANK LUGS

MAX TENSION LOAD CONSERVATIVELY

Assuming, LOAD REVERSAL

From P. 4

\. 5\, 2.86 \, \text{lb} / \text{in}

\begin{align*}
\sigma & = \frac{5}{2.86} = 1.71 \\
\epsilon & = \frac{1.71}{.438} = 3.92
\end{align*}

D = .438, \, 94

t = .468

A_{BRG} = .438 (1.468) = .205 \, \text{in}^2

A_t = (1.5 - .438 \times 1.468) = .50 \, \text{in}^2

HEAVY BEARING

K_{BR} = 1.6

P_{BRU} = K_{BR} \times A_{BRG} \times F_{tu} = 1.60 \times .205 \times 150000 = 49.2 \, \text{kips}

TENSION

K_t = .53

P_{tu} = K_t \times A_t \times F_{tu} = .53 \times .50 \times 150000 = 69.75 \, \text{kips}

\begin{align*}
\sum S_{tu} & = \frac{49200}{2 \times 5780} - 1 = 3.30
\end{align*}

LUG BENDING @ Toggle Adequate by Inspection!
LATCHING MECHANISM (cont.)

ROUND PIN - (30A60642)

SHFAR PIN DIA = 1.875 IN (SHANK)

(FROM NASIONAL RUN NO005/11
REF P. 51)

\[ F_x = 11.18 \text{ kips} \]
\[ F_y = 7.41 \text{ kips} \]

\[ R = \sqrt{11.73^2 + 7.91^2} = 14.15 \text{ kips} \]

\[ A = \frac{\pi (1.875)^2}{4} = 1.60 \text{ in}^2 \]

\[ \sigma_{\text{max}} = \frac{4}{3} \frac{R}{A} = \frac{4}{3} \frac{14.15}{1.60} = 31.44 \text{ ksi} \]

\[ \text{Ult. SHTFAR} \]

\[ \frac{1.13}{(31.44)} = 1 = 0.78 \text{, ULT SHTFAR} \]

SQUARE PIN (SAME SHANK AS ROUND PIN)

SAME M.S.
LATCHING MECHANISM (cont.)

ADAPTER/PIN INTERFACE

(from NASTRAN RUN N000311)
ref. p. 5

LOAD CASE 7
P,IN = 9.47 kips

SHEAR TEAR OUT

\[ \sigma_{\text{smax}} = \frac{3}{2} \frac{P}{A_s} \]

\[ = \frac{3}{2} \left( \frac{9.47}{1.35} \right) \]

\[ = 10.27 \text{ ksi} \]

2219-T8 AL
Ftu = 63 ksi
FSu = 37 ksi

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

Ref p. 51 for pin reactions

\[ P_H = 5.15 \text{ kip} \]
\[ P_V = 11.73 \text{ kip} \]
\[ I = 1.3 \text{ in}^3 \]

\[ M_{\text{min}} = 1.0P_H - 0.72P_V(1.1) \]
\[ = 5.19 - 12.9 \]
\[ = 7.713 \text{ in}-\text{kip} \]

\[ S_b = \frac{2.2}{3} = 25.7 \text{ ksi} \]

\[ S_t = \frac{P_V}{A} = \frac{11.73}{3.6} = 3.26 \text{ ksi} \]

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

\[ R_b = \frac{2(25.7)}{11} = .53 \]
\[ R_t = \frac{2(8.26)}{62} = .11 \]

\[ M.S.u = \frac{1}{S_b + S_t} = 1 = 0.56 \text{ ULT} \]
LATCHING MECHANISM (CONT.)

BEARING ON CONICAL START

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

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

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

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

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

\[ \text{MATL: 2219 T87 AL} \]
\[ F_{BPUL} = 99 \text{ ksi} \]

\[ M_{SCI} = \frac{99}{2 \times (2.51)} - 1 = \text{ LARGE} \]
ADAPTOR BASE PINS

From p. 51 MAX PIN REACTIONS

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

\[ \theta = 1.63^\circ \]

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

\[ TYP A \]

\[ 1.25 \text{ DIA THRU} \]

\[ \theta_{ATE} = 0.625 \]

\[ 0600615 \]
**ADAPTOR BASE PINS (cont.)**

**SHEAR ON MOUNTING BOLTS**

\[ P_s = \sqrt{11.73^2 + 7.9^2} = 14.14 \text{ kip} \]

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

\[ M, S_u = \frac{16.25}{2 (3.54)} = 1.30 \text{ UT SHEAR} \]

**BEARING**

\[ A_{BERG} = 0.437 (0.5) = 0.2185 \text{ in}^2 \]

\[ \sigma_{BF} = \frac{3.54}{0.2185} = 16.2 \text{ ksi (LOW)} \]

**SHEAR TEAR OUT IN PLATE**

\[ t = 0.44" \]

\[ A_s = 2x_t = (2)(0.50)(0.56) = 0.56 \]

\[ 2x = (5 - \frac{0.56}{2.8})(2) = 0.56 \]

\[ \sigma_s = \frac{3}{2} \frac{11.73}{0.56} = 31.42 \text{ ksi} \]

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

(FROM NAVITRON FOR NOCO-311)

P_{H1} = 7.91 kip
P_{Vv} = 11.73 kip

Refer diagram on p. 24:

\[ A_S = \left(1.625 \times 2 \times 0.56\right) = 0.70 \]

MAT'L - INCONEL 718
\[ F_{uH} = 150 \text{ ksi} \]
\[ F_{su} = 113 \text{ ksi} \]

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

\[ N_{H,S} = \frac{113}{2(25.14)} - 1 = 1.25 \]
Launching Mechanism (cont.)

Round Pin/Adapter Learing

\[ A_{brg} = 0.875 \times (1.0) = 0.875 \text{ in}^2 \quad \text{(Ref. Fig. P.48)} \]
\[ F_{brg} = \frac{14.15}{0.875} = 16.17 \text{ ksf} \]
\[ F_{bru} = 94.5 \text{ ksf} \]
\[ M_{S_{bru}} = \frac{94.5}{2(16.17)} - 1 = 1.92 \text{ Ultimate Bearing} \]

Square Pin Plate (30AG0644)

Shear Tearout

(from National Standards p.49)

Max Verte Shear = 11.69 kip

\[ A_5 = (1.075 - 0.625 \times 0.625)^2 = 0.5625 \text{ in}^2 \]
\[ S_{s_{max}} = 11.69 \times \frac{3/2}{0.5625} = 31.17 \text{ ksf} \]
\[ F_{su} = 113 \text{ ksf} \]
\[ M_{S_{su}} = \frac{113}{2(31.17)} - 1 = 81 \text{ Ultimate Shear} \]
LATCHING MECHANISM, cont.  

**SC PIN PLATE - BENDING**
(Based on material of previous page)

\[ I_{xx} = \frac{0.45^3 (0.625)}{12} = 0.004746 \text{ in}^4 \]

\[ I/c = \frac{0.004746}{0.45/2} = 0.0211 \text{ in}^3 \]

**Using Pt Load @ Center**

\[ N = \frac{P_l}{8} = \frac{11.69(1.6)}{8} = 2.358 \text{ in-kip} \]

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

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

\[ F_{tu} = 180(1.7) = 386 \]

\[ N/1_{xx} = \frac{204}{2(111.75)} = 0.37 \]

**Shear**

\[ R = \frac{11.69}{5.895 \text{ kip}} = 2.00 \]

\[ S_s = \frac{3}{2} \left( \frac{5.895}{0.625 (0.45)} \right) = 31.17 \text{ ksi} \]

\[ N/1_{xx} = \frac{113.4}{2(31.17)} = 0.82 \]

**INC 718**

\[ F_{su} = 113.4 \text{ ksi} \]
RODS POSITION HOLDER

SECTION A-A

MOUNTING BASE

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

1.25 RAD TYP.

.316 DIA (4 PICS)

SINGLE ROD HOLDER
30A60648
BASE ROD
POSITIONS 2 & 3

SECTION A - A

DOUBLE ROD BASE
LOCATOR ROD BASE FIG.

SINGLE ROD BASE (30A62647)
MOUNTING FASTENERS -

(4) 5/16-24 SCREWS M357960-106

Pu = 4.64 kip
Psu = 4.06 kip (based on 53 ksi CRES STEEL)

MAX ROD LOAD = 1560 lb (ref. ED23-88-42)

Moment @ BASE - (see Fig p 34)

\[ M = 1560 (3 + 1.6) = 7176 \text{ in.-kip} \]

TENSION -

\[ \frac{P}{\text{FAS.TENSILE}} = \frac{7176}{2.34(2)} = 1.6 \text{ kip} \]

Shear

\[ P_c = \frac{1560}{4} = 39 \text{ kip} \]

INTERACTION (ref p 49.1)

\[ T = \frac{2(1.6)}{4.16} = 0.69 \quad R_s = \frac{2(0.37)}{4.06} = 0.27 \]

\[ M.S. = \frac{0.90}{0.69} - 1 = 0.39 \text{ INTERACTION} \]
LOCATOR ROD BASE FIG. (cont.)

MOUNTING FASTENERS

DOUBLE ROD BASE - 30A60648

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

ULT SHARK

\[ P_5 = \frac{1560(2)}{4} = 780 \text{lb/FASTENER} \]

\[ \rho = \sqrt{4.0^2 + \left(\frac{3.5}{2}\right)^2} = 2.52 \text{ in.} \]

\[ P_{st} = \frac{1560(5.7)}{4 \times 2.52} = 835.7 \text{ lb/FASTEN.} \]

\[ \tan \theta = \frac{1.535}{2.10} = 0.7675 \]

\[ \theta = 39.5^\circ \]

\[ P_{sv} = 835.7 \cos (39.5^\circ) = 663.0 \text{ lb} \]

\[ P_{sth} = 835.7 \sin (39.5^\circ) = 508.7 \text{ lb} \]

RESULTANT SHEAR

\[ P_{sr} = \sqrt{(P_{sv} + P_{sv})^2 + P_{sth}^2} = \sqrt{(663 + 780)^2 + (508.7)^2} = 1580.0 \text{ lb} \]
LOCATOR ROD BASE FIG. (cont.)

MOUNTING FASTENERS

DOUBLE ROD BASE (cont.)

From p. 13, \( P_{sa} = 1,530 \text{ kips} \)

\( \frac{1}{16} - 24 \) FASTENERS

\( P_{tu} = 4,164 \text{ kip} \)

\( P_{su} = 4,006 \text{ kip} \)

\[ M_s.u = \frac{4,066}{2(1.53)} - 1 = 0.33, \text{ ULT SHEAR} \]
GUIDE RODS (301160649)  

MATERIAL: 2219-T87 AL  

$F_{tu} = 63$ ksi, $F_{su} = 38$ ksi

LOAD = 1560 lb  

5" from base

BOLT Dia. = 1"

$I = \pi (1)^4 / 64 = 0.049 \text{ in}^4$

$s = \frac{1560(3)(5)}{0.049} = 47.76$ ksi

Plastic bending (ref p. 4.27)

$F_{bu} = 47$ ksi

$\delta_{pl} = \frac{17}{2(47.76)} - 1 = 0.015$  

Plastic bending
SPARTAN REM

REM BASE MOUNTING BOLTS

Original page is of poor quality.

From p. 51

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

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

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

\[ R_s = \frac{2 \times 3.85}{33.15} = 0.23 \]
\[ P_t = 2 \times 11.08 = 22.16 \]

INTERACTION - (ref 4.9.1)

\[ M.S.u = \frac{0.88}{0.45} - 1 = 0.96 \]
REM BASE / PDM FASTENS

NAS 19560 C BOLT 5/8" DIA
Ptu = 49,000 lb
P10 = 13,500 lb

From Table 3, MAX TENSILE LOAD IS Pt = 10,660 lb

Pt = 4.24 lb
P5 = 5.69 lb

Ps = \sqrt{4.24^2 + 5.69^2} = 7.11 lb

Rt = \frac{10.66}{49.0} = 0.22

Ps = 2(7.11) = 14.22

111.5 = \frac{7.1}{4.35} - 1 = 0.63 \text{ ULT INTERACTION}

For Nut - MS21045C 5/8-18UNF-3B

Pcu = 34,130 lb

111.5 = \frac{34.13}{2(10.66)} - 1 = 0.60 \text{ ULT TENSION}
## ELM Adapter Stress Summary

### Original Page 18

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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 STRESSSES

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

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

\[ \text{Ftu} = 62 \text{ ksi} \]

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

REAR BASE STRESSSES

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

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

\[ M.S.u = \frac{62}{2 (13.51)} - 1 = 1.29 \]

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PREPARED BY: DSM  DATE: 5/84
CHECKED BY: EIC  DATE: 6/84
APPROVED BY:
CHECK STRESSES AROUND HOLE TO BE DRILLED IN 1/16 INFER

FROM NASTRAN MODEL ELEMENT 48
STRESSES @ PTS

\[ \sigma_{B} = \left( \frac{-1453.8 - 265.3}{5.5} \right) x + 265.3 = -312.6 \times + 265.3 \]
\[ \sigma'_{c} = 5.5 - 3.625 = 1.875 \]
\[ \sigma'_{B} = -320.8 \text{ psi} \]

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ADAPTER HOLE STRESSES (cont.)

STRESS IN SECTION C'-D
\[ \sigma_{C'-D} = \left( \frac{320.8 + 1403.7}{3.4} \right) \times -320.8 = \frac{507.2}{3.4} \times -320.8 \]

STRESS IN SECTION F'-E
\[ \sigma_{F'-E} = \left( \frac{1453.8 + 623.3}{5.75} \right) \times -1453.8 \]
\[ = \frac{361.2}{5.75} \times -1453.8 \]

\[ \sigma_{TOTAL} = \sigma_{B} + \sigma_{AXIAL} \]

FOR STRESSES @ HOLE EDGE, \( x = 1.875 - R \)
\[ = 1.875 - 1.375 = 1.5 \]
\[ \sigma_{C'-D} = 507.2(1.5) - 320.8 \]
\[ = 376.6 \text{ psi} \]
\[ \sigma_{F'-E} = 361.2(1.375) - 1453.8 \]
\[ = -957.15 \text{ psi} \]

TOTAL STRESS
\[ \sigma_{T} = 376.6 + 793.2 = 1166.8 \text{ psi} \] (C'-D)
\[ \sigma_{T} = -957.15 + 793.2 = -163.95 \text{ psi} \] (E'-F)
ADAPTER HOLE STRESSES (cont.)

For section C'-D (inner wall)

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

\[ \frac{e}{c} = \frac{1.875}{1.525} = 1.23 \]
\[ \frac{f}{c} = \frac{0.50}{1.875} = 0.2667 \]

From graph p:

\[ \sigma_{max} = 3.26 \]

For section E-F (outer wall)

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

\[ \frac{e}{c} = \frac{3.875}{1.875} = 2.067 \]
\[ \frac{f}{c} = \frac{5}{1.875} = 2.667 \]

From graph p

\[ \sigma_{max} = 3.24 \]
ADAPTER HOLE STRESSES (cont.)

USING STRESS CONCENTRATIONS -

SECTION C-D

\[ \tau_{\text{max}} = 3.265 \]

\[ \tau_{C'D} = 1166.8 \] \[ \therefore \tau_{\text{max}} = 3.26(1166.8) = 3803.8 \text{ psi} \]

SECTION E-F

\[ \tau_{\text{max}} = 3.245 \]

\[ \tau_{E'F} = 163.95 \text{ psi} \]

\[ \therefore \tau_{\text{max}} = 3.24(163.95) = 531.20 \text{ psi} \]

\[ M, S, u = \frac{63000}{(2)(3803.8)} - 1 = 7.28 \]
Ki BASED ON NET SECTION A-B
ASSUMING SECTION CARRIES LOAD \( \frac{\sigma_{ch}}{1- (\frac{\sigma}{\sigma})^2} \)
\[ K_i = \frac{\sigma_{max}}{\sigma_{net}} = \frac{\sigma_{max}}{\sigma_0} \left( \frac{(1-\frac{\sigma}{\sigma})}{\sqrt{1-(\frac{\sigma}{\sigma})^2}} \right) \]

STRESS CONCENTRATION FACTOR, Ki
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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<td>Fx</td>
<td>2.45</td>
<td>2.81</td>
<td>4.05</td>
<td>4.41</td>
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<tr>
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<td>Fz</td>
<td>6.81</td>
<td>6.28</td>
<td>6.81</td>
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<tr>
<td>205</td>
<td>Fy</td>
<td>-4.11</td>
<td>-7.4</td>
<td>-10.3</td>
<td>-13.2</td>
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<td>Fx</td>
<td>4.1</td>
<td>7.4</td>
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<td>13.2</td>
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<tr>
<td></td>
<td>Fz</td>
<td>6.81</td>
<td>6.28</td>
<td>6.81</td>
<td>7.2</td>
</tr>
</tbody>
</table>

- Load factors applied to payload, adapter & base cases.
- All forces in LBS.
- Fx indicates tension in fasteners.

(From NASBEAU Run 0003111 4/188)
FRACTURE ANALYSIS
<table>
<thead>
<tr>
<th>DRAWING NO.</th>
<th>DESCRIPTION</th>
<th>MATL</th>
<th>CLASSIFICATION</th>
<th>RATIONALE</th>
<th>PFC CAT.</th>
<th>CRITICAL CRACK SIZE (IN)</th>
<th>INSPECTION LIMIT (IN)</th>
<th>TYPE</th>
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<tbody>
<tr>
<td>30AG0641</td>
<td>ADAPTER</td>
<td>2219-T87AL</td>
<td>X</td>
<td>REDUNDANT LOAD PATH</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>30AG0648</td>
<td>BASE</td>
<td>2219-T87AL</td>
<td>X</td>
<td>REDUNDANT LOAD PATH</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30AG0647</td>
<td>BELCRANK SHAFT</td>
<td>A286 CRES</td>
<td>X</td>
<td>LOW STRESSES</td>
<td>X</td>
<td>.455</td>
<td>.25</td>
<td>MP</td>
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<tr>
<td>30AG0646</td>
<td>BELCRANK</td>
<td>4340 STL</td>
<td>X</td>
<td></td>
<td>X</td>
<td>.23</td>
<td>.05</td>
<td>ET</td>
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<td>30AG0649</td>
<td>TURNBUCKLE</td>
<td>4340 STL</td>
<td>X</td>
<td>AT ONLY 5% OF PRELOAD</td>
<td>X</td>
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<td>TOGGLE LINK</td>
<td>4340 STL</td>
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<td>.05</td>
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<td>INCONEL 718</td>
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<td>.1</td>
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<td>.05</td>
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<td>LOW COMPRESSION LOAD</td>
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<td>.1</td>
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<td>INCONEL 718</td>
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<td>.104</td>
<td>.1</td>
<td>ET</td>
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<td>.1</td>
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<td>.1</td>
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<tr>
<td>NAS19600</td>
<td>MOUNTING BOLTS</td>
<td>A286 CRES</td>
<td>X</td>
<td>REDUNDANT LOAD PATH</td>
<td>X</td>
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<td>AFT GUIDE - 1</td>
<td>2219-T87AL</td>
<td>X</td>
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<td>Y</td>
<td>.18</td>
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<td>PLATE BOLTS</td>
<td>A286 CRES</td>
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<td>X</td>
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<td>Y</td>
<td>.18</td>
<td>.10</td>
<td>ET</td>
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</table>

* NO CRACK GROWTH

ET - EDDY CURRENT
MP - MAGNETIC PARTICLE
<table>
<thead>
<tr>
<th>DRAWING NO</th>
<th>DESCRIPTION</th>
<th>MATL</th>
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<th>CRITICAL CRACK SIZE (IN)</th>
<th>INSPECTION LIMIT (IN)</th>
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<td>SHELF - POS. 3</td>
<td>2219-T87 AL</td>
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<td>NAS1955C</td>
<td>SHELF BOLTS</td>
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<tr>
<td>30A60021</td>
<td>PIN - WORM</td>
<td>MP35N STL</td>
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<td>MP35N STL</td>
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<td>416 CRES</td>
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<td>30A60102</td>
<td>WORM SHAFT</td>
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<td>X</td>
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</tbody>
</table>

* NOT DONE.
Fracture Analysis

Reference Leg

(30APR69b)

\[ F_t = 6.72 \text{ kips (Ref 4.1)} \]

\[ d = 0.343 \text{ in}^4 \]

Assume \( F_{\text{MIN}} = 0 \text{ kst} \)

(Conservative)

Loaded 26,000 cycles

(4 missions with S.F. = 4)

Checking for cracks off hole

Worst case del cracks

\[ t = 0.468 \text{ in} \]

\[ R = 0.219 \text{ in} \]

From computer analysis:

\( CF = 0.415 \text{ in} \)

Inspection - Magnetic Particle

Limits - 0.25 in

\( CF > \text{ Inspect. Limit} \)

\( 0.415 > 0.25 \)

Original page is

of poor quality.
BELLCRANK LUG (30A60696) - DOUBLE CRACK IN HOLE
FRACTURE ANALYSIS:

TIGHT LINK (2A60695)

\[ t = 0.313'' \]

.438'' DIA

LUG AREA

MATERIAL 4340 S7C

LOADED 26000 CYCLES

-4 MISSIONS WITH S.F. 4

FRONT STRESS ANALYSIS:

From p 4.10, \( F_T = 5.72 \text{kips} \) \( \Rightarrow \) LOAD/LUG = 2.86 kips

ASSUME \( P_{MIN} = 0 \) (CONSERVATIVE)

MODEL

\[ t = 0.219'' \]

\[ \frac{1}{2} = 0.15'' \]

\[ t = 0.343'' \]

CHECK - CRACK OFF HOLE

From computer analysis

\( CF = 0.230 \text{ in.} \)

INSPECTION - EDDY CURRENT

MINIMUM SIZE - 0.05''

\( CF > \text{INSP. LIMIT} \)

\( 0.23 > 0.05 \)

ORIGINAL PAGE IS OF POOR QUALITY.
Fracture Analysis

Toggle Link Pin (30A60700)

DIA = .438"  MATL - INO 718

From Stress Analysis:
(ref p. 4.14)  \( \sigma_{\text{max}} = 92.78 \text{ ksi} \)
Assume  \( \sigma_{\text{min}} = 0 \text{ ksi} \) (Conervative)

Loaded 26,000 cycles (includes 4 Miss/Day)

Assume Rod in Tension
Check for surface flaws

From Computer Analysis
\( \frac{1}{2} \sigma F = .052 \)
Or  \( \sigma F = .104 \)

Inspection - Eddy Current
Limits - .1 in minimum

\( .104 > .1 \)
**FRACUTRE ANALYSIS**

**TOGGLE LUG** (30A40694)

**MATL — INC-718**

(CONSERVATIVELY LET ONE LUG CARRY FULL REACTION

\[ F_{\text{MAX}} = 7.66 \text{ kips} \]  \( (P, L, 4) \)

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

LOADED 26000 CYCLES — 4 MISSION WITH S.F. = 4

CHECK FOR CRACKS OFF HOLE

FROM COMPUTER ANALYSIS —

\[ CF = 0.165 \text{ in} \]

**INSPECTION — EDDY CURRENT**

MIN SIZE — 0.05 in

\[ CF > \text{INSPE. LIMIT} \]

\[ 0.165 > 0.05 \]

**ORIGINAL PAGE IS OF POOR QUALITY**
**Fracture Analysis**

**Lug Pin (30466.698)**

- **Material:** 718 Inconel

Left: 1.64 in

**Loading is for 4 missions @ 50 Hz with SF = 4, or 26,000 cycles**

\( \sigma_{max} = 72.8 \text{ KSI} \)

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

**Model -**

Assume rod in tension

Check for surface flaws from computer analysis

\( 20F = .073 \) or .146

**Inspection done with Eddy Current -**

\( \text{MIN LIMITS ARE } .1 \text{ IN} \)

\( .146 > .1 \)

**Original Page Is Poor Quality**
TRAJETORY ANALYSIS

ROUND PIN (30A6D442)

SHANK AREA = \( \left( \frac{8.75}{4} \right)^2 \pi = 7.66 \) in\(^2\)

TENSILE ANALYSIS - \( P_{\text{max}} = 5.19 \text{ kips (965)} \)

\[ T_{\text{max}} = \frac{P_{\text{max}}}{S} = \frac{5.19}{0.601} = 8.63 \text{ KSI} \]

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

\[ \text{MFDL} \]

Assume rod in tension

Loaded 26,000 cycles
(For 4 missions and S.F. 4)
FRACTURE ANALYSIS

ROUND PIN (CONT.)

INSPECTION - Eddy 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 (30160095)

\[ P_{\text{max}} = 11.73 \text{kips} \quad \text{(ref p. 4.28)} \]

\[ A_t = (4.0 - 1.25)(0.25) = 1.71 \text{ in}^2 \]

\[ T = \frac{P_{\text{max}}}{A_t} = 6.86 \text{kips} \]

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

Check Round Pin Hole for Cracks

From computer analysis -

\[ CF = 1.0625 \text{ in} \]

INSP. - IDLY CURRNT

\[ \text{MINIMUM SIZE} = 0.05 \text{ in} \]

\[ CF7 \text{ INS}^3 \text{ MIN.} \]

\[ 1.0625 > 0.05 \]
FRACTURE ANALYSIS

SQUARE PIN (30A60643)

\[ A_s = 0.875 \times 0.875 = 0.765^2 \]

FROM STRESS ANALYSIS:

\[ A_s = 0.875^2 \]
\[ = 0.762 \text{ m}^2 \]

\[ \frac{C}{1762} = 5.19 \text{ kips (p 14.2)} \]

\[ \sigma_{max} = \frac{5.19}{1762} = 0.0\text{38 ksi} \]

\[ \text{Assume } \sigma_{min} = 0. \]

CHECKING FOR SURFACE FLAWS ON SHANK

WITH INITIAL FLAWS SIZES OF 80.076 OF

THE SHANK AREA THERE WAS NO CRACK GROWTH

AFTER 260,000 CYCLES
FRACTURE ANALYSIS

\( \tau = \frac{P}{b\cdot t} \) (J2A6C449)

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

\[ j = \frac{P}{\tau_0} = \frac{7.79 \text{ kips}}{1.5} = 5.19 \text{ kips} \]

Assume \( \tau_{min} = 0 \) (Conservative)

MODEL

\[ \begin{align*}
\text{CHECK SQUARE HOLE} \\
\text{CORRECT FOR CREEPS}
\end{align*} \]

\[ \begin{align*}
\text{from computer analysis:} \\
CF = 0.98 \text{ M}
\end{align*} \]

\[ \begin{align*}
\text{Eddy current inspection:} \\
\text{MIN SIZE} = 0.05 \\
\text{CT} > \text{INS} \text{ MIN,} \\
1.98 > 1.05
\end{align*} \]
Fracture Analysis.

RED HOLDER NO. (SCHL 647, 648)

1.25 RAD TYP.

.316 DIA (4 PLCS)

MOUNTING BASE

MATERIAL 2217-T87 AL

CRACK OFF RED NOLE - CHECK
LOAD - BERTING LOADS
INSTRESS ANALYSIS - MAX LOAD = 156010
ASSUME PMIN = 0 (CONSERVATIVE)
BASE RC'D POSITIONS 2 & 3

30A60648

DOUBLE AID BASE

SECTION A-A

DRILL & TAP FOR LOCKING HELICOIL TYP 4 PL 1.005 DIA 1.000 DEEP 2 PLCS

.316 DIA THRU (.4 PLCS)

.25 R

2.70

.75

2.11

.25 R

2.375

1.00

4.00 (REF)

1.3 R

.500 TYP

4.81

ReF

3.75

3.070

.310

1.85

1.56

2.00

1.060

3.8

DORR OR POOR QUALITY
ID HOLDERS - (CONT)

INITIAL CRACKS OF 20% OF LUG AREA SHOWN.

GROWTH

P = 156016
ref. p 4.36

SAME AS (30466647) SINGLE ROD HOLDER

NO GROWTH

NOTE - NO INSPECTION CURRENTLY DONE

NONE RECOMMENDED
TUBE ANALYSIS

TUBE PROD (300-796-16)

DIAM: 1.0
L: 3.0 & 4.0" O.D.

FROM STATIC ANALYSIS - MAX LOAD = 1560 lb

\[
\begin{align*}
\tau &= \frac{F}{A} \\
\tau &= \frac{1560}{\pi \times (1.0)^2} \\
\tau &= 50 \text{ ksi}
\end{align*}
\]

\[
\sigma_{\text{max}} = 4680 \text{ psi}
\]

\[
\sigma = 0.05 \text{ in}
\]

MODEL

ASSUME ROD

FROM COMPUTER ANALYSIS -

\[
\begin{align*}
\sigma_{\text{max}} &= 0.090 \\
\sigma_{\text{avg}} &= 0.18 \text{ in}
\end{align*}
\]

INSPECTION - EDDY CURRENT

LIMITS = 0.1 in

0.18 > 0.1
LOCATOR ROD (30A60649)
SURFACE FLAW
MAIL - 4/6 CRES

From Stress Analysis

\[ \sigma_{\text{max}} = \frac{F}{A} = 66.78 \text{ ksi} \]

Conservatively let

\[ F_{\text{min}} = 0 \]

Life Factor = 4

Design Life = 100 cycles x LF

= 100 x 4 = 400 cycles

Check cracks on YOUTH surface

MODEL

Critical Flaw Size

From computer analysis -

\[ 2CF = 0.5 \text{ in.} \]

Or \[ CF = 0.1 \text{ in.} \]

Eddy Current Inspection

Min Size = 0.1

\[ CF = \text{Min Size} = 0.1 \]

\[
\text{FROM EARLIER ANALYSIS - LOADS UNCHANGED}
\]
FRACTURE ANALYSIS

LOCKED GEAR PIN (30A660043)

MATL - MAR805 SIL

FROM STRESS ANALYSIS -

\[ \sigma_{\text{max}} = 145.3 \text{ ksi} \]

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

LOAD CYCLES:

\[ 200 \times 5 = 1000 \]

\[ 100 \times 4 = 400 \]

ASSUME ROD IN TENSION

CHECK FOR SURFACE FLAW

FROM COMPUTER ANALYSIS

\[ 20F = 1053 \text{ in} \]

\[ UC \times CF = 106 \text{ in} \]

EDDY CURRENT INSPECTION LIMIT - .1 in

106 > .1

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7 FROM PREVIOUS SPARTAN REN ANALYSIS LOADS UNCHANGED
WORM GEAR PIN (3041600043)
SURFACE FLAW

HALF CRACK LENGTH (2C, UN)

HALF CRITICAL FLAW SIZE .053
HALF INSPECTION LIMIT

100 200 300 400
CYCLES

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TRADITIONAL ANALYSIS

FORMD D/N (30A60021)

.1241 DIA

MATL-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 a rod in tension

From computer analysis
\[ Z\sigma = 0.045 \text{ in} \]
\[ \sigma = 0.09 \text{ in} \]

EDDY CURRENT INSPECTION LIMIT

\[ CF < \text{INSP LIMIT} \]

* CF < INSPECTION LIMIT

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* FROM PREVIOUS SPARTAN REM ANALYSIS LOADS UNCHANGED
HALF CRACK LENGTH

105

100 200 300 400

CYCLES

WORM PIN - (30H6/0021) SURFACE FLAW

ORIGINAL PAGE IS OF POOR QUALITY
FRACTURE ANALYSIS

WORM SHAFT (SCREW 12-2)

0.80 DIA

MATERIAL: 416 ODS

From Stress Analysis:

\[ T_{\text{max}} = 662,788 \text{ ksi} \]

Conservatively let \( T_{\text{min}} = 0 \)

LOADED 4000 Cycles

\[ 400 = 100,000 \times \text{LIFE FACTOR} \]

LIFE FACTOR = 4

ASSUME: REDUCTION IN TENSION WITH SURFACE FLAWS

From Computer Analysis:

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

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

INSPECTION - BODY CURRENT

MIN INSPECTION SIZE = 0.1 in

\( \text{CF} > \text{INSIZE} \)

0.125 > 0.1

\( \checkmark \) FROM PREVIOUS SPARTAN PFM ANALYSIS

ENDS UNCHANGED
HALF CRACK LENGTH - 2c (in)

-0.05
-0.1
-0.15

HALF CRITICAL
FLAW SIZE
0.4625

HALF
INSPECTION
LIMIT

WORM SHAFT (304L60102) - SURFACE FLAW

Cycles

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OF POOR QUALITY