2201
2277
2296
Shuttle Orbiter stress Analysis

J.O. R 4388 RTR 506 26 30 01

TPE CRUMPLER

This job consists of stress analysis of a Shuttle Orbiter model in the area of instrumentation grooves. Also check stress in fasteners holding wing to body.


Model will be tested in LTV 4x4 supersonic tunnel Dallas, Tex.

Loads - normal force = 2500#; temp F° = 175 for 40 seconds.

Est. level of effort 16 man hours

Est. start date 8-5-74

Est. comp. date 8-8-74
HAMPTON TECHNICAL CENTER
LTV Aerospace Corporation
3221 N. Armistead Avenue
Hampton, Va. 23666

TITLE

STRESS RE-CHECK
.015 SCALE SSV MODEL FOR
LTV 4X4 SUPERSONIC TUNNEL

SUBMITTED UNDER

REPORT NO.       DATED
NA-73-403       8-9-74

PROJECT        CONTRACT NO.

NASI-13500

PREPARED

REVIEWED

APPROVED

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THIS RE-CHECK OF STRESS ON .015 SCALE SSV MODEL, WITH INSTRUMENTATION CUTS AND INCREASED LOADING FOR LTV 4X4 SUPERSONIC BLOW-DOWN TUNNEL, SUPPLEMENTS THE ORIGINAL REPORT NA 73-403 BY NORTH AMERICAN ROCKWELL.

I. LOADING

\[ \frac{F}{N} = 2500 \text{#} \quad \text{Temp} = 175 \degree \text{OF FOR 40 SEC} \]

REQUIRED FACTOR OF SAFETY \( \geq 2 \)

MATERIAL 17-4PH H 900

\[ \frac{f_{tu}}{f_y} = 200 \text{ksi} \quad \frac{f_{su}}{f_{bru}} = 133 \text{ksi} \]

\[ \frac{f_y}{f_{bru}} = 170 \text{ksi} \quad \frac{f_{bru}}{f_{bru}} = 330 \text{ksi} \]

1. DETERMINE WING LOADING

\[ h_i = 2.0 \]

\[ h = 5.4 \]

\[ k = 8.4 \]

\[ A_{\text{wing}} = \frac{5.4(8.4+2)}{2} = 28 \text{in}^2 \]

\[ A_{\text{body}} = 3.3(5.5) + 2.5 = 61 \text{in}^2 \]

\[ A_{\text{total}} = 2(28) + 61 = 117 \text{in}^2 \]

WING LOADING = \( \frac{2500\#}{117\text{in}^2} \approx 22.4 \frac{\text{#}}{\text{in}^2} \)

2. FIND CENTROID OF WING

\[ k = \frac{h_k (t + b_t)}{3(t + b_t)} = \frac{5.4(8.4+4)}{3(8.4+2)} = 2.19 \text{in} \]
3. FIND ROOT BENDING MOMENT

(CONSERVATIVELY CONC. LOAD @ CENTROID)

\[ M = (\text{WING LOADING})(A_{\text{WING}})(\bar{X}) \]
\[ = (22)(28)(2.11) = 1350 \text{ IN.-#} \]

4. FIND CRITICAL SECTION

\[ A = \frac{2 + 6.8(4)}{2} = 17.6 \text{ in.}^2 \]
\[ \bar{X} = \frac{4(6.8 + 4)}{2(6.8 + 2)} = 1.64 \text{ in.} \]

\[ M_A = 1.64(400) = 656 \text{ in.-lb} \]

II. STRESS ANALYSIS

1. BENDING @ SECTION A-A

\[ f_b = \frac{M_A}{I} = \frac{656}{.0533} = 12,300 \text{ PSI} \]

Factor of Safety = \[ \frac{200,000}{12,300} > 16 \]

2. WING ATTACHMENTS (SEE NORTH AMERICAN DWGS SS-A00106 & SS-A00107)

a. UP LOAD
BENDING @ SECTION B-B

(Equiv) \[ \frac{M}{z} = \frac{1350}{0.25} = \frac{4(25)^2}{6} = 0.04166 \]

\[ \frac{P}{b} = \frac{1350}{z} = \frac{32,400}{0.04166} = 32,400 \text{ psi} \]

Factor of Safety = \( \frac{190,000}{32,400} = 5.8 \)

\( N \), Down Load

BENDING @ LINE OF SCREWS

\[ M = Pd \]
\[ P = A_{\text{wing}} \times \text{Start Load} = 28(15) = 420 \text{#} \]
\[ d = \frac{k + 1.575 - 0.75}{3.015} \]
\[ M = 420(3.015) = 1266 \text{ IP} \]

\[ f = \frac{M}{2} = \frac{1266}{0.0592} = 21,400 \text{ PSI} \]

**Factor of Safety** = \[ \frac{190,000}{21,400} = 8.8 \]

**Tension in 4 Screws**

\[ P = \frac{M}{d} = \frac{1266}{.75} = 1688 \text{#/} = \frac{422 \text{#/screw}}{4} \]

**Factor of Safety** = \[ \frac{3300}{422} = 7.8 \]

**III. Conclusions**

1. **Safety Factors Exceed 2 for All Portions of Model Under Start & Running Loads.**

2. **Strength of Model is Not Adversely Affected by Tunnel Operating Temperature.**
HAMPTON TECHNICAL CENTER
LTV Aerospace Corporation
3221 N. Armistead Avenue
Hampton, Va. 23666

TITLE
STRESS ANALYSIS OF
SPACE SHUTTLE BASE
DRAG MODEL MODIFICATION.

SUBMITTED UNDER
WORK ORDER H-024
REPORT NO. DATED

JUNE 24, 1975

PROJECT CONTRACT NO.
NASI-13500

PREPARED

REV. DATE REV. BY PAGES AFFECTED REMARKS

REVIEWED

APPROVED
SPACE SHUTTLE BASE DRAG MODEL

- DESIGN PRESSURE = 10 PSI
- MIN. F.S. = 3.0 @ YIELD

AFT & AFT INNER BULKHEAD

REF DWGS. LD534828 & LD534829

CONSERVATIVELY CHECK THESE AS BEAMS 2.5" WIDE (WIDTH OF SUPPORTING BOLT PATTERN), WITH A DISTRIBUTED LOAD, REACTED IN THE MIDDLE.

\[ N_{\text{max}} = WL^2/2 = 7.6 \times (4.55)^2/2 = 73.7 \text{ in-lb} \]

\[ f_b = 6M/6I = 6(73.7)/2.5(183^2+10^2) \]

\[ f_b = 4,165 \text{ PSI} \]

MAT'L: 7075-T6 \quad F_N = 69,000 \text{ PSI}

\[ \text{F.S.} = \frac{69,000}{4,165} = 16.6 \]

BULKHEAD - TO - ADAPTOR ATTACHMENTS

SEVEN (7) #10-32 CAP SCREWS REACT THE 69.2" LOAD.

LOAD PER SCREW = 9.9 *

ALLOW. LOAD = 3,240* (YIELD)

\[ \text{F.S.} = \frac{3,240}{9.9} = \text{LARGE} \]
BULKHEAD-TO-ADAPTOR ATTACHMENT CONT'D.

ASSUME 1000 THREADED ENGAGEMENT IN ADAPTOR:

\[ P_{sy} = 0.5 \times f_{sy} \times \text{(circumference)} \]

\[ = 0.5 \times 0.19 \times 23,000 \times 17 \times 0.15 \]

\[ P_{sy} = 1030 \, \# \]

F.S. = LARGE

ADAPTOR-TO-EE03R BALANCE ATTACHMENT.

FOUR (4) \( \frac{5}{8}'' \)-24 CAP SCREWS REACT THE 69.2\(^\circ\)

LOAD PER SCREW = 17.3\( \# \)

ALLOWED LOAD = 15,930 \( \# \)

F.S. = LARGE
\[ C_D = 0.35 = \frac{\Delta P}{\eta} = \frac{\Delta P}{800} \]

\[ \Delta P = 0.35(800) = 280 \text{ #/ft}^2 \]

\[ A_B = (0.03416)^2 (427 \text{ ft}^2) = 0.498 \text{ ft}^2 \]

\[ \text{Force} = 0.498(280) = 104.6 \text{ #} \]

\[ C_A = 0.04 \text{ Base Drag Est} \]

\[ C_A = \frac{Axial}{45} = 0.04 = \frac{Axial}{800(3.5)} \]

\[ Axial = 0.04(800)(3.5) = 112.0 \text{ #} \]

\[ A = (800 \times 0.04) 113 \text{ 25} \]

\[ Q = 5.5 \]

\[ A = 113 \]
<table>
<thead>
<tr>
<th>Size</th>
<th>( N )</th>
<th>LOADS ( \text{mm} )</th>
<th>( m )</th>
<th>( l )</th>
<th>( n )</th>
<th>( y )</th>
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<tbody>
<tr>
<td>FF01</td>
<td>4x4x4</td>
<td>60</td>
<td>360</td>
<td>120</td>
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<tr>
<td>FF02</td>
<td>4x4x4</td>
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<td>360</td>
<td>120</td>
<td>120</td>
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<tr>
<td>FF02R</td>
<td>3x3.3x9.3</td>
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<td>FF03</td>
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<td>480</td>
<td>120</td>
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<td>FF04</td>
<td>2x2x5</td>
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<td>480</td>
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<td>120</td>
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<tr>
<td>FF05</td>
<td>2x2x5</td>
<td>110</td>
<td>480</td>
<td>120</td>
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<td>120</td>
</tr>
<tr>
<td>FF06</td>
<td>2x2x5</td>
<td>110</td>
<td>480</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>FF07</td>
<td>4x4x4.7</td>
<td>60</td>
<td>720</td>
<td>720</td>
<td>720</td>
<td>720</td>
</tr>
</tbody>
</table>

**Additional Note:**

FF03R 3" D x 10" L  120 120 1200 360 1200 1200 1200 120

*WFA.*
BASE DRAG MODEL MODIF  1-23-75

REMOVE AFT END THEN BALANCE MOUNT AFT END AS PER SKETCH ON LE 533382

REQUESTED APRIL 1, '75  R-4388

BAL WILL BE DETERMINED BY WARE (FF 02 BAC) OR FFO1

MODEL WILL BE AVAILABLE W1 OR 2-3RD

Secured Balance drawing FFO2 and George Ware said it couldn't be used but it has the same mounting dimensions and size as the FFO1.
Jim,

I am sending you three drawings of FF-02 balance.

Dw 6. #5

IRD 1306 sheet 1 of 6
sheet 2 of 6
sheet 5 of 6

Please return.

Sito Boisseau
ph- 2184
M 3 355
Bldg. 643
Rm 1 10
Force acting on base of shuttle

1. Base area (F.S.) = 422 ft²

2. Model scale = 0.3614

3. Model base area = \((0.3614)^2 \times 422) = 0.5512\text{ ft}^2

\[ C_p = \frac{\Delta P}{q} = 0.32 \]

\[ \Delta P = 0.32 \times 9 = 0.32 \times 600 \text{ lb/ft}^2 = 192 \text{ lb/ft}^2 \]

Base force = 192 lb/ft² \((0.5512 \text{ ft}^2) = 105.8 \text{ lb} \]
Model in LIPT (Bill Beasley)

Flow = 300 ft/sec

Balance - FF028 3" OD x 9.3" L

UT 12 OR 28 FF03R - 2.840 DIA. 9.6 Long

\( \text{Square} \)

\( N = 120 - 120 - \text{Quinn} \)

\( A = 120 - 120 \)

\( \text{in/lb} \)

Calib Check

Bob Carter Delta
Joe Black

\( P = 200 \text{ in/lb} \)

Roll = 50 in/lb
Requests stress analysis on Shuttle orbiter LD 938915

(REP. ANALYSIS BEFORE INSTRUMENTATION)

LTV DALLAS REQUIRES ANALYSIS AFTER INSTRUMENTATION CUTS -

MAX $f_N = 2500$ ft

Temp $F = 175$ for 40 sec.

LTV 4 X 4 SUPERSONIC TUNNEL TEST - BLOW DOWN

INFO REQD BY 8-12-74

Goodwin LTV returned 8-9-74 10 HRS
Weymouth
Shuttle Oraline Wing
ARMCO 17-4PH with H-900
Heat treat

Bernie
Structural Analysis
of the
.015 Scale SSV
Model
42-0 & 42-OTS

DATE May 18, 1973
NO. OF PAGES

North American Aviation / Los Angeles
North American Rockwell
International Airport, Los Angeles, California 90009, (213) 670-9151
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<td>19, 20</td>
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INTRODUCTION

This report contains the structural analysis of the .015 Scale SSV Model 42-0 and 42-OTS. The model will be tested in the LRC LIPT, LRC UPWT, wind tunnels.

The maximum anticipated loads on the model and the location of the loads for each tunnel are shown on pages 6a to 6h. All loads are considered as concentrated (therefore conservative) and the analysis is intended to show that a component is strong enough and not how strong a component is.

The margins of safety are based on a safety factor of five (5) on the ultimate allowable stress, which ever is critical. A margin of safety greater than five (5) is considered high and is so noted.

The components of this model not analyzed in this report are considered not critical.
MARGINS OF SAFETY

All margins are based on a safety factor of five and at room temperature conditions; if exposed to prolonged (½ hour) elevated temperatures the safety factors can be considered as follows:

At 800°F Less 20%  
At 1200°F Less 70%

To use the above criteria realistically the actual temperature at these parts should be monitored.
REFERENCES

1. ROARK, R. J. "FORMULAS FOR STRESS AND STRAIN" FOURTH EDITION, McGRAW HILL BOOK CO., 1965.

2. MIL-HDBK-5 "METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURES."

3. NA-52-332 "MODEL DESIGN STRUCTURAL MODEL."

4. SFT WIND TUNNEL LOADS LETTER, SFT/WTO/73-104

5. NA DRAWING:
   NR Dwg.  SS-A00106
   NR Dwg.  SS-A00107
### MODEL MATERIALS OF CONSTRUCTION

#### VASCOMAX 300 CVM
- **Ult. Tensile Strength**: 288,000
- **Yield Strength**: 281,000
- **Shear Strength**: 150,000
- **Bearing Strength**: 347,000

#### 17-4 PH STAINLESS STEEL (H 300)
- **Ult. Tensile Strength**: 200,000
- **Yield Strength**: 170,000
- **Shear Strength**: 133,000
- **Bearing Strength**: 330,000

#### 2024 - T351 ALUM. ALLOY
- **Ult. Tensile Strength**: 62,000
- **Yield Strength**: 55,000
- **Shear Strength**: 37,000
- **Bearing Strength**: 93,000

#### MILD STEEL
- **Ult. Tensile Strength**: 55,000
- **Yield Strength**: 36,000
- **Shear Strength**: 35,000
- **Bearing Strength**: 90,000

#### 4340 STEEL
- **Ult. Tensile Strength**: 180,000
- **Yield Strength**: 163,000
- **Shear Strength**: 109,000
- **Bearing Strength**: 250,000

#### 7075 - T6 ALUM. ALLOY
- **Ult. Tensile Strength**: 83,000
- **Yield Strength**: 75,000
- **Shear Strength**: 46,000
- **Bearing Strength**: 100,000
<table>
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<tr>
<th>CONFIGURATION</th>
<th>ATTITUDE</th>
<th>LOADS - POUNDS</th>
<th>CARRIER of PRESSURE</th>
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<tbody>
<tr>
<td>ORBITER - alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha = 30^\circ, \beta = 0 )</td>
<td>( M = 1.2 )</td>
<td>370, 720</td>
<td>ON ( C_1 )</td>
</tr>
<tr>
<td>( M = 1.2 ) ( S_e = +10^\circ )</td>
<td>( S_e_{RF} = 40^\circ ) (rev)</td>
<td></td>
<td>X_c_p is at ( x_0 = 16.63 ) in</td>
</tr>
<tr>
<td>( \alpha = 0^\circ, \beta = +10^\circ )</td>
<td>( S_R = -20^\circ )</td>
<td>170</td>
<td>ON ( C_2 )</td>
</tr>
<tr>
<td>( M = 1.2 ) ( S_e = 0^\circ )</td>
<td>( S_e_{RF} = 0^\circ )</td>
<td>160</td>
<td>ON ( C_3 )</td>
</tr>
<tr>
<td>( \alpha = 0^\circ, \beta = 0^\circ )</td>
<td>( S_R = 0^\circ )</td>
<td>( S_e = -40^\circ )</td>
<td>( S_{PR} = +10^\circ )</td>
</tr>
</tbody>
</table>

Maximum rolling moment: 270 in-lb \( \alpha = 0^\circ, \beta = 0^\circ \)

\( S_e = +15^\circ, S_e = 0^\circ \)
## Steady State Loads

### Orbiter Components

**Model:** 0.015  
**Tunnel:** AR-3.5; ITC LIPT, UPWT  
**Mach No.:** 0.2 to 10

<table>
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<th>Design g</th>
<th>1,000 psf</th>
</tr>
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<td><strong>Angle of attack:</strong></td>
<td>-10° to 60°</td>
</tr>
<tr>
<td><strong>Angle of yaw:</strong></td>
<td>-5° to 41°</td>
</tr>
</tbody>
</table>

Reference Dimensions:

- **Area:** 2,400 ft²
- **Length:** 12 ft 0.5 in.
- **Span:** 9 ft 63 in.

A safety factor of 5 based on the ultimate strength or 3 based on the yield strength (whichever is critical) should be used in all applicable design calculations.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Attitude</th>
<th>Loads - Pounds</th>
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</thead>
<tbody>
<tr>
<td><strong>Orbiter Wing</strong></td>
<td>$\alpha = 50^\circ$</td>
<td>752</td>
</tr>
<tr>
<td></td>
<td>$\beta = 0^\circ$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$M = 5$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_e = +10$</td>
<td></td>
</tr>
<tr>
<td><strong>Orbiter Half-Wing</strong></td>
<td>$\alpha = 50^\circ$</td>
<td>376</td>
</tr>
<tr>
<td></td>
<td>$\beta = 0^\circ$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$M = 5$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_e = +10$</td>
<td></td>
</tr>
<tr>
<td><strong>Orbiter Elevons:</strong></td>
<td>$\alpha = 30^\circ$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\beta = 0^\circ$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_e = +10$</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>$M = 1.2$</td>
<td></td>
</tr>
</tbody>
</table>

Maximum rolling moment:

**Orbiter Wing:** $Y_o = 2.73$ in, $X_o = 18.83$ in

**Orbiter Half-Wing:** $Y_o = 3.01$ in, $X_o = 21.56$ in

**Orbiter Elevons:** $Y_o = 5.55$ in, $X_o = 21.73$ in
### Steady State Loads

<table>
<thead>
<tr>
<th>Model</th>
<th>0.015</th>
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<tr>
<td>Tunnel</td>
<td>APC 3.5 ft</td>
</tr>
<tr>
<td>Mach No.</td>
<td>0.2 to 10</td>
</tr>
<tr>
<td>Design q</td>
<td>1,000 psf</td>
</tr>
<tr>
<td>Angle of attack</td>
<td>-12 to 60°</td>
</tr>
<tr>
<td>Angle of yaw</td>
<td>-5 to 410°</td>
</tr>
</tbody>
</table>

Reference Dimensions:
- Area: 2,690 ft²
- Length: 1,270.3 in
- Span: 360.3 in

A safety factor of 5 based on the ultimate strength or 3 based on the yield strength (whichever is critical) should be used in all applicable design calculations.

### Orbiter Components

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Attitude</th>
<th>Loads - Pounds</th>
<th>Center of Pressure</th>
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</thead>
<tbody>
<tr>
<td>Orbiter Rudder</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>S RF = 40</td>
<td></td>
<td>Z₀ = 10.13 in</td>
</tr>
<tr>
<td></td>
<td>S R = -20</td>
<td></td>
<td>X₀ = 24.3 in</td>
</tr>
<tr>
<td></td>
<td>β = +10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>α = 0°</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M = 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbiter - Vertical Tail</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>S RF = 70°</td>
<td></td>
<td>Z₀ = 9.53 in</td>
</tr>
<tr>
<td></td>
<td>S R = +15°</td>
<td></td>
<td>X₀ = 22.7 in</td>
</tr>
<tr>
<td></td>
<td>α = 20°</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>β = -10°</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M = 1.2</td>
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<td></td>
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<tr>
<td></td>
<td>121</td>
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</tbody>
</table>

Maximum rolling moment: ___________________________
Sect A-A Sending

\[ \frac{1}{x\times y} = 0.0416 \text{ in}^4 \]

(per NH 72-797)

\[ c = 0.516 \]

\[ f_b = \frac{720 \times 4.6 \times 0.516}{0.4116} = 41,000 \text{ psi} \]

Sending Allow. 220,000 (bending mod.)

\[ M.S. = \frac{220,000}{(5) 41,000} - 1 = 0.07 \]

5/16 Bolt Tension

\[ P_t = \frac{4.6'' \times 720^4}{(2) 1.3''} = 1280 \text{#} \]

Allow. is 9,800#

\[ M.S. = \frac{9,800}{(5) 1280} - 1 = 0.5 \]
Wing Attachment

376 lbs

Not to Scale

#10-32 AMCS
(4 Places)

35 A-0052 Wing

\[ A_t = \frac{376 \times 1.5}{50} = 1120 \text{ in}^2 \text{ or } \frac{1120}{4} = 253 \text{ in}^2 \text{ per screw} \]

\[ P_{allow} = 3300 \text{ lbs} \]

\[ M_S = \frac{3300}{5 \times 263} - 1 = 1.34 \]
WING SPICE PLATE

M = 2.8" x 376"

= 5052 in^2

L_{effective} = 4.625 - (4)(3.12)

= 3.37"

f = \frac{6M}{L \cdot t^2}

= \frac{6 (1052)}{(3.37) (4)^2}

= 11,700 psi

M.S. = \frac{150,000}{(5) 11,700} \quad -1 \quad = \quad \frac{-1}{2.74}
VERTICAL TAIL ATTACHMENT

\( P = 121 \text{#} \times 2.5'' \)
\( = 303 \text{#} \) or
\( \frac{303}{3} = 101 \text{#} \text{/ /crew} \)

Price: $300**

\[ M_S = \frac{2,300}{(5)} \times \frac{1}{100} = \frac{460}{50} = 9.2 \]

And 20% of 9.2 = 2.56
**Rudder**

- **Material:** ALXCO 17-4
- **#8-36 AHCS**

**Bending at A-A:**

\[
rac{f_b}{f_{eq}} = \frac{6 \times 60 \times .80}{2.0 \times .13} = \frac{8.52}{31}
\]

**Tension in #8-32 Screws**

\[
P_t = \frac{60 \times .80}{3 \times .20} = 80\text{ #}
\]

\[
M_s = \frac{2,300}{5 \times 80} - 1 = 4.75
\]

**Allowance:** 2,300 #
ELEVONS

BENDING AT A-A

\[ F_b = \frac{6 \times 48 \times 16}{3.2 \times 0.13^2} \]
\[ F_b = 5,325 \text{ psi} \]

\[ N.S. = \frac{190,000}{5 \times 5,325} \]
\[ N.S. = 6.13 \]

TENSION in 10-32 STUDS

\[ P_t = \frac{48 \times 1.2}{4 \times 0.2} \]
\[ P_t = 72 \text{ lb} \]

Allow. 26,000 lb

\[ N.S. = \frac{26,000}{5 \times 72} \]
\[ N.S. = \text{High} \]
**Balance Pin Shear**

\[ P_M = 270 \text{ "#,} \]

\[ P_{sh} = 270 \text{ ")" } \div 1 = 270 \text{ ");} \]

\[ \text{Pin. Dia} = 0.25 \text{ in} \]

\[ P_{hollow} = 7065 \text{ ");} \]

\[ M.S. = \frac{7065}{(5) 270} \]

\[ 4 \]