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STRESS ANALYSIS OF 1/12 SCALE HOVERING AND TRANSITION MODEL

September 1957

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The number of pages included in this report including Title Page, Table of Contents, and Illustrations, is 2/2
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Written By: [Signature]

Checked By: [Signature]  
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AVRO SPECIAL PROJECT GROUP TECHNICAL REPORTS.

AVRO/SPG/TR 29: AIR CUSHION EFFECT TESTS - PART 2
AVRO/SPG/TR 33: AIR CUSHION EFFECT TESTS - PART 3
AVRO/SP6/TR 98: TEST SPECIFICATIONS FOR THE \( \frac{1}{2} \) SCALE HOVERING & TRANSITION MODEL.

GENERAL REFERENCES.

- AN-C-5. - MARCH 1955 -

- THEORY OF PLATES & SHELLS - S. TIMOSHENKO.

- RESISTANCE DES MATERIAUX APPLIQUEE A L'AVIATION - P. VALLAT.
  PUBLISHED BY : MENARD - EDITEURS - 8 RUE DES REGANS - TOULOUSE - FRANCE.
1-0 SUMMARY

The strength and stiffness of the \( \frac{1}{2} \) scale hovering and transition model, its supporting structure and fairings are analyzed.

The testing of all parts except the wing load gauges is carried out with an ultimate load factor of 6.

The strength of all components has been found satisfactory and the deflections small enough to be negligible.

Balance calibration procedure is outlined and pertinent data provided.
2-0 INTRODUCTION

As a part of the system 606 A test program, a 1/12 scale model of the P.V. 704 aircraft has been designed for installation in the 20' diameter Marie Memorial Wind Tunnel at Wright-Patterson Air Force Base. The purpose of the model is to study the take-off, hovering, and transition to forward flight characteristics of the aircraft. The proposed tests are outlined in AVRO/SPG/TR 98 - Test Specifications for the 1/12 scale Hovering and Transition model. The development of loads and the shaping of the model, model support structure and fairings are contained in this report.

The model is circular in planform: 35.3' OA, with intake and jet exhaust flows simulated. These flows are supplied through large diameter pipes which also serve to support the model on the wind tunnel balance. In order for the balance to be affected by the supply pressures, these pipes come out of the tunnel in a horizontal plane to supply the vertical pipes supporting the model.

The wind tunnel balance is a three component balance measuring lift, pitching moment and drag. However, due to the distance involved compared with the size of the model and the relatively light aerodynamic and heavy face loading of the installation, sufficiently accurate readings of drag and moments cannot be obtained. For this reason, and to provide for the measurement of rolling moments, a second, body fixed balance system
is provided near the model.

This second balance employs ring type load gages to measure drag forces and pitching and rolling moments. Lift forces are also indicated on this balance, but since they include forces due to the model supply pressure, readings of lift will be taken on the tunnel balance only.

Aerodynamic loads on the model and support structure fairings are estimated using standard aerodynamic theory; the model lift, drag and moment coefficients being estimated from the results of previous tests. Hovering loads are based on Avro reports: AVRO/SPG/TR 29 & AVRO/SPG/TR 33. An ultimate load factor of 4 is used throughout.
3.0 DESCRIPTION OF INSTALLATION

3.1 GENERAL

Fig. 1 shows the general arrangement of the installation. The model is suspended from a vertical arm below a horizontal tube attached to the main balance strut. The incidence of the model is adjusted by using the rear balance strut acting on a control arm extending from the horizontal tube.

In order to remove the airload from the model mounting, the whole installation is enclosed in a fairing supported independently of the balance system on the strut fairing. Additional streamlined of the horizontal tube fairing is provided but has not been shown on Fig. 1 for clarity.

3.2 MODEL

The model is composed of two disk-shaped steel turnings joined together to form a hollow circular wing; and these profiled turnings joined to form a circular center body (Fig. 2). The two halves of the wing are held apart by 24 radial ribs and attached together by screws into these ribs and into each other around the outer edge of the model. Each half contains three sets of holes distributed around three circles concentric with the model center as shown in Fig. 8. The holes are covered by segmented plates containing matching holes of a smaller diameter. Several sets of plates with different hole sizes are provided in order to vary the size of the final openings.
The perpendicular outlets are 316 holes .242" dia. distributed along a circle of rad. 15.825". They are covered with segment plates having holes of dia. ranging in steps from .242" to .180" dia. Plates are also provided to close the holes completely.

The propulsive outlets are 48 holes .160" dia. distributed along a circle of rad. 15.00". They are covered by the segment nozzle plates which direct the airflow aft at about 20° to the wing surface. Plates are also provided to close the holes completely.

Both of these outlets are covered by the same plates. Various arrangements of propulsor and control being provided by changing the plate.

The center outlets are 96 holes .453" dia. distributed along a circle of rad. 11.312". They are covered with segment plates having holes of dia. ranging in steps from .453" to .227" dia. Plates are also provided to close the holes completely.

The wing is clamped by bolts between two of the center body turnings. The upper turning (A in fig. 2) is in the shape of a dummy intake and ramps and is attached to the outlet model support tube. The center turning (B in fig. 2) forms the lower intake ramp and connects with an inner tube to form a duct leading to the wing. High pressure air is admitted through this duct to exhaust through the openings described above to simulate the aircraft propulsive system.

The lower turning (C in fig. 2) forms the lower intake roof and forms a duct leading to the center tube.
3-0 DESCRIPTION OF INSTALLATION

3-2 MODEL cont'd.

This tube is partially evacuated to draw air through the intake to simulate lower intake airflow. The lower
heating is attached to the center supply tube by a
suspension rod and to center heating by six soldered
stubs. These tubes also direct some of the high pressure
air through a central nozzle in the lower tunnel
to simulate the aircraft liner exhausts.

This model is intended to simulate take-off,
hovering and transition configurations close to a simulated
ground board. For this reason, only the lower intake is used.
Hvering conditions will be tested for the model
horizontal and tilted up to 20°

Transition will be tested for angles of attack ranging
from -10° to +45°

Ground distance will be adjusted from zero to about 2 dia.

3-3 MODEL SUPPORT STRUCTURE

The model is attached at the end of a vertical arm
(Fig. 3) by a suspension rod and straining gages measuring
pitching and rolling moments and loads parallel to the model.
The vertical arm is made up of two concentric tubes,
which are connected to the model through elastic joints at the
3-3  MODEL SUPPORT STRUCTURE - CONT'D.

measuring gage section. The outside tube carries the pressure supply to the model while the inner tube carries the section.

The lower part of the arm is removable, together with the model and gage section by disconnecting a flange on the outside tube. The top & bottom of the inner tube in the removable section are connected to the upper part of the inner tube and to the model by sliding couplings so that all loads transmitted to the upper part of the arms are carried by the outer tube.

The model suspension rod is attached to the outer tube by means of a cruciform bracket at the level of the connecting flange. This bracket also supports the lower part of the inner tube.

The vertical arm is welded at its upper end to the horizontal tube and to the control arm.

The horizontal tube supplies pressure to the nozzles of the model on one side and suction to the intake of the model on the other side. It is supported at both ends by ball-bearing assemblies (fig 4) bolted to the end of the main balance struts. It is attached to the external parts by means of bel lows allowing free movement of the ends and is fixed against side motion at the pressure side ball-bearing. It is free to slide on the suction side to allow for thermal expansion. A tension rod takes the load due to pressure and suction in the tubes. This rod is attached at its outer end to a 3 armed bracket welded inside the horizontal tube coming through the tunnel wall on the pressure side.
3.0 DESCRIPTION OF INSTALLATION

3.3 MODEL SUPPORT STRUCTURE - CONT'D.

A similar bracket at the other end contains ball-bearing to avoid twisting of the rod when changing the angle of incidence of the model.

The control arm (fig. 5) is a welded steel structure in the shape of an I beam with height decreasing toward the rear balance strut.

3.4 FAIRINGS -

The vertical arm of the fairing (fig. 6) is a streamlined light alloy structure with wooden ribs and formers. The two lower part of the fairing are removable to give access to the measuring gage section. It is attached at its upper end to the steel fairing of the control arm and to the horizontal tube fairing (fig. 7).

The horizontal tube fairing is another steel tube concentric with the model support tube and supported at each end on plain bearings attached to the sides of boxes extending below the main balance strut fairing. In the section between tunnel wall and main balance strut, the fairing and the inner tube are assembled as a rigid unit. They are supported by the tunnel walls and the box extending below the main balance strut fairings.

The control arm fairing is a steel box and is attached by a linkage to the rear balance strut fairing. All fairings are completely independent of
3.0 DESCRIPTION OF INSTALLATION

3.4 FAIRINGS - CONT'D.

The balance system and clearances are provided to ensure that no contact will occur through possible deflection of the structure or misalignments.

A follow-up mechanism maintains the alignment between the model support rails and the fairings when changing the angle of attack of the model.
FIG 1 - GENERAL ARRANGEMENT OF INSTALLATION
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

FIG. 2 - 1/2 SCALE HOVERING AND TRANSITION MODEL
FIG. 3 - DETAILS OF MODEL SUPPORT - A
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

Fig. 4 - Details of Model Support - B

Diagram showing the details of model support with labels for ball-bearing assembly, pressure, tension rod, and removable section.
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

FIG. 5 - CONTROL ARM
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

FIG. 6 - VERTICAL FAIRING

HORIZONTAL TUBE CENTER PART FAIRING

CONTROL ARM FAIRING

VERTICAL ARM FAIRING LIGHT ALLOY

REMOVABLE SECTIONS

HARD WOOD RIBS & FORMER

WRITTEN BY
S. Jacques

CHECKED BY
P.C. Fingarette

DATE
Sept. 1947

ISSUE

SECRET DECLASSIFIED

AVRO EA 1110
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

FIG. 7 - HORIZONTAL FAIRING.

TUNNEL WALL
MAIN BALANCE STRUTS E
CENTER FAIRING
TUNNEL WALL
OUTER FAIRING
OUTER FAIRING

BOX EXTENDING FROM BALANCE STRUT FAIRING.

BELLOW
PLAIN BEARING
4-0  LOAD ANALYSIS

4-1  LOADING CONSIDERATIONS

4.1.1 General

The model forces are taken by the ring load measuring gauges and transferred through the model support to the 3 balance units.

The faring loads, both static and aerodynamic, are taken by the 3 balance 'string' farings.

4.1.2 Loads on the model

The model loads include: weight, aerodynamic loads, jet reaction and pressure force on the ducting.

Jet reaction: In the hovering case, the jet reaction is entirely directed downward. In the flying case, the jet reaction may be divided between lifting and propelling thrust. In all cases, it must be assumed that the jets will be operating with the tunnel stopped, thus the loads will not be reduced by air drag or lift. Pressure and suction on the ducting area at the inlet of the model will add a force normal to the plane of the model. These pressures and suction will be assumed uniform over the area thus having no moment about the center of the model. It should be noted that this may not be true in practice. However, since the moment is likely to be relatively small and owing to difficulties in obtaining reliable estimates, this moment has been neglected in the analysis. Also, the full defining pressure and suction have been used while some drop is to be expected.

Aerodynamic loading: The model can be placed in the tunnel at angles $\alpha$ varying between $-10^\circ$ and $45^\circ$ with a preferential range from $-10^\circ$ to $20^\circ$. The tunnel is to
4.0 LOAD ANALYSIS.

4.1 LOADING CONSIDERATIONS - CONT'D.

In operation, it is planned to operate the model at a 1:30 scale factor for the preferential range and its speed will be reduced for the range 20° to 45° so that the airloads do not exceed those produced in the preferential range. This allows the use of smaller ring load measuring gages at the model attachment.

Since accurate values of \( C_L \), \( C_D \), and \( C_m \) are not available, these parameters have been taken on the high side in order to ensure that the planning of the model will virtually cover all possible cases.

4.1.3 Model supporting structure. The model supporting structure takes the model loading plus the static loads due to its own weight and pressure loads in the ducting.

4.1.4 Fairings: The fairing loading is both static and aerodynamic, i.e., fairing weight and air drag. In addition, it has been assumed that a deviation of the airflow in the tunnel would not induce more than a 5° angle of attack to the vertical fairing hence producing a side load on the attachment of the fairing.

4.1.5 Load Factor: A load factor \( n = 4 \) is applied to all parts of the structure except the ring load measuring gages which are tested for their operating conditions as per report AVRO/SPG/TR 87.
### Load Analysis

#### Model Loads

#### Loading Cases

<table>
<thead>
<tr>
<th>( \alpha )</th>
<th>( T )</th>
<th>( L_{ref} )</th>
<th>( \frac{L}{T} )</th>
<th>( \frac{M}{L} )</th>
<th>( \frac{S}{T} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>FULL</td>
<td>0</td>
<td>2.0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>20°</td>
<td>FULL</td>
<td>0</td>
<td>2.0</td>
<td>0</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Ref: AVRO/SPG/TR 29 & AVRO/SPG/TR 33

### Transition Cases

<table>
<thead>
<tr>
<th>( \alpha )</th>
<th>( T )</th>
<th>( P )</th>
<th>( L_{ref} )</th>
<th>( C_L )</th>
<th>( C_D )</th>
<th>( C_{m_{yy}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10°</td>
<td>0</td>
<td>FULL</td>
<td>30</td>
<td>-1.30</td>
<td>.05</td>
<td>- .60</td>
</tr>
<tr>
<td>0°</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>.05</td>
<td>.05</td>
<td>- .20</td>
</tr>
<tr>
<td>0°</td>
<td>FULL</td>
<td>FULL</td>
<td>0</td>
<td>2.1</td>
<td>.60</td>
<td>0.18</td>
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<tr>
<td>20°</td>
<td>0</td>
<td>FULL</td>
<td>30</td>
<td>2.1</td>
<td>.60</td>
<td>0.18</td>
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<tr>
<td>35°</td>
<td>0</td>
<td>FULL</td>
<td>30</td>
<td>2.8</td>
<td>1.20</td>
<td>.32</td>
</tr>
<tr>
<td>45°</td>
<td>0</td>
<td>FULL</td>
<td>18</td>
<td>3.0</td>
<td>1.70</td>
<td>* .98</td>
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</table>

* As determined from assumed distribution.

### Symbols

- \( T \): Thrust
- \( P \): Supply Pressure
- \( L \): Tunnel dynamic pressure
- \( C_L, C_D, C_{m_{yy}} \): Thrust efficiencies in hovering cases

### Note

Transition cases were selected for most adverse loads on the gages rather than actual test cases.
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

4-0 LOAD ANALYSIS

4-2-1 LOADING CASES

LOADS DUE TO INTERNAL PRESSURE:

- max. model pressure: 30.74 psi (simulated hot thrust with hot nozzle area)
- max. operating pressure*: 22.96 psi in jet flow circuit
  - 9.8 psi in intake flow circuit

* based on:
- simulated hot thrust with cold nozzle area
- pressure loss in jet flow circuit = 5 x dynamic head based on area internal flow area and nozzle total head.
- pressure loss in intake flow circuit = 1.5 x dynamic head based on intake flow area and intake total head.

Suction Area: $\frac{\pi}{4} (4.3)^2 = 14.5$ ft$^2$
Pressure Area: $\frac{\pi}{4} (7.5 - 4.5)^2 = 22.6$ ft$^2$

LOADS DUE TO PRESSURE:

Force due to static pressure: $(22.96 - 14.7) \times 22.5 = 189 \frac{1}{4}$
Force due to momentum flow:
net force

LOADS DUE TO SUCTION

Force due to static pressure: $(4.98 - 14.7) \times 14.5 = -138 \frac{1}{4}$
Force due to momentum flow:
net force:

net load on model: $320 - 34 = 286 \frac{1}{4}$
4.6 LOAD ANALYSIS

4.2.2 HOVERING CASES

Lift provided by A or B or A+B: 150 lb
Lift provided by C: 11 lb

Ground efficiency: \( \frac{1}{7} = 2.0 \)

Total lift on the model: \( 2.0 \times (150 + 11) = 322 \text{ lb} \)

In the absence of more accurate data, \( \frac{1}{2} \) of this load will be taken as concentrated at the jets, the other \( \frac{1}{2} \) as a uniform pressure on the underside.

Wing area: \( 35.33 \times \frac{2}{4} = 978 \text{ in}^2 \)

Pressure: \( \frac{161}{978} = 0.165 \text{ psi} \)
4.0 Load Analysis

4.2.2 Hovering Case

<table>
<thead>
<tr>
<th>Lift</th>
<th>322 ³/₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>200 ¹/₂</td>
</tr>
<tr>
<td>Press</td>
<td>286 ¹/₂</td>
</tr>
</tbody>
</table>

Net Load: \(200 + 286 - 322 = 16\,\frac{1}{4}\)
H-2.2 - HOVERING CASE

HOVERING AT 20°
AIR LOADS

Efficiency:

LIFT IN GROUND: \( L = \frac{V}{T} = 2.0 \Rightarrow L = 2T \)

MOMENT: \( E_H = \frac{M}{Tb} = 0.15 \Rightarrow M = 0.15 Tb \)

SIDE LOAD: \( E_S = \frac{S}{T} = 0.30 \Rightarrow S = 0.30 T \)

Lift provided by A or B or A + B = 150 lb
Lift provided by C = 11 lb

Total lift on the model: \( 2 \times 161 = 322 \frac{1}{2} \) lb normal to the floor.

In the absence of more accurate data, lift distribution will be taken as for hovering case at \( X = 0 \).

Moment: \( 0.15 \times 161 \times 15.3 = 853 \text{ in} \cdot \text{lb} \)

Side load: \( 0.30 \times 161 = 48.3 \frac{1}{2} \) in any direction in the plane of the floor.
4-0 LOAD ANALYSIS

4-2-2 HOVERING CASE

HOVERING AT 20°
NET LOADS

LIFT: 322 lb normal to the floor ↑
SIDE LOAD: 48.3 lb in any direction. Here taken as shown →
MOMENT: 853 in lb
WEIGHT: 286 lb normal to the floor ↑
PRESSURE: 200 lb normal to the model ↑

Total force normal to the model:

\[
286 + 200 \cos 20° - 322 \cos 20° + 48.3 \sin 20° =
\]

\[
286 + 188 - 302 + 16.5 = 188.5 \text{ lb}
\]

Total force parallel to the model:

\[
200 \sin 20° - 322 \sin 20° + 48.3 \cos 20° =
\]

\[
68.4 - 110 + 45.4 = 3.8 \text{ lb}
\]
4-0  LOAD ANALYSIS

4-2.3  TRANSITION CASE

-10° CASE - q = 30 PSF

AIR LOADS

\[ C_L = -0.30 \]
\[ C_D = 0.08 \]
\[ C_{M_1} = -0.60 \]

Tunnel q = 30 PSF
Wing area = 6.8 ft²
Wing chord = 2.94 ft

LIFT: \[ -0.30 \times 6.8 \times 30 = -61.20 \text{ lb} \]

DRAG: \[ 0.08 \times 6.8 \times 30 = 16.32 \text{ lb} \]

MOMENT: \[ -0.60 \times 2.94 \times 6.8 \times 30 = -360 \text{ ft lb} = -4320 \text{ in lb} \]
4-0  LOAD ANALYSIS

4-2-3  TRANSITION CASE

10° CASE - $q = 30$ PSF

NET LOADS

<table>
<thead>
<tr>
<th>LIFT</th>
<th>- 61.20 $\frac{1}{4}$</th>
</tr>
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<tbody>
<tr>
<td>DRAG</td>
<td>16.32 $\frac{1}{4}$</td>
</tr>
<tr>
<td>MOMENT</td>
<td>4320 $\text{in}^4$</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>200 $\frac{1}{4}$</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>286 $\frac{1}{4}$</td>
</tr>
</tbody>
</table>

Total force normal to the model:

$$286 + 200 \cos 10^\circ + 61.2 \cos 10^\circ + 16.32 \sin 10^\circ =$$

$$286 + 197 + 60.30 + 2.83 = 546.13 \frac{1}{4}$$

Total force parallel to the model:

$$-200 \sin 10^\circ - 61.2 \sin 10^\circ + 16.32 \cos 10^\circ =$$

$$-34.7 - 10.6 + 16.08 = -23.22 \frac{1}{4}$$
4-2-3 TRANSITION CASE

Lift $L = 0.05 \times 6.8 \times 30 = 10.2 \text{ lb}$

Drag $D = 0.05 \times 6.8 \times 30 = 10.2 \text{ lb}$

Moment $M = 2.34 \times -0.20 \times 6.8 \times 30 = -120 \text{ lb"} = -1440 \text{ in"}$

$C_L = 0.05$

$C_D = 0.05$

$C_{N_z} = -0.20$

Tunnel $q = 30 \text{ PSF}$

Wing area $6.8 \text{ ft}^2$
4.0 - LOAD ANALYSIS

4.2.3 TRANSITION CASE

LIFT: 10.2 \(^\text{lb}\) ↑
DRAG: 10.2 \(^\text{lb}\) →
MOMENT: 1440 \(^\text{lb} \cdot \text{in}\) C
WEIGHT: 200 \(^\text{lb}\) ↓

TOTAL FORCE NORMAL TO MODEL:

\[ +200 -10.2 = 189.8 \text{ lb} \]

TOTAL FORCE PARALLEL TO MODEL:

\[ 10.2 \text{ lb} \]
4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE

MAX. THRUST CASE

\[ \alpha = 0 \]
\[ T = 141 \frac{1}{2} \]
\[ \alpha = 0 \]
\[ V = 0 \]

Thrust: 150 000 20° 20° = 141 \frac{1}{2}
stress analysis of 1/2 scale hovering & transition model

4.0 load analysis

4.2.3 transition case

max thrust case \( \alpha = 0 \) net loads

\[ \begin{align*}
\text{thrust} & : 141 \frac{1}{4} \\
\text{weight} & : 200 \frac{1}{4} \\
\text{pressure} & : 286 \frac{1}{4} \\
\text{total force normal to model} & : 200 + 286 = 486 \frac{1}{4} \\
\text{total force parallel to model} & : 141 \frac{1}{4}
\end{align*} \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

L.O. LOAD ANALYSIS

20° CASE - q = 30 PSF

AIRLOADS

$C_{L} = 2.1$

$C_{D} = 0.60$

$C_{n_{e}} = 0.18$

Tunnel q = 30 PSF

Wing area = 6.8 ft²

Wing load = 2.04 ft²

LIFT = $2.1 \times 6.8 \times 30 = 428 \frac{ft}{lb}$

DRAG = $0.60 \times 6.8 \times 30 = 122.5 \frac{ft}{lb}$

MOMENT = $0.18 \times 6.8 \times 30 \times 2.04 = 108 \frac{ft}{lb} = 129.5 \frac{in}{lb}$
4.0 Load Analysis

4.2.3 Transition Case

20° Case - q = 30 psf

Net Loads

Lift: 428 lb
Drag: 122.5 lb
Moment: 1287 lb-ft
Weight: 200 lb
Pressure: 286 lb/sq ft

Total Force Normal To The Model:

286 + 200 cos 20° - 488 cos 20° - 122.5 sin 20° =
286 + 188 - 402 - 41.8 = 30.2 lb

Total Force Parallel To The Model

200 sin 20° - 428 sin 20° + 122.5 cos 20° =
68.4 - 146.4 + 115 = 37.2 lb
4.0 LOAD ANALYSIS

4.2.3 TRANSITION CASE

35° CASE - q = 30 PSF

AIRLOADS

\[ C_l = 2.8 \]
\[ C_d = 1.20 \]
\[ C_m^e = 0.32 \]

Tunnel q = 30 PSF

Wing area: 6.8 ft²
Wing chord: 2.9 ft

LIFT: \[ 2.8 \times 6.8 \times 30 = 570 \text{ lb} \]

DRAG: \[ 1.20 \times 6.8 \times 30 = 245 \text{ lb} \]

MOMENT: \[ 0.32 \times 6.8 \times 30 \times 2.9 \text{ ft} = 142 \text{ ft}^2 \text{ lb} = 2300 \text{ in} \text{ lb} \]
4.2.3 Transition Case

35° Case - q = 30 psf

Net Loads

Lift: 570 lb
Drag: 245 lb
Moment: 2300 lb-ft
Weight: 200 lb
Pressure: 286 lb

Total Force Normal to the Model:

\[ 286 + 200 \cos 35° - 570 \cos 35° - 245 \sin 35° = \]
\[ 286 + 164 - 466 - 140 = -156 lb \uparrow \]

Total Force Parallel to the Model:

\[ 200 \sin 35° - 570 \sin 35° + 245 \cos 35° = \]
\[ 104.8 - 327 + 201 = -21.2 lb \leftarrow \]
**STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL**

**4-0 | LOAD ANALYSIS**

**4-2.3 | TRANSITION CASE**

**45° CASE - q = 20 PSF**

**AIRLOADS**

\[ C_L = 3.0 \]
\[ C_D = 1.7 \]

**Wing area:** 68.8 ft²

**TUNNEL AT 30°**

**LIFT.**

\[ 3.0 \times 6.8 \times 30 = 612 \text{ lb} \]

**DRAG.**

\[ 1.7 \times 6.8 \times 30 = 347 \text{ lb} \]

Approx. press. distribution as shown.

Center of pressure:

\[ X = \frac{N}{V} \]

Volume element:

\[ dV = \frac{1}{2} \times dy \times P \sin \theta \]

\[ N = -\frac{P}{2} r^2 \sin^3 \theta \, d\theta \]

\[ \int_{\theta} V = \int_{0}^{\frac{\pi}{2}} \int_{\theta} -\frac{P}{2} r^2 \sin^3 \theta \, d\theta \, d\theta \]

\[ dM = -\frac{P}{2} r^2 \sin^3 \theta \, d\theta \, \frac{1}{3} r \sin \theta \]

\[ dM = -\frac{P}{3} r^3 \sin^4 \theta \, d\theta \]

**WRITTEN BY:**

J. Jacques

**CHECKED BY:**

T. Young

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AVRO EA 3110

SECRET DECLASSIFIED
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

LOAD ANALYSIS

\[ M = \int \frac{4 \cdot 0}{3} \frac{P}{r^3} \sin^4 \theta \, d\theta \]

\[ \therefore X = \frac{1}{3} \int_0^{\pi/2} P \cdot \frac{r^3}{3} \sin^4 \theta \, d\theta = \frac{2}{3} \cdot \frac{r}{16} \int_0^{\pi/2} \sin^4 \theta \, d\theta = \frac{3}{16} \pi r = .59 \pi r \]

\[ V = \frac{2}{3} P r^2 \quad \text{where } V \text{ is component normal to the disc.} \]

\[ \therefore X = .59 \cdot \frac{35.3}{2} = 10.4'' \]

Moments of lift & drag about center of model:

\[ \left( \frac{612 + 347}{10.4} \right) \frac{10.4}{V^2} = 706 \text{ in-lb} \]

Component normal to surface of disc:

\[ V = \left( \frac{612 + 347}{10.4} \right) \frac{1}{V^2} = 678 \text{ in-lb} \]

\[ \therefore P = \frac{1}{2} \cdot 678 \cdot \left( \frac{35.3}{2} \right)^2 = 5.26 \text{ in-lb} \]

Component in the plane of the disc:

\[ \left( \frac{612 - 347}{10.4} \right) \frac{1}{V^2} = 187.5 \text{ in-lb} \]
Stress Analysis of 1/12 Scale Hovering Transition Model

4-O Load Analysis

4-2-3 Transition Case

45° Case: \( q = 30 \text{ PSF} \)

Net Loads

Lift: 612 lb \( \uparrow \)

Drag: 347 lb \( \rightarrow \)

Moment: 7060 in-lb \( \times \)

Weight: 200 lb \( \downarrow \)

Pressure: 286 lb \( \ddot{\downarrow} \)

Total Force Normal to the Model:

\[ 286 \cos 45^\circ - 612 \cos 45^\circ + 200 \cos 45^\circ - 347 \sin 45^\circ = \]

\[ 286 \cdot 0.707 + 141.4 - 245 = -250 \text{ lb} \]

Total Force Parallel to the Model:

\[ 200 \sin 45^\circ - 612 \sin 45^\circ + 347 \cos 45^\circ = \]

\[ 141.4 - 433 + 245 = -46.6 \text{ lb} \]
4.2.3 TRANSITION CASE

45° CASE - q = 30 PSF.

Determination of $C_{M_x}$ at $\alpha = 45°$.

The moment about the center of the model is: $7060 \text{ in} \cdot \text{lbf}$

This moment is due to aerodynamic forces alone. Hence, the value of $C_{M_x}$ is:

$$C_{M_x} = \frac{M}{\frac{1}{2} \rho A \bar{c}} = \frac{7060}{\frac{35.3}{12} \times 6.8 \times 20} = \frac{7060}{7200} = +0.98$$
4.0 LOAD ANALYSIS

4.2.3 TRANSITION CASE

CASE 45°, TUNNEL OPERATING AT 18°

\[
\text{Lift: } 612 \times \frac{19}{50} = 367 \text{ lbf}
\]

\[
\text{Drag: } 347 \times \frac{12}{50} = 208 \text{ lbf}
\]

\[
\text{Moment: } 7060 \times \frac{18}{50} = 4230 \text{ in-lbf}
\]

FORCE NORMAL TO THE MODEL:

\[
286 + 200 \cos 45° - 367 \cos 45° - 208 \sin 45° = 286 + 141 - 253 - 147 = +21.6
\]

FORCE PARALLEL TO THE MODEL:

\[
200 \sin 45° + 208 \sin 45° - 367 \sin 45° = 141 + 147 - 253 = 38.4
\]
A-2-4  SUMMARY OF CRITICAL LOADING CASES

The critical case is the transition case for $\alpha = -10^\circ$ which gives together the max. pitching moment and the max. downward load normal to the model.

The max. drag load is obtained in the zero thrust case and the max. forward load in the max. thrust case.

The max. upward load normal to the model occurs at $\alpha = 35^\circ$.

The hovering cases are not critical so only the transition cases will be used to check the model support structure.

### SUMMARY OF LOADING ON THE MODEL

<table>
<thead>
<tr>
<th>LOADING CASES</th>
<th>LIFT 16</th>
<th>DRAG 16</th>
<th>MOMENT in lb</th>
<th>NORMAL LOAD 16</th>
<th>PARALLEL LOAD 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOVERING: $\alpha = 0^\circ$</td>
<td>322 ↑</td>
<td>48.3 →</td>
<td>853 C</td>
<td>164 ↓</td>
<td>3.8 →</td>
</tr>
<tr>
<td>HOVERING: $\alpha = 20^\circ$</td>
<td>322 ↑</td>
<td>48.3 →</td>
<td>853 C</td>
<td>164 ↓</td>
<td>3.8 →</td>
</tr>
<tr>
<td>TRANSITION $\alpha = -10^\circ$</td>
<td>61.2 ↓</td>
<td>16.32 →</td>
<td>4320 C</td>
<td>546.13 ↓</td>
<td>29.22 →</td>
</tr>
<tr>
<td>&quot; &quot; ZERO THRUST</td>
<td>10.2 ↑</td>
<td>10.2 →</td>
<td>1440 C</td>
<td>119.8 ↓</td>
<td>10.2 →</td>
</tr>
<tr>
<td>&quot; &quot; MAX. THRUST</td>
<td>10.2 ↑</td>
<td>10.2 →</td>
<td>1440 C</td>
<td>119.8 ↓</td>
<td>10.2 →</td>
</tr>
<tr>
<td>&quot; &quot; $\alpha + 20^\circ$</td>
<td>428 ↑</td>
<td>122.5 →</td>
<td>1295 J</td>
<td>36.2 ↓</td>
<td>37 →</td>
</tr>
<tr>
<td>&quot; &quot; $\alpha + 35^\circ$</td>
<td>570 ↑</td>
<td>245 →</td>
<td>2300 U</td>
<td>156 ↑</td>
<td>21.2 →</td>
</tr>
<tr>
<td>&quot; &quot; $\alpha + 45^\circ$</td>
<td>367 ↑</td>
<td>208 →</td>
<td>4230 J</td>
<td>21 ↑</td>
<td>38 →</td>
</tr>
</tbody>
</table>

* $g = 18$ PSF.

### VE SYMBS

LIFT  ANOMAL LOAD

NOMENT

DRAG   PARALLEL LOAD

### WRITTEN BY

G. Yeomans

### CHECKED BY

### DATE

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### ISSUE

### AIRCRAFT
4-3  MODEL SUPPORT STRUCTURE LOADS
4-3-1  LOADING CONSIDERATIONS

Since the model support structure is entirely shielded from the airflow, the only loads applied to it are its own weight and the loads coming from the model.

The model support structure is supported on the 3 balance struts. The two main balance struts take vertical and horizontal loads and the rear balance strut takes vertical load only.

Side loads on the model structure are due mostly to pressure in the delivery pipes. The side load due to model airload has been estimated not to exceed 50 lb.
4.3 Model Support Structure Loads
4.3.2 Model Loads & Reactions

Equations of Equilibrium:

\[ R_{AV} = \frac{L}{2} + \frac{M}{2b} \sin \alpha \cos \beta + \frac{L}{L_{AV} - D}{b} \cos \alpha \]
\[ R_{BV} = \frac{L}{2} + \frac{M}{2b} \sin \alpha \cos \beta + \frac{L}{L_{BV} - D}{b} \cos \alpha \]
\[ R_c = -\frac{M}{b} \left( \frac{L}{L_{BV} - D} \right) - \frac{M}{b} \]
\[ R_{AH} = \frac{D}{2} - \frac{L}{2a} \sin \beta \]
\[ R_{BH} = \frac{D}{2} + \frac{L}{2a} \sin \beta \]
\[ R_{AS} = S \]
EQUATIONS OF EQUILIBRIUM - CONT'D.

We have: \( a = 80'' \), \( b = 40'' \), \( R = 50'' \).

Furthermore: \( S = 50^\circ \) assumed for all cases.
and \( \alpha = -10^\circ, 0^\circ, 20^\circ, 45^\circ \).

Then, substituting:

\[ R_u = \frac{L}{2} + \frac{M}{96} + 0.522 L \tan \alpha - 0.522 D = 31.25 \cos \alpha \]
\[ R_v = \frac{L}{2} + \frac{M}{96} + 0.522 L \tan \alpha - 0.522 D = 31.25 \cos \alpha \]
\[ R_c = -1.042 \left[ L \tan \alpha - D \right] - \frac{M}{48} \]
\[ R_{ah} = \frac{D}{2} - 31.25 \sin \alpha \]
\[ R_{bh} = \frac{D}{2} + 31.25 \sin \alpha \]
\[ R_{as} = 50^\circ \]

LOADING CONDITIONS

<table>
<thead>
<tr>
<th>( \alpha )</th>
<th>(-10^\circ)</th>
<th>(0^\circ)</th>
<th>(0^\circ) MAX. THRUST</th>
<th>(20^\circ)</th>
<th>(45^\circ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td>-61.20</td>
<td>10.2</td>
<td>0</td>
<td>42.8</td>
<td>367</td>
</tr>
<tr>
<td>( D )</td>
<td>16.32</td>
<td>10.2</td>
<td>-141</td>
<td>125.5</td>
<td>208</td>
</tr>
<tr>
<td>( M )</td>
<td>-4320</td>
<td>-1440</td>
<td>0</td>
<td>1835</td>
<td>4830</td>
</tr>
<tr>
<td>( \sin \alpha )</td>
<td>-0.1737</td>
<td>0</td>
<td>0</td>
<td>0.346</td>
<td>-707</td>
</tr>
<tr>
<td>( \cos \alpha )</td>
<td>0.985</td>
<td>1.0</td>
<td>1.0</td>
<td>0.940</td>
<td>-707</td>
</tr>
<tr>
<td>( \tan \alpha )</td>
<td>-0.176</td>
<td>0</td>
<td>0</td>
<td>0.364</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Ref: SECTION 4-2-4
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

4-3-2 MODEL LOADS & REACTIONS.

CALCULATION OF LOADS:

\(-10^\circ\) CASE:

\[ R_{AV} = -\frac{61.2}{2} - \frac{4320}{96} + 1.522 (\frac{-61.2}{2}) (\frac{-176}{2}) - (1.522 \times 16.32) - (31.25 \times 0.85) \]

\[ R_{AV} = -30.6 - 45 + 5.62 - 8.52 - 30.8 = -107.30 \text{ lb} \uparrow \]

\[ R_{BV} = -30.6 - 45 + 5.62 - 8.52 + 30.8 = -47.70 \text{ lb} \uparrow \]

\[ R_{C} = 1.042 \left[ (\frac{-61.2 \times -176}{2}) - \frac{4320}{4} \right] = 51.80 + 90 = 141.80 \text{ lb} \downarrow \]

Check on total vertical load: \(-107.30 - 47.70 + 141.80 = 61.2\text{ lb}\) @ 61.2. OK

\[ R_{AH} = \frac{16.32}{2} = 8.16 \left(\frac{-176}{2}\right) = 8.16 + 5.43 = 13.59 \text{ lb} \downarrow \]

\[ R_{BH} = \frac{16.32}{2} + 31.25 \left(\frac{-176}{2}\right) = 8.16 - 5.43 = 2.73 \text{ lb} \downarrow \]

Check on total horizontal load: 13.59 + 2.73 = 16.32 @ 16.32. OK

\[ R_{AS} = 50 \text{ lb} \downarrow \]
STRESS ANALYSIS OF \(\frac{1}{12}\) SCALE HOVERING & TRANSITION MODEL -

A - 3  MODEL SUPPORT STRUCTURE LOADS

A - 3 - 2  MODEL LOADS & REACTIONS

CALCULATION OF LOADS - CONT'D.

0° CASE:

\[
R_{AV} = \frac{10.2}{2} - \frac{1440}{96} + .522 \times 10.2 \times 0 - .522 \times 10.2 - 31.25 \times 1.0 = \\
5.1 - 15 + 0 - 5.32 - 31.25 = -46.47 \uparrow
\]

\[
R_{BV} = 5.1 - 15 + 0 - 5.32 + 31.25 = +16.03 \downarrow
\]

\[
R_{C} = -1.048 \left[10.2 \times 0 - 10.2\right] - \frac{-1440}{48} = \\
+10.62 + 30 = +40.62 \uparrow
\]

Check on total vertical load: 40.62 + 16.03 - 46.47 = 10.18 @ 10.20.

\[
R_{AW} = \frac{10.2}{2} - 31.25 (0) = 5.1 \uparrow
\]

\[
R_{BH} = \frac{10.2}{2} + 31.25 (0) = 5.1 \uparrow
\]

Check on total horizontal load: 5.1 + 5.1 = 10.2 @ 10.2.

\[
R_{AS} = 50.16 \downarrow
\]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4-3. MODEL SUPPORT STRUCTURE LOADS
4-3.2. MODEL LOADS & REACTIONS.

CALCULATION OF LOADS - CONT'D.

0° CASE - MAX. THRUST -

\[
R_{AV} = \frac{0}{2} - \frac{6}{96} + 0.592 \times 0 - 0.582 \times (-141) - (81.25 \times 1) \\
= + 73.5 - 31.25 = 42.25 \text{ lb}
\]

\[
R_{BV} = 73.5 + 31.25 = 104.5 \text{ lb}
\]

\[
R_{c} = -1.042 \left[ 0 \times 0 - (-141) \right] - \frac{0}{N} = -147 \text{ lb}
\]

Check on total vert. load: 104.5 + 42.25 - 147 = -25 \text{ lb}

\[
R_{AH} = \frac{-141}{2} - 81.25 \times 0 = -70.5 \text{ lb}
\]

\[
R_{NH} = \frac{-141}{2} + 31.25 \times 0 = -70.5 \text{ lb}
\]

Check on total horizontal load: -70.5 - 70.5 = -141 \text{ lb} (-141 lb)

\[
R_{A} = 50 \text{ lb}
\]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4.3 MODEL SUPPORT STRUCTURE LOADS
4.3.2 MODEL LOADS & REACTIONS

CALCULATION OF LOADS - CONT'D.

20° CASE -

\[ R_{AV} = \frac{40.2}{2} + \frac{15.35}{96} + (0.522 \times 428 \times 364) - (0.522 \times 122.5) - (31.25 \times 9.4) = \]
\[ = 214 + 16 + 81.3 - 64 - 23.4 = 217.9 \text{ lb} \]

\[ R_{BV} = \frac{40.2}{2} + \frac{15.35}{96} + (0.522 \times 428 \times 364) - (0.522 \times 122.5) + (31.25 \times 9.4) = \]
\[ = 214 + 16 + 81.3 - 64 + 23.4 = 276.7 \text{ lb} \]

\[ R_c = -1.042 \left[ 428 \times 364 \times 122.5 \right] - \frac{15.35}{48} = -33.9 - 32 = -66.9 \text{ lb} \]

Check on Total Vertical Load: 217.9 + 276.7 - 66.9 = 427.7 lb @ 428.

\[ R_{AV} = \frac{122.5}{2} - 31.25 \times 342 = 61.25 - 10.68 = 60.57 \text{ lb} \]

\[ R_{BV} = \frac{122.5}{2} + 31.25 \times 342 = 61.25 + 10.68 = 71.93 \text{ lb} \]

Check on Total Horizontal Load: 60.57 + 71.93 = 122.5 @ 122.5
4-3 MODEL SUPPORT STRUCTURE LOADS
4-3-2 Model Loads & Reactions

**Calculation of Loads — Cont'd.**

**45° Case —**

\[ R_{AV} = \frac{367}{2} + \frac{4230}{96} + (1.522 \times 367 \times 1.0) - (1.522 \times 208) + (31.05 \times 707) = 183.5 + 44 + 192 - 108.5 - 22.1 = 288.9\text{ lb} \]

\[ R_{BV} = \frac{367}{2} + \frac{4230}{96} + (1.522 \times 367 \times 1.0) - (1.522 \times 208) + (31.05 \times 707) = 183.5 + 44 + 192 - 108.5 + 22.1 = 333.1\text{ lb} \]

\[ R_c = -1.042 \left( (367 \times 1) - 208 \right) - \frac{4230}{48} = -166 - 88.2 = -254.2\text{ lb} \]

Check on total vertical load: 288.9 + 333.1 = 254.2 = 367.8 \(\approx\) 367

\[ R_{AV} = \frac{208}{2} - (31.05 \times 707) = 104 - 22.1 = 81.9\text{ lb} \]

\[ R_{BV} = \frac{208}{2} + (31.05 \times 707) = 104 + 22.1 = 126.1\text{ lb} \]

Check on total horizontal load: 81.9 + 126.1 = 208 \(\approx\) 208

\[ R_{AS} = 50\text{ lb} \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4.3 MODEL SUPPORT STRUCTURE LOADS

4.3.3 LOADS DUE TO STATIC WEIGHT & REACTIONS.

MODEL MOUNT - TOTAL WEIGHT, INCLUDING MODEL.

TOTAL WEIGHT OF ASSEMBLY -

\[ 200 + 1.20 + 11.0 + 192 + 24.62 + 2 \left( 4.9 + 42.75 + 5.2 \right) = \]
\[ 200 + 1.20 + 11.0 + 192 + 24.6 + 287.5 = 715.80 \] \( \frac{1}{4} \)

Cock in balance string -

Main string:

\[ - \frac{715.8 - 10}{2} \approx - 353 \frac{1}{4} \]

Inclined string:

\[ - 24 \cdot \frac{20}{48} = - 10 \frac{1}{6} \]
4-3 MODEL SUPPORT STRUCTURE LOADS
4-3-3 LOADS DUE TO STATIC WEIGHT & REACTIONS

REACTION ON INCIDENCE STRUT FOR ANGLES \( \neq 0 \):

MODEL MOUNT

\(-10^\circ:\)

Moment about point O:

\[
\begin{align*}
(107 \times 2.5 \sin \alpha) & - (200 \times 50 \sin \alpha) + (20 \times 20) \cos \alpha \\
& - 24 \times (107 \times 2.5 + 200 \times 50) + 480 \cos \alpha
\end{align*}
\]

\[
= -12570 \sin \alpha + 480 \cos \alpha
\]

Reaction at incidence strut:

\[
-12570 \sin \alpha + 480 \cos \alpha = 262 \tan \alpha - 10
\]

Reaction when \( \alpha = -10^\circ:\)

\[-10 + 262 \tan (-10^\circ) = -56.2 \text{ lb} \]

Reactions on main struts:

\[
- \left( \frac{715.8 - 56.2}{2} \right) = -329.8 \text{ lb}
\]

\[+20^\circ\]

Reaction at incidence strut:

\[262 \tan (20^\circ) - 10 = 85.2 \text{ lb} \]

Reactions on main struts:

\[
- \left( \frac{715.8 + 85.2}{2} \right) = -400.5 \text{ lb} \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4-3  MODEL SUPPORT STRUCTURE LOADS

4-3-3  LOADS DUE TO STATIC WEIGHT & REACTIONS

REACTION ON INCIDENCE STRUT FOR ANGLES $\alpha \neq 0$ CONT'D

$+45^\circ$

Reactions at incidence strut:

$-262 \tan \alpha + 10 = -262 \tan 45^\circ + 10 = -252 \text{ lb}$

Reactions on main struts:

$\frac{-715.8 + 252}{2} = -483.9 \text{ lb}$

SUMMARY OF STATIC STRUT REACTIONS:

<table>
<thead>
<tr>
<th>$\alpha^\circ$</th>
<th>MAIN STRUT</th>
<th>INCIDENCE STRUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>-329.8</td>
<td>-56.2</td>
</tr>
<tr>
<td>0</td>
<td>-353.0</td>
<td>-10.0</td>
</tr>
<tr>
<td>20</td>
<td>-400.5</td>
<td>-85.2</td>
</tr>
<tr>
<td>45</td>
<td>-483.9</td>
<td>-252</td>
</tr>
</tbody>
</table>

All loads in lb
STRESS ANALYSIS OF ½ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS
4-3-1 LOADS DUE TO PRESSURE & SUCTION.

HORIZONTAL LOAD ON MODEL SUPPORT.
OPERATING CASE:

The max load occurs when the model is completely closed and the pump delivering max pressure and suction.

In the operating case, the load decreases to 782 lb static load and 64 lb reaction to mass flow on the pressure side and 287 lb static load and 28 lb reaction to mass flow on the suction side:

Sum: 782 + 64 + 28 + 287 = 1211 lb

PRESSURE CASE:

TUBE AREA: \[
\left[7 - \left(2 \times \frac{1}{8}ight)\right]^{2} \pi \frac{1}{4} = 34.5 \text{ in}^2
\]

MAX. ABS. PRESSURE: 44.7 psia
MIN. ABS. PRESSURE: 6.34 psia

TOTAL LOAD: (44.7 - 6.34) 34.50 + 50 = 1872 lb
## Stress Analysis of 1/2 Scale Hovering & Transition Model

### 4-3 Model Support Structure Loads

#### 4-3-5 Net Loads & Reactions

**Balance Struts Loads due to Model Loads Only**

**Summary**

Arrows show direction of the loads & reactions.

- **Applied Load**
- **Reaction**

### Table

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>-10°</th>
<th>0</th>
<th>0 Max. Thrust</th>
<th>20°</th>
<th>45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{AV}$</td>
<td>-109.31</td>
<td>-16.47</td>
<td>42.25</td>
<td>217.9</td>
<td>288.9</td>
</tr>
<tr>
<td>$R_{BV}$</td>
<td>-47.71</td>
<td>16.03</td>
<td>104.5</td>
<td>276.7</td>
<td>333.1</td>
</tr>
<tr>
<td>$R_{C}$</td>
<td>-95.82</td>
<td>40.62</td>
<td>-147</td>
<td>-66.3</td>
<td>-254.2</td>
</tr>
<tr>
<td>$R_{AH}$</td>
<td>13.59</td>
<td>5.1</td>
<td>-70.5</td>
<td>50.57</td>
<td>81.9</td>
</tr>
<tr>
<td>$R_{BH}$</td>
<td>2.73</td>
<td>5.1</td>
<td>-70.5</td>
<td>71.93</td>
<td>186.1</td>
</tr>
<tr>
<td>$R_{AS}$</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

$R_{AS}$ total operating:

Press. Case: 1372

-VE reaction is a down or forward load on the strut.
4.3 MODEL SUPPORT STRUCTURE LOADS

4.3.5 NET LOADS & REACTIONS

NET LOADS ON BALANCE STRUTS

<table>
<thead>
<tr>
<th>θ</th>
<th>-10°</th>
<th>0</th>
<th>0 MAX. THRUST</th>
<th>20°</th>
<th>45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{AS}$</td>
<td>-439.11</td>
<td>-399.47</td>
<td>-310.75</td>
<td>-182.6</td>
<td>-195.0</td>
</tr>
<tr>
<td>$R_{BV}$</td>
<td>-377.51</td>
<td>-336.97</td>
<td>-248.5</td>
<td>-123.8</td>
<td>-150.8</td>
</tr>
<tr>
<td>$R_{C}$</td>
<td>+39.62</td>
<td>+30.62</td>
<td>+157.0</td>
<td>+18.3</td>
<td>-2.2</td>
</tr>
<tr>
<td>$R_{AH}$</td>
<td>+13.59</td>
<td>+5.10</td>
<td>-70.5</td>
<td>+50.57</td>
<td>+81.9</td>
</tr>
<tr>
<td>$R_{BH}$</td>
<td>+2.73</td>
<td>+5.10</td>
<td>-70.5</td>
<td>+71.93</td>
<td>+126.1</td>
</tr>
</tbody>
</table>

- Reaction $R_{AS}$ is not shown here as it is not taken by the struts.
- Reactions $R_{AS}$ & $R_{BV}$ and $R_{AH}$ & $R_{BH}$ are interchangeable depending on the direction of the side load on the model.

In the above table, the reaction is a down or forward load on the strut.
The fairings are loaded by aerodynamic drag force and static weight only. A side load due to lift on the vertical fairing caused by a deviation of the tunnel airflow has been considered.

A drag coef. \( C_D = 1.0 \) has been taken for the horizontal tube. Aerodynamic characteristics for the vertical fairing at an angle of incidence \( \alpha = 5^\circ \) have been estimated by comparison with other thick airfoils.

The loads on the fairings are taken by the balance strut fairing, the main strut fairings taking vertical and horizontal loads and the rear strut fairing taking vertical load only.

The part of fairing tube between tunnel wall and balance strut are considered as simply supported beams under loading deriving between the I supports.
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

H-4
FAIRING LOADS
H-4-2
LOADS DUE TO AERODYNAMIC FORCES

For a Circular Cylinder, the drag coef. \( C_D = 1.0 \)

Thus, for a 10" tube, the drag per running foot is:

\[
D = C_D \frac{q}{2} = 1.0 \times \frac{1}{2} \times 33 = 0.833 \text{ lb}
\]

Hence, at the max speed of the tunnel: \( q = 20 \text{ PSF} \)

\[
D = 30 \times 0.833 = 25 \frac{1}{4} \text{ lb}
\]

and at the reduced speed: \( q = 18 \text{ PSF} \)

\[
D = 18 \times 0.833 = 15 \frac{1}{4} \text{ lb}
\]

Length of tube between balance struts: 80"
Length of tube outside balance struts: 230 - 80 = 150"

Thus, on balance struts fairing, the load is:

at 20 \( \frac{q}{2} \):

\[
25 \left( \frac{80}{4 \times 12} + \frac{150}{4 \times 12} \right) = 25 \left( 3.33 + 3.75 \right) = 164 \frac{1}{4} \text{ lb}
\]

and load on tunnel walls:

\[
25 \frac{150}{4 \times 12} = 25 \times 3.13 = 78.25 \text{ lb}
\]

at 18 \( \frac{q}{2} \):

on strut fairing: \( 15 \times 6.46 = 96.9 \frac{1}{4} \text{ lb} \)

on tunnel wall: \( 15 \times 3.13 = 46.9 \frac{1}{4} \text{ lb} \)

Drag on vertical fairing

The drag coef for the streamlined shape will be taken at:

\( C_D = .20 \)

Frontal area: \( \frac{4.2 \times 1}{144} = .0294 \text{ ft}^2 \)
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4-4 FAIRING LOADS.

4-4.2 LOADS DUE TO AERO dynamic FORCES

Drag on vertical fairing, cont'd.

Drag force: \(0.20 \times 3.2 \times q = 0.64 q\).

High speed case: \( q = 30 \text{ PSF} \), \( D = 0.64 \times 30 = 19.20 \text{ lb} \).
Low speed case: \( q = 18 \text{ PSF} \), \( D = 0.64 \times 18 = 11.50 \text{ lb} \).

Load on strut fairing:
\( q = 30 \text{ PSF} \), \( D = 19.20 \div 2 = 9.60 \text{ lb} \).
\( q = 18 \text{ PSF} \), \( D = 11.50 \div 2 = 5.75 \text{ lb} \).

REACTION ON INCIDENCE STRUT FAIRING.

\( \alpha = 0^\circ \):
\[
\begin{align*}
(30 & q) \quad 19.20 - \frac{26}{47} = 10.4 \text{ lb} \\
(18) \quad 11.50 - \frac{26}{47} = 6.22 \text{ lb}
\end{align*}
\]

\( \alpha = 45^\circ \):
At this angle, the airload on the fairing will be approximately balanced by that on the dome fairing. Hence, the reaction will be small and can be neglected.

\( \alpha = 20^\circ \):
Since the reaction at \( \alpha = 0^\circ \) is only \( 10.4 \text{ lb} \), it will be conservative to assume the same value for \( \alpha = 20^\circ \).
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

4-4. FAIRING LOADS
4-4.2 LOADS DUE TO AERODYNAMIC FORCES.

SUMMARY OF LOADS ON STRUTS FAIRINGS & TUNNEL WALLS.

HORIZONTAL LOADS:

ON MAIN STRUTS FAIRINGS:

\[ q = 30 \text{ PSF} : \quad 164 + 9.60 = 173.6 \quad (\text{lb}) \]
\[ q = 18 \text{ PSF} : \quad 97 + 5.75 = 102.75 \quad (\text{lb}) \]

ON TUNNEL WALL:

\[ q = 10 \text{ PSF} : \quad 78.6 \quad (\text{lb}) \]
\[ q = 18 \text{ PSF} : \quad 46.9 \quad (\text{lb}) \]

VERTICAL LOADS:

\[ q = \begin{cases} 
10 \text{ PSF} & \text{ON MAIN STRUTS:} \quad 5.2 \quad (\text{lb}) \\
18 \text{ PSF} & \text{ON REAR STRUT:} \quad 10.1 \quad (\text{lb}) 
\end{cases} \]

\[ q = \begin{cases} 
10 \text{ PSF} & \text{ON MAIN STRUTS:} \quad 3.11 \quad (\text{lb}) \\
18 \text{ PSF} & \text{ON REAR STRUT:} \quad 6.22 \quad (\text{lb}) 
\end{cases} \]
H-4 FAIRING LOADS

H-4-3 LOADS DUE TO STATIC WEIGHTS

FAIRINGS - TOTAL WEIGHT.

Load on balance strut fairings:
\[ \frac{43.50 + 10 + \frac{189}{2}}{2} + \frac{43.85 + 23.25}{2} + \frac{34.7 + 21.70}{2} = 234.185 \text{ lb} \]

Load on tunnel wall attachment:
\[ \frac{189}{2} - 94.5 \text{ lb} \]

TOTAL WEIGHT OF FAIRINGS:
\[ (189 \times 2) + (10 \times 2) + (43.50 \times 2) + (43.85 \times 2) + (23.25 \times 2) + 34.7 + 21.70 = 680.50 \text{ lb} \]
FAIRMING LOADS

LOADS DUE TO STATIC WEIGHT & REACTIONS

REACTION ON INCIDENCE STRUT FAIRING FOR ANGLES $\alpha \neq 0$

Moment about point O:

$21.70 \times 28 \sin \alpha - 24 \times 46.5 \cos \alpha$

$= 608 \sin \alpha - 1118 \cos \alpha$

Reaction at incidence strut:

$\frac{608 \sin \alpha - 1118 \cos \alpha}{48 \cos \alpha} = 12.65 \tan(-10^\circ) - 23.25$

$\alpha = -10^\circ$

Reaction at incidence strut:

$12.65 \tan(-10^\circ) - 23.25 = -2.23 - 23.25 = -25.48\ lb$

Reaction at main strut:

$-234.20 + \frac{2.23}{2} = -233.10\ lb$
Stress Analysis of 1/12 Scale Hovering & Transition Model

4-4 FAIRING LOADS
4-4.3 LOADS DUE TO STATIC WEIGHT & REACTIONS

Reaction on incidence strut fairing for angles $\alpha \neq 0$ - cont'd.

$\alpha = 20^\circ$

Reaction at incidence strut:

$12.65 \tan 20^\circ - 23.25 =$

$= 23.25 + 4.6 = 28.66$  

Reactions at main struts:

$234.20 - \frac{4.6}{2} = 236.50$  

$\alpha = 45^\circ$

Reaction at incidence strut:

$12.65 \tan 45^\circ - 23.25 =$

$= 23.25 + 12.65 = 35.90$  

Reactions at main struts:

$234.20 - \frac{12.65}{2} = 240.50$

Summary of static loads on strut fairings & tunnel walls.

<table>
<thead>
<tr>
<th>$\alpha^\circ$</th>
<th>Main Strut Fairing</th>
<th>Incidence Strut Fairing</th>
<th>Tunnel Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>233.10</td>
<td>25.5</td>
<td>94.5</td>
</tr>
<tr>
<td>0</td>
<td>234.20</td>
<td>23.2</td>
<td>94.5</td>
</tr>
<tr>
<td>20</td>
<td>236.50</td>
<td>18.6</td>
<td>94.5</td>
</tr>
<tr>
<td>45</td>
<td>240.50</td>
<td>10.2</td>
<td>94.5</td>
</tr>
</tbody>
</table>

All loads in lb.

The loads are pull on fairings or down loads on tunnel wall.

Written by: G. Jacquier
Checked: Sept. 1977
Issue: Aircraft

DECLASSIFIED
### Stress Analysis of \( \frac{1}{12} \) Scale Hovering & Transition Model

#### 6-4-4 FAIRING LOADS

#### 4-6-4 NET LOADS & REACTIONS

![Diagram showing forces and reactions](image)

<table>
<thead>
<tr>
<th>REACTIONS</th>
<th>( \alpha = -10^\circ )</th>
<th>( \alpha = 0^\circ )</th>
<th>( \alpha = 20^\circ )</th>
<th>( \alpha = 45^\circ )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{A_Y} )</td>
<td>238.8</td>
<td>233.4</td>
<td>241.7</td>
<td>243.6</td>
</tr>
<tr>
<td>( R_{B_Y} )</td>
<td>238.3</td>
<td>239.4</td>
<td>241.7</td>
<td>243.6</td>
</tr>
<tr>
<td>( R_{A_N} )</td>
<td>173.6</td>
<td>173.6</td>
<td>173.6</td>
<td>102.7</td>
</tr>
<tr>
<td>( R_{B_N} )</td>
<td>173.6</td>
<td>173.6</td>
<td>173.6</td>
<td>102.7</td>
</tr>
<tr>
<td>( R_{C} )</td>
<td>15.1</td>
<td>12.8</td>
<td>8.2</td>
<td>4.38</td>
</tr>
<tr>
<td>( R_{D_Y} )</td>
<td>94.5</td>
<td>94.5</td>
<td>94.5</td>
<td>94.5</td>
</tr>
<tr>
<td>( R_{E_Y} )</td>
<td>94.5</td>
<td>94.5</td>
<td>94.5</td>
<td>94.5</td>
</tr>
<tr>
<td>( R_{D_H} )</td>
<td>78.2</td>
<td>78.2</td>
<td>78.2</td>
<td>46.9</td>
</tr>
<tr>
<td>( R_{E_H} )</td>
<td>78.2</td>
<td>78.2</td>
<td>78.2</td>
<td>46.9</td>
</tr>
<tr>
<td>( R_{E} ) OPERATING</td>
<td>0</td>
<td>121.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( R_{E} ) PRESSURE</td>
<td>1372.0</td>
<td>1372.0</td>
<td>1372.0</td>
<td>1372.0</td>
</tr>
</tbody>
</table>

*REF: 4-3.5

---

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**WRITTEN BY**

G. Jacobson

**CHECKED BY**

D. J. Williams

**DATE**

Sept. 1957

**ISSUE**

**AIRCRAFT**
Stress Analysis of 1/12 Scale Hovering & Transition Model

5-0  Model Stress Analysis

5-1-1  Loading Considerations

The aerodynamic loads developed in section 4 have been used together with pressure in the supply tube, only to check the strength of the attachment of the model to its supporting structure (see sections 6 & 7).

Due to the robust nature of the model structure, stresses induced in the model by these external loads will be low and can be neglected. The validity of this statement is illustrated by the pessimistic assessment of the loads on the wing attachment bolt (section 5-2-1).

The highest stresses will be those due to the pressure differential between the interior and outside of the model.
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

S-0 - FIG-B - $\frac{1}{12}$ SCALE MODEL - SCHEMATIC DIAGRAM

48 - 1.4" HOLES

33G - .242" HOLES

96 - .453" HOLES

6 REMOVABLE SEGMENTS ON EACH FACE

6 REMOVABLE SEGMENTS ON EACH FACE

FIG - 1

PRESSURE & SUCTION SUPPLY

TUNNEL SPEED: $V = \frac{138.8 \text{ ft}}{\text{sec}}$ $q = 30 \text{ PSF}$

WRITTEN BY: G. Jacques
CHECKED BY: J. Johnson
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AIRCRAFT: AVRO EA 3110

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5-1-2 Differential pressure on the wing upper surface.

Max. internal pressure in the wing: 30.74 PSI

Assume the A/C is at 45° incidence, and a pressure distribution giving an average value of $C_p = -5$ on the front part of the wing.

Assume also that the mean value of $C_p$ over the first 3” after C.G. is $C_p = -10$.

Hence: the local pressure: \( \Delta P = C_p \rho g \)

\[
\Delta P_{avg} = -5 \times 30 = -150 \text{ PSF} = -1.04 \text{ PSI}
\]

\[
\Delta P_{tip} = -10 \times 30 = -300 \text{ PSF} = -2.08 \text{ PSI}
\]

Hence total external pressure: \( P_{avg} = 14.7 - 1.04 = 13.66 \text{ PSI} \)

\( P_{tip} = 14.7 - 2.08 = 12.62 \text{ PSI} \)

Differential pressure taken by the wing structure:

\[
\Delta P_{avg} = 30.74 - 13.66 = 17.08 \text{ PSI}
\]

\[
\Delta P_{tip} = 30.74 - 12.62 = 18.12 \text{ PSI}
\]

A general stressing of the wing will be carried out using 17.10 PSI and a local stressing near the leading edge using 18.20 PSI.

With a load factor of 4, these pressures become:

\[
17.1 \times 4 = 68.4 \text{ PSI}
\]

\[
18.2 \times 4 = 72.8 \text{ PSI}
\]
As a covering story, the bolt is assumed to take in shear the moment calculated from the diagram below under an arbitrary pressure of 5 psi. At the same time, it will be considered under the tension due to internal pressure of 684 psi on an area of 10 in².

Hence: tension in the bolt:
$$684 \times 10 = 6840 \text{ lb}$$

Area of the wing segment:
$$A = \frac{2 \times 4.6 \times 7.5}{2} = 32.5 \text{ in}^2$$

Moment about the bolt:
$$4 \times 32.5 \times 5 \times 5.1 = 3808 \text{ in}^\text{lb}$$

Shear on the bolt:
$$\frac{3808}{1.75} = 2160 \text{ lb}$$

Strength of the 3/8'' bolt as per AN-C-1-T:
- Tension: 2160 lb
- Shear: 2070 lb

Combined loading: allowable tension:
$$\gamma = \sqrt{\frac{b^2(1 - \frac{x^2}{a^2})}{a^2}} = \sqrt{1 - \frac{x^3}{a^2}}$$

$$\gamma = 2160 \sqrt{1 - \left(\frac{2070}{2160}\right)^2} = 2160 \times \left(1 - .835\right) = 2160 \times .165 = 360 \text{ lb}$$

M.S.:
$$\frac{875}{684.0} - 1 = .128$$
Assume:
1. all sides can be considered as fixed against rotation
2. all sides can be assumed held against deflection in Z direction.

Area of panel: \( \frac{\pi}{360} \times 17.6^2 \times 7.8 = \frac{\pi}{24} \times (110 - 61) = 52.5 \text{ in}^2 \)

Max pressure force on panel: \( 52.5 \times 17.10 = 556 \text{ lb} \)

Length of area: \( 17.6 \times .2615 = 4.6'' \) \( \frac{7.8 \times .2615 = 2.04''}{\text{mean length: 3.32''}} \)

15°
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

5-0  MODEL STRESS ANALYSIS
5-2-2  WING SKIN PANELS

Consider the rectangular plate shown in dotted lines. This plate is relatively thick and will take the load in bending rather than as a membrane.

we have: \( b = 3.32'' \), \( a = 9.80'' \), \( \frac{b}{a} = 0.335 \)

Ref: Resistance des matériaux appliquées à l'architecture by Paul Vallat

Max. bending stress in the plate: \( f_m = \frac{P b}{b^2} \)

Max. deflection at the center: \( w_m = C \frac{P b^4}{E (1 - v^2) b^2} \)

(Ref: A from curve (2) Diagram 32-1 - \( A = 0.50 \))

(Ref: C from curve (2) Diagram 32-1 - \( C = 0.812 \))

Thus: \( f_m = 0.50 \times 17.10 \left( \frac{3.32}{0.15} \right)^2 = 4190 \text{ PSI} \) @ 55,000 PSI.

\( w_m = 0.812 \times 17.10 \times 6.32 \left( \frac{3.32}{0.15} \right)^3 = 0.000203'' \)

Fully factored bending stress: \( H \times 4190 = 16780 \text{ PSI} \)

\( M.S. \frac{55000}{16780} - 1 = 2.28 \)
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL.

FLAT PLATES UNDER TRANSVERSE LOADING.

The following is translated from "RÉSISTANCE DES MATERIAUX APPLIQUÉE A L'AÉRONAUTIQUE" by PAUL VALLAT.
1st Edition - 1944 - Published by: MENARD - ÉDITEURS
8 RUE DES REGNAS - TOULOUSE
FRANCE.

\[ \sigma_{b} = \frac{\mathcal{A} P (\frac{b}{t})^{2}}{b} \]

MAX. DEFLECTION AT THE CENTER OF THE PLATE:

\[ w_{c} = \frac{P b}{E (1 - \nu^2)} \left( \frac{b}{t} \right)^{3} \]

WHERE:

- \( E \) = Young's modulus.
- \( \nu \) = Poisson's ratio.
- \( \mathcal{A} \) = Coeff. obtained from curve next page.
- \( C \) = Coeff. obtained from curve next page.
- \( a, b, t \) = dimensions of the plate as shown above.
- \( P \) = Applied uniformly distributed pressure.

*: For simply supported edges: max. bending stress at the center of the plate.

W R I T T E N  B Y

D. Jacquemin

C H E C K E D  B Y

Date

I S S U E

A I R C R A F T

AVRO EA 3110

D E C L A S S I F I E D
ATTACHMENT SCREWS.

The skin is held on the rib by 6 screws.

AN-510 #4 or #5.

Screws strength in tension as per specification:

#5: 396 lbf
#4: 313 lbf

Load per screw with a max pressure face of 556 lbf per panel at a pressure of 17.10 psi. (unfactored)

\[
\frac{556}{6} = 92.67 \text{ lbf (unfactored)}
\]

Fully factored load per screw: 69.5 x 4 = 278 lbf

Considering now a screw at the outer end of the rib and using the higher pressure 18.2 psi.

Fully factored load per screw:

\[
\frac{278 \times 18.2}{17.1} = 296.4 \text{ lbf (average load)}
\]

Considering the drawing, it can be seen that the outer screw will take approximately the pressure on a strip 4" long and 1.3" wide. Hence a load at 72.8 psi (fully factored)

\[
72.8 \times 4 \times 1.3 = 379.6 \text{ lbf}
\]

\[\frac{396}{379.6} - 1 = 0.068\]

\[\frac{396}{379} \approx 1\]

* NOTE: This Margin of safety is pessimistic as no account was taken of the effect of the edge attachment.

* 068

WRITTEN BY
G. Jacques

CHECKED BY
W. F. Williams

DECLASSIFIED
Sept. 1957

AIRCRAFT
STRESS ANALYSIS OF \( \frac{1}{2} \) SCALE HOVERING & TRANSITION MODEL.

5-0 Model Stress Analysis

5-2-3 Wing Nozzle Region

WING EDGE SHOWN WITH COVER PLATE REMOVED

MAT.
MILD STEEL
SAE 1020
OF SAE 1025.

STEEL SCREWS
AN-510
#5 or #4.

SECTION B'-B'

WING FLANGES EDGE ATTACHMENT

SECTION A'-A'

COVER PLATES ATT'T & FLANGES TO RIB ATT'T.

FIG. 9 DETAILS OF OUTER EDGE

WRITTEN BY
G. Jacques

CHECKED BY

DATE

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DECLASSIFIED
STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODEL

5-0 - MODEL STRESS ANALYSIS
5-2-3 - WING NOZZLE REGION

ASSUMPTIONS FOR STRESSING THE EDGE.

1. The differential pressure will be taken at 18.20 psi as calculated previously.

2. The edge will be first treated as a rectangular plate .086" thick with all four sides fixed. Size: $2 \times b = 4.5' \times 2.0'$
   
   
   This assumption can be made since it was found that the deflection at the center of the $1/16''$ thick plate would be of the order of .0002" hence negligible. (Page 68)

3. The max. stress in bending found from plate theory will be assumed to be constant over the plate for the purpose of stressing the 5 sections A, B & C indicated on the sketch, but will be factored up to the local reduction in section.

4. Section A will be considered .086" thick.
   Section B will be considered as two plates: .086" + .064" working together independently.
   Section C will be considered .086" thick.

Note: The .064" plate has to be assumed ineffective near its edges due to insufficient attachment. It is assumed however that enough load can be picked up by the plate to make it effective between the 1/4" holes at section B.

BENDING STRESS IN THE PLATE AS PER ASSUMPTIONS 1 & 2

$$f_b = A P \left( \frac{b}{k} \right)^2 = 0.43 \times 18.20 \left( \frac{2.0}{0.086} \right)^2 = 4830 \text{ psi}$$

$$A = 0.43 \quad \text{(from 2)}$$

WRITTEN BY  G. Jacques
CHECKED BY  T. L. Martin
DATE   Sept. 1957
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AVRO EA 3110
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

S-0  MODEL STRESS ANALYSIS
S-2-3  WING NOZZLE REGION

STRESSING OF THE EDGE.

SECTION B.

Basic section in bending will be assumed to be a 15° arc of radius 15.00"

i.e.: 4.16" long having a section modulus:

$$\frac{4.16 \times 0.0625}{6} .00512 \text{ in}^3$$

The actual section is made of $\left(1.34'' \times 0.086''\right) + \left(1.34'' \times 0.064''\right)$

daving a section modulus: $\frac{1.34}{6} \left(0.086^2 + 0.064^2\right) = 0.0257 \text{ in}^3$

Hence, the bending stress:

$$\frac{4030 \times 0.0257}{96000} = 96.40 \text{ PSI} \quad @ \quad 55000$$

Fully factored: $96.40 \times 1.5 = 38600 \text{ PSI}$

M.S. $= \frac{55000}{38600} - 1 = -0.25$

SECTION C.

Basic section in bending will be assumed to be a 15° arc of radius 16.95"

i.e.: 4.43" long having a section modulus:

$$\frac{4.43 \times 0.0625}{6} .00545 \text{ in}^3$$

The actual section has only $1.43'' \times 0.096''$

having a section modulus: $\frac{1.43}{6} \times 0.0625 = 0.01832 \text{ in}^3$

Hence, the bending stress:

$$\frac{4030 \times 0.01832}{14400} = 14.40 \text{ PSI} \quad @ \quad 55000$$

Fully factored: $14.40 \times 1.5 = 57600 \text{ PSI}$

M.S. $= \frac{55000}{57600} - 1 = -0.04$

ACTUAL MARGIN OF SAFETY ON APPLIED LOAD

3.95:

WITTEN BY
G. Jacobson

CHECKED BY
P.R. Plott

DATE
Sept. 1957

ISSUE

AIRCRAFT
AVRO EA 3110
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS
5-2-4 WING EDGE ATTACHMENT

STRESSING OF THE EDGE.

ATTACHMENT SCREWS.

Strength in tension of \#5-44 \& \#4-48 - AN-510 SCREWS per turn of thread.

Screw strength in tension as given by AN-510 Spec,
\#5 = 396 \text{lbf}
\#4 = 313 \text{lbf}

The strength is based on threads engaged in a standard nut,
min height of nut \& nb of turns of thread:
\#5-44 :
\[ h = 0.102" - 0.114" \quad n = 4.48 \]
\#4-48 :
\[ h = 0.087" - 0.098" \quad n = 4.17 \]

Strength per turn of thread:
\#5-44 :
\[ \frac{396}{4.48} = 88.4 \text{lbf} \]
\#4-48 :
\[ \frac{313}{4.17} = 75.0 \text{lbf} \]

SCREWS ATTACHING WING FLANGES AT THE EDGE.

- Length of thread engaged = 0.15" > 0.102" hence full strength available.
- Each screw can be considered as taking a maximum load equal to
the pressure over 2\text{\(\frac{\text{in}}{2}\)} = 17.2 \times 2 = 34.4 \text{lbf}

\[ \frac{315}{34.4} = 9.2 \text{\(\frac{\text{in}}{2}\)} \]

If \#5 screws are used:
\[ M.S. = \frac{315}{36.4} = 8.7 \]

If \#4 screws are used:
\[ M.S. = \frac{396}{36.4} = 10.9 \]

SCREWS ATTACHING THE COVER PLATES.

- Length of thread engaged = 0.086" \Rightarrow \% of thread engaged:
\#5 : 3.78 available strength : 88.4 \times 3.78 = 334 \text{lbf}
\#4 : 4.13 available strength : 75 \times 4.13 = 310 \text{lbf}

Omitting again 2\text{\(\frac{\text{in}}{2}\)} pressure as a max load : 36.4 \text{lbf per screw}.
5-0  Model Stress Analysis
5-2-5  Wing .064" Cover Plates

Attachment Screws cont'd.

Screws Attaching the Cover Plates - cont'd.

If 9/4 screws are used: M.S. \[ \frac{210}{23.264} \cdot 4 = \] 1.1

\[ \frac{35}{23.264} \cdot 4 = \] 1.2

.064" Cover Plate.

This plate will be covered for the case where it is used to blanket the 2 sets of holes. Due to tension every other side; it must be considered as a plate under uniform loading supported at 6 points. The max pressure of 19.2 PSI will be considered over the plate.

Using Timoshenko "Plates & Shells"
page 243

\[ \frac{b}{d} = \frac{2.6}{2} = 1.3 \]

\[ \alpha = \frac{0.0423}{20} \]

\[ \beta = 0.0210 \]

\[ \beta_1 = 0.0385 \]

Deflection at center of plate:

\[ \omega = \frac{q \cdot b^4}{E \cdot h^3} = \frac{0.0423 \cdot 11.2 \cdot 2.6^4}{20 \cdot 10^6 \cdot 0.0446^3} = 0.00446" \]

\[ M_x = \beta \cdot q \cdot b^2 = 0.0210 \cdot 11.2 \cdot 2.6^2 = 2.585 \text{ in-lb} \]

\[ M_y = \beta_1 \cdot q \cdot b^2 = 0.0385 \cdot 11.2 \cdot 2.6^2 = 1.730 \text{ in-lb} \]

\[ \sqrt{M_x^2 + M_y^2} = \sqrt{2.585^2 + 1.73^2} = 3.02 \text{ in-lb} \]
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

5-0. MODEL STRESS ANALYSIS

5-2-5. WING .064" COVER PLATE

.064" COVER PLATE - CONT'D.

Section modulus of \( .064" \times 1.00" \) of plate:

\[ \frac{1 \times .064^2}{6} = .000684 \text{ in}^3 \]

Max Bending stress in the plate:

\[ \frac{5.22}{.000684} = 7810 \text{ PSI} \] @ 55000

Fully factored:

\[ 7800 \times 1.5 = 31200 \text{ PSI} \]

M.S. \[ \frac{55000}{31200} - 1 = .765 \]
5-0  MODEL STRESS ANALYSIS
5-2-6  WING - MAX. PRESSURE PERMISSIBLE.

PRESSURE REQUIRED TO PRODUCE STRUCTURAL FAILURE OF THE WING.

The weakest point of the wing is section C of the edge with a margin of safety: 0.48 and a load factor \( n = 4 \).

Hence, the failure pressure:\[ 4 \times 18.20 \times (1-0.48) = 69.4 \text{ PSI} \]

Pressure at yield of the material: \( 69.4 \times \frac{36}{55} = 45.3 \text{ PSI} \)

PRESSURE REQUIRED TO PRODUCE FAILURE OF THE .064" COVER PLATE.

The minimum margin of safety on the cover plate is: 0.762

Hence, the failure pressure:\[ 4 \times 18.20 (1+0.762) = 128 \text{ PSI} \]

Pressure at yield of the material: \( 128 \times \frac{36}{55} = 83.7 \text{ PSI} \)
STRESS ANALYSIS OF \( \frac{1}{2} \) SCALE HOVERING & TRANSITION MODEL.

5-0 MODEL STRESS ANALYSIS
5-3 BOTTOM INTAKE ROOF.

MAX. DIFFERENTIAL PRESSURE: ESTIMATED: 1 PSI.
Each spoke will be considered as taking the load applied on a 15° segment of an annulus of radius: 17.92" = 3.70". Since the rigidity of the annulus is much larger than that of the spokes, the spokes will be working as cantilever beams having their free end fixed against rotation.

Area of annulus interesting each spoke,
\[ A = \pi (7.92^2 - 3.70^2) \times \frac{15}{360} = 6.61 \text{ in}^2 \]

Net load per spoke: fully factored - estimated differential pressure: 1 PSI

6.61 \times 1 \times 4 = 26.444

The smallest section of the spoke: .20" x .09" will be assumed constant along the .80" length:

\[ \sigma = \frac{F}{\frac{bh}{2}} = 3 \frac{PL}{bh^2} = 3 \frac{26.65 \times .80}{.09 \times .20^2} = \frac{61.5}{.0036} = 17100 \text{ PSI} \]

\[ M.S. \frac{55000}{17100} - 1 = 2.22 \]
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS
5-3 BOTTOM INTAKE ROOF
5-3-2 EXHAUST TUBES ATTACHMENT.

CALIBRATION CASE

\[ \frac{44 \times 1325}{12} + 200 = 1048 \]

The max. loads on this attachment will occur in the calibration case from section 10 under the max. down load of 1925 lb. 44% of this down load is taken by the rod: 1048 lb.

Hence, load per tube fully factored: 1048 \( \frac{4}{4} \) = 698 lb.

Area of holder in shear: 1.125 \( \frac{1}{4} \) x .35 = 1.238 in\(^2\).
Stress Analysis of 1/12 Scale Hovering & Transition Model

5-0 Model Stress Analysis
5-3 Bottom Intake Roof
5-3-2 Exhaust Tubes Attachment

Axial load on each tube: \( \frac{698}{\cos 32°} = 824 \frac{lb}{in} \)

Shear stress on the solder: \( \frac{824}{1.238} = 665 \text{ PSI} \)

The solder used is a 95% tin - 5% lead type.

Ref: AP-370, Chapter 405-3-18 Ultimate shear strength of solder: 1000 PSI

M.S. \( \frac{4000}{665} - 1 = 5.00 \)
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

6-0 LOAD GAGE DESIGN
6-1 LOAD ANALYSIS

6-1-1 LOADING CONSIDERATIONS

DESCRIPTION OF GAGE SECTION

**FIG. 10** GAGE SECTION

The model is attached at the bottom of the vertical arm by means of a vertical steel rod and four rings load measuring gages as shown above.

The suspension rod is used to support the model in such a way that no load due to model weight is registered by the gages when the arm is vertical.

Gages A, B & C will measure both pitching moments and loads normal to the plane of the model. In addition, gages B & C

DECLASSIFIED
### Stress Analysis of 1/2 Scale Hovering & Transition Model

<table>
<thead>
<tr>
<th>6-0</th>
<th>Load Gage Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-1</td>
<td>Load Analysis</td>
</tr>
<tr>
<td>6-1-1</td>
<td>Loading Considerations</td>
</tr>
</tbody>
</table>

#### Description of Gage Section - Cont'd

- Gage D will measure rolling moments. Gage D will measure loads parallel to the plane of the model.

#### Load Paths Through Gage Section

The loads resolved at the model center consist of three forces: vertical, fore/aft and side, and two moments: pitching and rolling. Due to symmetries around the vertical axis, no yawing moment can be produced.

Due to the offset between model center and gage center, the gages will have the following response to the case of fore/aft and side load:

1. **Fore/aft load**: Gage D will indicate a pull or a push. Gages A, B & C will indicate a pitching moment.
2. **Side load**: Gages B & C will indicate a rolling moment.

Side forces will be taken as side loads on gages A, B & C which are designed to resist them without affecting their normal load measuring accuracy.

The gage center in the case of fore/aft load is obviously contained in a horizontal plane passing through the drag gage D. In the case of side load, it must be in a...
LOAD PATHS THROUGH GAGE SECTION - CONT'D

plane passing by the points of zero bending in gages A, B & C operating as cantilever beams with the free end pivoted against rotation. Since the point of zero bending of gages A, B & C is at the mid distance between the two flanges and since gage D is also placed at mid distance between the same two flanges, the two planes are coincident. The gage center under vertical loads lies on the vertical axis. Hence, the center of all gages is at the intersection of the vertical axis and the plane defined above.

NOTE.

At the time this section of the report was written, the geometry of the gage section was as shown on 6-1-2. Later on, this geometry has been slightly modified to the dimensions shown in 6-3. Since this modification does not materially alter the gage loading, the section has not been rewritten. However, should exact values of the loads on the gages be needed, they can be computed easily from the equations given in 6-3.
6.0 - LOAD GAGE DESIGN
6.1.2 - LOADS RESOLVED
   AT GAGE CENTER.

LOADS RESOLVED AT POINT O,
A 50 lbf side load is assumed acting at the center of the model.

+ 20° CASE -

\[ M_x = 1295 - (37 \times 5.0) = 1110 \text{ in} \cdot \text{lbf} \]
\[ M_y = 50 \times 5.0 = 250 \text{ in} \cdot \text{lbf} \]

- 10° CASE

\[ M_x = 4320 - (29.2 \times 5.0) = 4174 \text{ in} \cdot \text{lbf} \]
\[ M_y = 50 \times 5.0 = 250 \text{ in} \cdot \text{lbf} \]
STRESS ANALYSIS OF ½ SCALE HOVERING & TRANSITION MODEL

6.0 LOAD GAGE DESIGN

6.1.2 LOADS RESOLVED AT GAGE CENTER.

+45° CASE - TUNNEL AT \( q = 50 \text{ PSF} \)

\[
M_c = 7060 + (46.6 \times 5.0) = 7293 \text{ in-lb}
\]

\[
M_t = 50 \times 5.0 = 250 \text{ in-lb}
\]

Value of \( q \) required to reduce the moment \( M_c \) to 4200 in-lb in order not to exceed the strength requirements of the range of \(-10° < \alpha < 20°\).

\[
q_{45} = 30 \frac{4200}{7293} = 17.25 \text{ PSF}, \quad \text{SAY 18 PSF}
\]

+45° CASE - TUNNEL AT \( q = 18 \text{ PSF} \).

\[
M_c = 4230 - (38 \times 5) = 4090 \text{ in-lb}
\]

\[
M_t = 50 \times 5.0 = 250 \text{ in-lb}
\]
Stress Analysis of 1/12 Scale Hovering & Transition Model

6-0 Load Gage Design

6-1-2 Loads Resolved at Gage Center.

+35° Case:  \( q = 30 \text{ psf} \)

\[
M_L = 2735 + (21.2 \times 5) = 2841 \text{ in}-\text{lbf}
\]

\[
M_T = 50 \times 5.0 = 250 \text{ in}-\text{lbf}
\]

In this case, the moment is considerably smaller than 4200 in-lbf hence the tunnel can be operated at \( q = 30 \text{ psf} \).
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

6-1.3 - LOAD DISTRIBUTION

DISTRIBUTION OF A NORMAL LOAD ON GAGES A, B & C.

DISTRIBUTION OF A SIDE LOAD ON GAGES A, B & C.

LOAD ON GAGE A:

\[
\begin{align*}
W &= 2.2, \quad .350W \text{ NORMAL} \\
P &= 2.2, \quad .350P \text{ SIDE}
\end{align*}
\]

LOAD ON GAGES B & C:

\[
\begin{align*}
W &= \frac{4.1}{6.3 \times 2} = .325W \text{ NORMAL} \\
P &= \frac{4.1}{6.3 \times 2} = .325P \text{ SIDE}
\end{align*}
\]

DISTRIBUTION OF A LONGITUDINAL MOMENT ON GAGES A, B & C

LOAD ON GAGE A:

\[
M_L = 0.159 M_L
\]

LOAD ON GAGES B & C

\[
- \frac{M_L}{2 \times 6.3} = -0.07545 M_L
\]

DISTRIBUTION OF A TRANSVERSAL MOMENT ON GAGES B & C

LOADS ON GAGES B & C

\[
\frac{M_T}{6.7} = \pm 0.1432 M_T
\]
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

6-1-3 LOAD DISTRIBUTION
LOADS ON THE GAGES - EFFECT OF MOMENTS ONLY

\[ +m \text{ load on gage } A \text{ : compression on the gage} \]
\[ +m \text{ on } B \text{ & } C \text{ : tension on the gage.} \]

\[ -10^\circ \text{ CASE} \]

**GAGE**

\[ A = -0.153 \times 4174 = \frac{664.16}{\text{lbs}} \]
\[ B = (-0.07345 \times 4174) + (-1.1492 \times 250) = -332 + 37.3 = \frac{294.7}{\text{lbs}} \]
\[ C = (-0.07345 \times 4174) - (-1.1492 \times 250) = -332 - 37.3 = \frac{369.3}{\text{lbs}} \]

\[ +20^\circ \text{ CASE} \]

**GAGE**

\[ A = -0.153 \times 111 = -176.5 \text{ lbs} \]
\[ B = (0.07345 \times 111) + (1.1492 \times 250) = 88.0 + 37.3 = \frac{125.3}{\text{lbs}} \]
\[ C = (0.07345 \times 111) - (1.1492 \times 250) = 88.0 - 37.3 = \frac{50.7}{\text{lbs}} \]

\[ +45^\circ - 18 \text{ g. CASE} \]

**GAGE**

\[ A = 0.153 \times 4040 = \frac{643.16}{\text{lbs}} \]
\[ B = (0.07345 \times 4040) + (1.1492 \times 210) = 321.5 + 37.3 = \frac{358.8}{\text{lbs}} \]
\[ C = (0.07345 \times 4040) - (1.1492 \times 210) = 321.5 - 37.3 = \frac{284.2}{\text{lbs}} \]

**SUMMARY OF GAGE LOADS**
**EFFECT OF MOMENTS ONLY**

<table>
<thead>
<tr>
<th>CASE</th>
<th>-10°</th>
<th>+20°</th>
<th>+45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel 4</td>
<td>30</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>GAGE A</td>
<td>664.16 T</td>
<td>-176.5 C</td>
<td>643.16 C</td>
</tr>
<tr>
<td>GAGE B</td>
<td>125.3 C</td>
<td>125.3 C</td>
<td>358.8 T</td>
</tr>
<tr>
<td>GAGE C</td>
<td>50.7 C</td>
<td>50.7 C</td>
<td>284.2 T</td>
</tr>
</tbody>
</table>

**REQUIRED GAGE RATING**

\[ A = 800 \text{ lbs} \]
\[ B = 350 \text{ lbs} \]
\[ C = 350 \text{ lbs} \]
6-1-3 LOAD DISTRIBUTION
SUSPENSION ROD

The rod is designed at an operating stress of 20,000 psi. to take a max. load of 550 lb.

Required diameter: \( \sqrt{\frac{4}{\pi}} \frac{W}{F} = D \)

\[ D = \sqrt{\frac{4 \times 550}{20000}} = \sqrt{0.035} = 0.187'' \]

Sectional area: \( 0.187^2 \pi \frac{W}{4} = 0.0275 \text{ in}^2 \)

ELONGATION: \( \varepsilon = \frac{W L}{A E} \)

MAT: SAE-4130 - CHR. NICKEL STEEL

@ 128,000 PSI UTS

ELONGATION PER POUND LOAD:

\[ \varepsilon = \frac{W \times 20}{0.0275 \times 20 \times 10^6} = 2.12 \times 10^{-5} \text{ W in/ft} \]
SECTION 6.1.3 LOAD DISTRIBUTION

DISTRIBUTION OF LOAD BETWEEN GAGES AND CENTER ROD

Deflection rate:
Gage A: \(2.66 \times 10^{-5}\) in/ft
Gage B: \(7.42 \times 10^{-5}\) in/ft

For a unit gage load:
Deflection at A: \(0.38 \times 2.66 \times 10^{-5} = 0.93 \times 10^{-5}\) in
Deflection at B: \(0.325 \times 7.42 \times 10^{-5} = 2.415 \times 10^{-5}\) in

Then: deflection at O:
\[
\left[\frac{2.415}{2.415 - (0.93)} \times \frac{2.2}{6.3}\right] \times 10^{-5} = 1.895 \times 10^{-5}\text{ in}
\]

Deflection rate of the rod: \(2.42 \times 10^{-5}\) in/ft

Now, let \(W_1, \Delta W_1\) be the load and deflection of the rod and \(W_2, \Delta W_2\) be the load and deflection of the gage system at point O and \(\Delta W\) the incremental load on the system.

Then, we must have: \(\Delta W = W_1 + W_2\) and \(\Delta W_1 = \Delta W_2\)

Let \(\Delta W = 1\) and calculate a relation between \(W_1, W_2\)

we have: \(\Delta W_1 = 2.42 \times 10^{-5} W_1\),
\(\Delta W_2 = 1.895 \times 10^{-5} W_2\)

Thus:
\[2.42 \times 10^{-5} W_1 = 1.895 \times 10^{-5} W_2\]

\[W_2 = \frac{2.42}{1.895} W_1 = 1.278 W_1\]

Hence:
\[\Delta W = W_1 + 1.278 W_1 = 2.278 W_1 = 1\]

Then:
\[W_1 = \frac{1}{2.278} = 0.44\text{ in}; \text{the rod takes 44% of } W_1\]
**STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL**

**G-1-3 LOAD DISTRIBUTION**

**DISTRIBUTION OF LOAD BETWEEN GAGES & CENTER ROD - cont'd.**

From Page 89, the load on gauge A has been found to be 35% of the total load on the gage system and 32.5% on gauge B & C respectively.

Hence, in terms of the incremental load ΔW,

- Load on gauge A: \(0.56 \times 0.35 = 0.196 = 19.6\%\)
- Load on gauge B or C: \(0.56 \times 0.325 = 0.182 = 18.2\%\)

Hence: The load distribution is:

<table>
<thead>
<tr>
<th>ROD</th>
<th>GAGE A</th>
<th>GAGE B</th>
<th>GAGE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>44%</td>
<td>19.6%</td>
<td>18.2%</td>
<td>18.2%</td>
</tr>
</tbody>
</table>
### STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

#### 6-1.3 LOAD DISTRIBUTION

Load on the gages with the rod adjusted to take 2004.

**SUCTION ON**

**-10° CASE -**

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL WEIGHT</td>
<td>200</td>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>296</td>
<td>126</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>AIRLOAD</td>
<td>63.3</td>
<td>27.8</td>
<td>12.4</td>
<td>11.5</td>
</tr>
<tr>
<td>MOMENTS</td>
<td>10</td>
<td>0</td>
<td>66</td>
<td>-295</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-363</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>352.48</td>
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</tbody>
</table>

**+20° CASE -**

<table>
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<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODEL WEIGHT</td>
<td>200</td>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>266</td>
<td>126</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>AIRLOAD</td>
<td>143.8</td>
<td>-195.2</td>
<td>87</td>
<td>80.8</td>
</tr>
<tr>
<td>MOMENTS</td>
<td>0</td>
<td>222.5</td>
<td>177.565</td>
<td>74</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>143.52</td>
<td></td>
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</tbody>
</table>

**NOTE**: Airload + pressure load + normal component of model weight =

net normal load given page 90.

Load given above under normal component is the change in normal load due to model weight with angle of attack.

**WRITTEN BY**: G. Jacques

**CHECKED BY**: [Signature]

**DATE**: Sept. 1957

**ISSUE**: [Signature]

**AIRCRAFT**: [Signature]
### Stress Analysis of 1/2 Scale Hovering & Transition Money

#### 6-1-3 Load Distribution

Load on the gages with the rod adjusted to take 200 lb.

**+45° Case** - \( g = 18 \text{ PSF} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>44%</td>
<td>19.6%</td>
<td>18.2%</td>
<td>18.2%</td>
</tr>
<tr>
<td>Model Weight</td>
<td>200</td>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Normal Comp.</td>
<td>-59</td>
<td>26</td>
<td>-11.56</td>
<td>-10.72</td>
</tr>
<tr>
<td>Pressure</td>
<td>286</td>
<td>126</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>Air Load</td>
<td>-486</td>
<td>178.9</td>
<td>-79.5</td>
<td>-73.8</td>
</tr>
<tr>
<td>Moments</td>
<td>0</td>
<td>643</td>
<td>359</td>
<td>284</td>
</tr>
<tr>
<td></td>
<td>121.1</td>
<td>678.06</td>
<td>326.48</td>
<td>251.48</td>
</tr>
</tbody>
</table>

**Suction Off**

-10° Case - \( g = 80 \text{ PSF} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>44%</td>
<td>19.6%</td>
<td>18.2%</td>
<td>18.2%</td>
</tr>
<tr>
<td>Model Weight</td>
<td>200</td>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Normal Comp.</td>
<td>-3</td>
<td>-1.32</td>
<td>-0.528</td>
<td>-0.546</td>
</tr>
<tr>
<td>Pressure</td>
<td>320</td>
<td>141</td>
<td>62.6</td>
<td>58.2</td>
</tr>
<tr>
<td>Air Load</td>
<td>63.13</td>
<td>27.8</td>
<td>12.4</td>
<td>11.5</td>
</tr>
<tr>
<td>Moments</td>
<td>664</td>
<td>295</td>
<td>569</td>
<td></td>
</tr>
<tr>
<td></td>
<td>367.48</td>
<td>718.412</td>
<td>-225.85</td>
<td>-299.85</td>
</tr>
</tbody>
</table>

* See page 20

See note page 34

**Written By**

G. Jacques

**Checked By**

D. J.

**Date**

Sept. 1957

**Issue**

Aircraft

AVRO EA 3110

SECRET DECLASSIFIED
### Load Distribution

**Load on the Gages with the Rod Adjusted to Take 200 lbf**

**Suction Off**

**+20° Case -**  \( g = 30 \text{ PSF} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model Weight</strong></td>
<td>200 lbf</td>
<td>0 lbf</td>
<td>0 lbf</td>
<td>0 lbf</td>
</tr>
<tr>
<td><strong>Normal Comp 141</strong></td>
<td>-12 lbf</td>
<td>-5.28 lbf</td>
<td>-235 lbf</td>
<td>-2.185 lbf</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>141 lbf</td>
<td>62.6 lbf</td>
<td>58.2 lbf</td>
<td>58.2 lbf</td>
</tr>
<tr>
<td><strong>Airload</strong></td>
<td>-195.2 lbf</td>
<td>-17.0 lbf</td>
<td>-80.8 lbf</td>
<td>-80.8 lbf</td>
</tr>
<tr>
<td><strong>Moments</strong></td>
<td>0 lbf</td>
<td>222.5 lbf</td>
<td>149.5 lbf</td>
<td>74 lbf</td>
</tr>
</tbody>
</table>

\[ \text{Result:} 140.52 \downarrow, -249.25 \uparrow, 293.765 \downarrow, 49.215 \downarrow \]

**+45° Case -**  \( g = 18 \text{ PSF} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model Weight</strong></td>
<td>200 lbf</td>
<td>0 lbf</td>
<td>0 lbf</td>
<td>0 lbf</td>
</tr>
<tr>
<td><strong>Normal Comp 141</strong></td>
<td>-26 lbf</td>
<td>-11.55 lbf</td>
<td>-10.72 lbf</td>
<td>-10.72 lbf</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>141 lbf</td>
<td>62.6 lbf</td>
<td>58.2 lbf</td>
<td>58.2 lbf</td>
</tr>
<tr>
<td><strong>Airload</strong></td>
<td>-178.5 lbf</td>
<td>-79.5 lbf</td>
<td>-73.8 lbf</td>
<td>-73.8 lbf</td>
</tr>
<tr>
<td><strong>Moments</strong></td>
<td>0 lbf</td>
<td>643 lbf</td>
<td>359 lbf</td>
<td>234 lbf</td>
</tr>
</tbody>
</table>

\[ \text{Result:} 136.5 \downarrow, -671.45 \uparrow, 332.68 \downarrow, 257.68 \downarrow \]

*See Note Page 94*

---

**Written By:**

G. Jacques

**Checked By:**

L. J. Coates

**Date:**

Sept. 1957

**Issue:**

Avro EA 3110

---

**SECRET**

**DECLASSIFIED**
### Stress Analysis of 1/2 Scale Hovering & Transition Model

#### 6-1-3 - Load Distribution -

Load on the gages with the rod disconnected:

**Suction On:**

- **-10° Case:** \( g = 30 \text{ psf} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>35%</td>
<td>32.5%</td>
<td>32.5%</td>
</tr>
<tr>
<td>Weight Comp.</td>
<td>197</td>
<td>0</td>
<td>63</td>
<td>64</td>
</tr>
<tr>
<td>Pressure *</td>
<td>286</td>
<td>0</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Airload</td>
<td>-83.13</td>
<td>0</td>
<td>22.1</td>
<td>20.5</td>
</tr>
<tr>
<td>Moments</td>
<td>0</td>
<td>664</td>
<td>-285</td>
<td>-369</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>855.1</td>
<td>-117.5</td>
<td>-191.5</td>
</tr>
</tbody>
</table>

**+ 20° Case:** \( 1 = 30 \text{ psf} \)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>35%</td>
<td>32.5%</td>
<td>32.5%</td>
</tr>
<tr>
<td>Weight Comp.</td>
<td>188</td>
<td>0</td>
<td>65.8</td>
<td>61.1</td>
</tr>
<tr>
<td>Pressure *</td>
<td>286</td>
<td>0</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>Airload</td>
<td>-143</td>
<td>0</td>
<td>-155.4</td>
<td>-144.2</td>
</tr>
<tr>
<td>Moments</td>
<td>0</td>
<td>-222.5</td>
<td>148.55</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-212.1</td>
<td>158.4</td>
<td>83.9</td>
</tr>
</tbody>
</table>

* See Page 20

See Note Page 94

---

**Written By:**

G. Jacques

**Checked By:**

L. Y. Cir

**Date:**

Sept. 1977

**Issue:**

**Aircraft:**
Stress Analysis of 1/12 Scale Hovering & Transition Model

G-1-3 Load Distribution

Load on the cases with the rod disconnected.

Suction on

+45° Case \(1 = 18\) PSF

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Comp.</td>
<td>141</td>
<td>0</td>
<td>44.1</td>
<td>45.8</td>
</tr>
<tr>
<td>Pressure</td>
<td>286</td>
<td>0</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>Airload</td>
<td>-406</td>
<td>0</td>
<td>-142</td>
<td>-132</td>
</tr>
<tr>
<td>Moments</td>
<td></td>
<td>0</td>
<td>-643</td>
<td>359</td>
</tr>
</tbody>
</table>

Suction off.

-10° Case \(1 = 30\) PSF

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Comp.</td>
<td>197</td>
<td>0</td>
<td>69</td>
<td>64</td>
</tr>
<tr>
<td>Pressure</td>
<td>320</td>
<td>0</td>
<td>112</td>
<td>104</td>
</tr>
<tr>
<td>Airload</td>
<td>63.13</td>
<td>0</td>
<td>22.1</td>
<td>20.5</td>
</tr>
<tr>
<td>Moments</td>
<td></td>
<td>0</td>
<td>664</td>
<td>-295</td>
</tr>
</tbody>
</table>

\* See page 20

See note page 94
### 6.1.3 Load Distribution

**Load on the Gages with the Rod Disconnected.**

**Suction Off:**

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>35%</td>
<td>32.5%</td>
<td>32.5%</td>
<td></td>
</tr>
<tr>
<td>WEIGHT COMP.</td>
<td>187</td>
<td>0</td>
<td>65.1</td>
<td>61.1</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>(*)</td>
<td>320</td>
<td>112</td>
<td>104</td>
</tr>
<tr>
<td>AIRLOAD</td>
<td>-441.1</td>
<td>0</td>
<td>-144.2</td>
<td>-144.2</td>
</tr>
<tr>
<td>MOMENTS</td>
<td>0</td>
<td>0</td>
<td>-223.5</td>
<td>144.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-200.1</td>
<td>169.4</td>
<td>94.9</td>
</tr>
</tbody>
</table>

**+ 45° Case:**

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ROD</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>35%</td>
<td>32.5%</td>
<td>32.5%</td>
<td></td>
</tr>
<tr>
<td>WEIGHT COMP.</td>
<td>141</td>
<td>0</td>
<td>45.6</td>
<td>45.6</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>(*)</td>
<td>320</td>
<td>112</td>
<td>104</td>
</tr>
<tr>
<td>AIRLOAD</td>
<td>-406</td>
<td>0</td>
<td>132</td>
<td>132</td>
</tr>
<tr>
<td>MOMENTS</td>
<td>0</td>
<td>0</td>
<td>355</td>
<td>284</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>-623.6</td>
<td>176.8</td>
<td>301.8</td>
</tr>
</tbody>
</table>

* See page 20

See note page 94
### Stress Analysis of 1/2 Scale Hovering & Transition Model

#### Load Distribution

**Summary of Loads on Gages & Rods**

<table>
<thead>
<tr>
<th>CASE</th>
<th>q (PSF)</th>
<th>Suction</th>
<th>Rod Preload</th>
<th>Rod 16</th>
<th>A 16</th>
<th>B 16</th>
<th>C 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-10</td>
<td>30 ON</td>
<td>200</td>
<td>352.48</td>
<td>731.8</td>
<td>-232.1</td>
<td>-306.1</td>
</tr>
<tr>
<td></td>
<td>+20</td>
<td>30 ON</td>
<td>200</td>
<td>145.52</td>
<td>-555.85</td>
<td>117.56</td>
<td>43.02</td>
</tr>
<tr>
<td></td>
<td>+45</td>
<td>18 ON</td>
<td>200</td>
<td>121.80</td>
<td>-678.06</td>
<td>326.48</td>
<td>257.48</td>
</tr>
<tr>
<td>2</td>
<td>-10</td>
<td>30 OFF</td>
<td>200</td>
<td>367.86</td>
<td>718.41</td>
<td>-205.85</td>
<td>-299.85</td>
</tr>
<tr>
<td></td>
<td>+20</td>
<td>30 OFF</td>
<td>200</td>
<td>140.52</td>
<td>-349.12</td>
<td>223.77</td>
<td>41.22</td>
</tr>
<tr>
<td></td>
<td>+45</td>
<td>18 OFF</td>
<td>200</td>
<td>114.5</td>
<td>-671.45</td>
<td>332.6</td>
<td>257.48</td>
</tr>
<tr>
<td>3</td>
<td>-10</td>
<td>30 ON</td>
<td>0</td>
<td>855.1</td>
<td>-175.4</td>
<td>-191.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+20</td>
<td>30 ON</td>
<td>0</td>
<td>-212.1</td>
<td>168.4</td>
<td>83.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+45</td>
<td>18 ON</td>
<td>0</td>
<td>-635.6</td>
<td>265.8</td>
<td>290.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-10</td>
<td>30 OFF</td>
<td>0</td>
<td>867.1</td>
<td>-106.7</td>
<td>-180.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+20</td>
<td>30 OFF</td>
<td>0</td>
<td>-200.1</td>
<td>169.4</td>
<td>94.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+45</td>
<td>18 OFF</td>
<td>0</td>
<td>-623.6</td>
<td>376.8</td>
<td>301.8</td>
<td></td>
</tr>
</tbody>
</table>

**Gage Rating:**

- 800
- 350
- 350

- Gage in tension
- Gage in compression

**Notes:**

1. The gages are designed for cases (1) & (2)
2. Cases (1) & (3) are measurement cases.
   Case (2) & (4) are tunnel starting cases.
3. Loads on gages B & C are interchangeable depending on the direction of the side load.

---

**Written By:**

G. Jacques

**Checked By:**

D. S. Thompson

**Date:**

Sept. 1977

**Issue:**

DECLASSIFIED
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

6-2  GAGE DESIGN

6-2-1
GAGE A  800 lb

This gage is designed according to report AVRO/SPG/TR-87 for an operating max stress of 40,000 PSI at the strain gage section.

Required thickness:

\[ t = \sqrt{0.07425 \times K^2 + 0.545 \times 3 \times K} - 0.2725 \times K \]

where \( K = \frac{W}{h0000} = \frac{600}{40000 \times 0.032} = 0.032 \)

\[ t = \sqrt{0.07425 \times 0.032^2 + 1.635 \times 0.32} - 0.2725 \times 0.032 \]

\[ t = \sqrt{0.000076 + 0.0523} - 0.00876 = \sqrt{0.052376} - 0.00876 = 0.2287 - 0.0087 = 0.220 \]

MATERIAL:

AN-99-S-689  COND "F"

FSa: 125,000 PSI  Fsy: 100,000 PSI  Fsv: 75,000 PSI
6-2 GAGE DESIGN

GAGE A - cont'd.

With reference to "Formulas for Stress and Strain" by Roark:

a) Max. bending in the ring at the flexure: 3183 W/in²
b) Max. bending in the ring at the shear gage: 1817 W/in²

at a), we also have a max. shear load = \( \frac{W}{2} \) per section

at b), we also have a tensile or compressive load = \( \frac{W}{2} \) per section

Section modulus of the ring: \( \frac{.625 \times .22^2}{6} = .00504 \text{ in}^3 \)

Sectional area of the ring: \( .625 \times .22 = .1375 \text{ in}^2 \)

Bending moments:

at a/ : \( 3183 \times 800 \times \frac{3\times.22}{2} = 354 \text{ in}lb \)

at b/ : \( 1817 \times 800 \times \frac{3\times.22}{2} = 202 \text{ in}lb \)

Shears at point a/:

Bending: \( \frac{354}{.00504} = 70200 \text{ PSI} \)

Shear: \( \frac{800}{2 \times .1375} = 2910 \text{ PSI} \)

Principal stress: \( \frac{70200}{2} + \sqrt{\left(\frac{70200}{2}\right)^2 + 2910^2} = 70320 \text{ PSI unfactored} \)

Shears at point b/:

Bending: \( \frac{202}{.00504} = 40000 \text{ PSI} \)

Tension: \( \frac{800}{2 \times .1375} = 2910 \text{ PSI} \)

Total stress: \( 40000 + 2910 = 42910 \text{ PSI unfactored} \)
6-2  GAGE DESIGN

6-2-1
GAGE A - cont'd.

Bending moment at attachment:
17.5 \times 2.25 = 39.4 \text{ in}^2 \text{ft}

Bending moment in ring:
17.5 \times 1.39 = 24.35 \text{ in}^2 \text{ft}

Ring friction modulus: 10050 \text{ psi in}^2
Ring sectional area: 0.1375 \text{ in}^2

Bending stress in ring:
\frac{12.175}{0.00504} = 2420 \text{ psi}

Normal stress:
\frac{8.75}{12.175} = 0.72 \text{ in}^2

Max. total normal stress:
2420 + 0.72 \times 2500 = 7282 \text{ psi}

Total stress at the ring at this point:
7032 + 2500 = 7582 \text{ psi, insufficient}

\text{LIM. M.S.} \quad \frac{10000}{72820} - 1 = -0.37

* Other margin of safety is quoted against the actual stress, the factor \(\psi = 4\) does not apply in this case.
6-2 GAGE DESIGN

6-2-1 GAGE A - cont'd.

FLEXURES.

From report AVRO/SPG/1 TR-87 for a flexure operating at 20000 PSI under 800 lb with width b = .50"

Thickness k = .080" - Sectional area = .5 x .08 = .040 sq in

Flexure length = .55"

The side loads on the ring induce a bending moment:

17.6 x 2.05 = 35.3 in lb

Section modulus:

\[ \frac{3}{4} k b^2 = .00333 \text{ in}^3 \]

Bending stress:

\[ \frac{35.3}{.00333} = 10600 \text{ PSI} \]

Total max normal stress: 20000 + 10600 = 30600 PSI unfactored.

Stability in compression as per MANSFIELD'S FORMULA.

Elastic moment of inertia:

\[ \frac{.5 x .08^2}{12} = .00002135 \text{ in}^4 \]

Ratios of section:

\[ f = \sqrt{\frac{.00002135}{.040}} = \sqrt{0.533} = .0231 \]

Slenderness ratio:

\[ \lambda = \frac{.55}{.0231} = 23.8 \]

Buckling stress: Johnson's formula:

\[ f_c = f_u - \frac{1}{4E} \left( \frac{f_u k^2}{11} \right) \]

\[ f_c = 125000 - \frac{1}{4 \times 3 \times 10^7} \left( \frac{125000 \times 23.8}{11} \right)^2 = 125000 - \frac{29.5 \times 10^6}{12 \times 10^7} \]

\[ = 125000 - 7450 = 117550 \text{ PSI} \]

unfactored: MARGIN OF SAFETY: 117550 - 10000 = 2.82
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

6-2 GAGE DESIGN

6-2-1 GAGE A - CONT'D.

ATTACHMENT BOLTS -

Attachment is by means of: 2 - 1/4" AN STEEL BOLTS - at each end.
Steel @ 125,000 psi - Tensile strength of one bolt: Rep. ASR-C-5: 1080 lb

Available strength: 1080 x 2 = 2160 lb

Applied load: max. load with factor of 4:
600 x 4 = 2400 lb

4.5

\[
\frac{2400}{2160} = 1.11
\]
This gage is designed according to report AVRO/SPRG/TR-87 for an operating maximum of 60,000 PSI at the strain gage section.

Required thickness

\[ t = \sqrt{\frac{0.07425 \times K^2 + 0.545 \times 3 \times K}{0.04000 \times 0.04000 \times 0.050}} = 0.2725 \times K \]

\[ w = \frac{W}{40000 \times b} = \frac{350}{40000 \times 0.050} = 0.0175 \]

\[ t = \sqrt{0.07425 \times 0.0175^2 + 0.635 \times 0.0175} = 0.2725 \times 0.0175 \]

\[ t = \sqrt{-0.00002275 + 0.0286} = 0.004768 \approx \frac{0.02862275}{0.004768} = 16.453 \]

Take \( t = 0.1650 \) in.

**MATERIAL:**

AN - CG - S - 689 - Cond. F

**F_tu:** 125,000 PSI  -  **F_s:** 75,000 PSI
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

6-2  GAGE DESIGN

6-2-2

GAGE B & C - cont'd.

With reference to "Formulas for Stress and Strain" by Roark:

a) Max bending in the ring at the flange: \(0.3183 \text{ W Rm } \text{ in}^2\)
b) Max bending in the ring at the strain gage: \(0.1817 \text{ W Rm } \text{ in}^2\)

at a), we also have a max shear load = \(\frac{W}{2}\) per section

at b), we also have a tensile or compressive load = \(\frac{W}{2}\) per section.

Section modulus of the ring: \(\frac{50 \times 0.165^2}{6} = 0.00227 \text{ in}^3\)

Sectional area of the ring: \(50 \times 0.165 = 0.0825 \text{ in}^2\)

Bending moment:

at a): \(0.3183 \times 350 \times \frac{3-0.165}{2} = 158 \text{ in-lb.}\)
\(0.1817 \times 350 \times \frac{3-0.165}{2} = 90.2 \text{ in-lb.}\)

Stresses at point a): Bending:

\(\frac{158}{0.00227} = 69,600 \text{ PSI}\)

Shear:

\(\frac{350}{2 \times 0.0825} = 2125 \text{ PSI}\)

Principal Stresses:

\(\frac{69,600}{2} + \sqrt{\left(\frac{69,600}{2}\right)^2 + 2125^2} = 70,000 \text{ PSI, unfactored}\)

Stresses at point b):

Bending:

\(\frac{90.2}{0.00227} = 39,750 \text{ PSI}\)

Tensile:

\(\frac{350}{2 \times 0.0825} = 2125\)

Total Stress: \(39,750 + 2125 = 41,875 \text{ PSI, unfactored}\)
6-2 GAGE DESIGN

6-2-2
GAGES B & C

Side load on the gages:
50 x 325 = 16,250

Torsoental section modulus
of the wing section

\[ K = \beta \times \frac{165}{\delta} \]

\[ \beta = 270 \quad \text{for} \quad \frac{165}{\delta} = 330 \]

\[ K = 27 \times \frac{165}{330} = 0.0367 \text{ in}^{-3} \]

Max. Normal shear stress:

\[ \frac{\sigma}{K} = \frac{4230}{0.0367} = 115,525 \text{ PSI} \]

Direct shear stress on the section:

\[ \frac{5160}{5160} = 9.5 \text{ PSI} \]

Total shear stress on the section:

4230 + 9.5 + 2125 = 6458.5 PSI

Principal stress:

\[ \frac{69600}{2} + \sqrt{\left(\frac{69600}{2}\right)^2 + 6458.5^2} = 70,200 \text{ PSI unfractured} \]

\[ \text{LIM M.S.} \]

\[ \frac{1,000,000}{70,200} = 14.2 \]

* This margin of safety is quoted against the actual stress
The factor \( n = 4 \) does not apply in this case.

**END**
6-2 GAGE DESIGN

6-2-2 GAGES B & C

FLEXURES:

From report AVRO SPG/TE 27, for a plane operating at 80,000 psi under 3500° with width b = .375" ; thickness h = .047"

Sectional area: \( .375 \times .047 = .0176 \text{ in}^2 \)

Flexural length: .55"

The side load on the wing induces a bending moment:

\[ 16.25 \times 2.05 = 33.3 \text{ in kips} \]

Section modulus:

\[ \frac{.047 \times .375^2}{6} = .0111 \text{ in}^3 \]

Bending stress:

\[ \frac{33.3}{.0111} = 30200 \text{ psi} \]

Total max stress: 20000 + 30200 = 50200 psi

Stability in compression as per Johnson's Formula.

Buckling stress: Johnson Formula:

\[ \sigma_c = \frac{F_a}{A} - \frac{1}{4.5} \left( \frac{h_a}{h} \right)^2 \]

\[ \sigma_c = 125000 - \frac{1}{4 \times 1.107} \left( \frac{125000 \times 40.4}{.047} \right) = 125000 - \frac{525000}{12000} = 125000 - 21500 = 103500 \text{ psi} \]

Unfactored: MARGIN OF SAFETY: \[ \frac{103500}{50200} -1 = 1.06 \]
6-2 - GAGE DESIGN

6-2-2
GAGES B & C - cont'd.

ATTACHMENT BOLTS

Attachment by means of: 2 - \( \frac{1}{4} \)" AN STEEL BOLTS at each end.

Steel @ 125,000 psi - Tensile strength of the bolt. Ref. AN-C-5: 4080 lb

Available strength: \( 4080 \times 2 = 8160 \) lb

Applied load: max. load with factor of 4

\( 350 \times 4 = 1400 \) lb

\( \frac{8160}{1400} - 1 = 4.8 \)
Stress Analysis of 1/12 Scale Hovering & Transition Model.

6-2
6-2-3
GAGE D

RATED LOAD 150 psi

This gage is designed according to report AVRO/SRG/TR-87 for an operating max. stress of 100 psi at the strain gage section.

Required Thickness:

\[ t = \sqrt{\frac{0.07425 \times 150 + 0.545 \times 2 \times 0.00938}{0.00938}} = 0.2725" \]

where \( R = \frac{W}{40000b} = \frac{150}{40000 \times 40} = 0.00938 \)

\[ t = \sqrt{0.07425 \times 0.00938^2 + 0.545 \times 2 \times 0.00938} = 0.2725 \times 0.00938 \]

\[ t = \sqrt{0.0000652 + 0.01225 - 0.002555} = \sqrt{0.00025652} = 0.02555 \]

\[ 0.1027 - 0.01225 = 0.09047" \]

Say \( t = 0.10" \)

MATERIAL:

AN - FF - S - 689 COND. "F"

Fr: 125,000 PSI - Fry: 190,000 PSI - Tsu: 75,000 PSI

WRITTEN BY: J. Jacques
CHECKED BY: J. C. Lewis
DATE: Sept. 1977
ISSUE: 2
AIRCRAFT: AVRO EA 3110
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

6-2 - GAGE DESIGN

6-2-3

GAGE D - cont'd.

Will reference to "Formulas for Stress and Strain" by Rank.
as a) Max. bending in the wing at the flaps: .3193 W in.
b) Max. bending in the wing at the strain gage: .1817 W in.

at a), we also have a max shear load = \( \frac{W}{2} \) per section.
at b), we also have a tensile or compressive load = \( \frac{W}{2} \) per section.

Section modulus of the wing: \( \frac{.40 \times 10^2}{6} = 0.000667 \text{ in}^3 \)

Sectional area of the wing: \( .40 \times .10 = .040 \text{ in}^2 \)

Bending moments:

at a): \( \frac{.3193 \times .150 \times 2 - .10}{2} = 46.6 \text{ in} \)

at b): \( \frac{.1817 \times .150 \times 2 - .10}{2} = 26.6 \text{ in} \)

Stresses at point a):

Bending: \( \frac{46.6}{0.000667} = 70000 \text{ PSI} \)

Shear: \( \frac{150}{2 \times .040} = 1875 \text{ PSI} \)

Principal Stress: \( \frac{70000}{2} + \sqrt{\left(\frac{70000}{2}\right)^2 + 1875^2} = 70150 \text{ PSI unfactored} \)

unfactored: L1M. H.S. \( \frac{100000}{70150} - 1 = .43 \)

Stresses at point b):

Bending: \( \frac{26.6}{0.000667} = 40000 \text{ PSI} \)

Torsion: \( \frac{150}{2 \times .040} = 1875 \text{ PSI} \)

Total Stress: \( 40000 + 1875 = 41875 \text{ PSI unfactored} \)

WRITTEN BY

Checked by

Date

Issue

Aircraft
6-2 GAGE DESIGN

6-2-3 GAGE D - cont'd.

FLEXURES:

From report AVRO/SPG/TR 87, for a flexure operating at 20000 PSI under 150° twist with width b = 0.25" thickness h = 0.010"
Flexure length 1.35"
Sectional area 0.25 x 0.03 = 0.0075 in^2

Stability in compression as per JOHNSON'S FORMULA.

Least moment of inertia \( I = \frac{b^2 \times h^3}{12} = \frac{0.25 \times 0.03^3}{12} = 0.5625 \times 10^{-6} \text{ in}^4 \)

Radius of gyration \( r = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.5625 \times 10^{-6}}{0.0075}} = 0.866 \times 10^{-2} = 0.00866" \)

Slenderness ratio \( \lambda = \frac{r}{h} = \frac{0.00866}{0.010} = 0.866 \)

Buckling stress JOHNSON'S FORMULA \( f_c = f_u - \frac{1}{4E} \left( \frac{h^2}{r^4} \right) \)

\( f_c = 125,000 - \frac{1}{4 \times 1 \times 10^7} \left( \frac{0.010^2}{0.00866^4} \right) \)

\( = 125,000 - \frac{1}{12 \times 10^7} \left( 25.95 \times 10^2 \right) = 125,000 - 21650 = 103,350 \text{ PSI} \)

MARGIN OF SAFETY \( \frac{103,350 - 21,650}{21,650} = 4.7 \)

NOTE: A large Margin of Safety is necessary on this flexure as bending strains due to deflection of the other gages could not be measured with sufficient accuracy.

DECLASSIFIED
6.2 GAGE DESIGN

6.2-3 GAGE D - cont’d.

Attachment by means of: 1 - ¼” AN steel bolt at each end.

Steel @ 120,000 psi - Bolt pin shear

Shear strength: Ref AN-9-5 - single shear: 3680 lb

Strength of bolt: 3680 x 2 = 7360 lb

Applied load: max. load with factor of k:

\[ \frac{7360}{600} - 1 = \]

M.S.
6.3 GAGE EQUATIONS - LOAD ON GAGES.

<table>
<thead>
<tr>
<th>GAGE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGHT</td>
<td>0.196 W (1.1)</td>
<td>0.182 W (1.1)</td>
<td>0.182 W (1.1)</td>
<td>W min x</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>4.87 P</td>
<td>4.09 P</td>
<td>4.09 P</td>
<td>0</td>
</tr>
<tr>
<td>SUCTION</td>
<td>2.87 P</td>
<td>2.64 P</td>
<td>2.64 P</td>
<td>0</td>
</tr>
<tr>
<td>NORMAL LOAD</td>
<td>-0.16 N</td>
<td>-0.182 N</td>
<td>-0.182 N</td>
<td>0</td>
</tr>
<tr>
<td>DRAG LOAD</td>
<td>0.766 (D + W min)</td>
<td>-0.810 (D + W min)</td>
<td>-0.810 (D + W min)</td>
<td>D</td>
</tr>
<tr>
<td>SIDE LOAD</td>
<td>0.626 L</td>
<td>-0.626 L</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PITCHING M</td>
<td>0.1575 M</td>
<td>-0.07975 M</td>
<td>-0.07975 M</td>
<td>0</td>
</tr>
<tr>
<td>ROLLING M</td>
<td>0.150 M</td>
<td>0.150 M</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The load on each gage is the column addition of the load components tabulated above.

WHERE:
- W = model weight: 16
- P = pressure in outer pipe: psig
- Po = pressure in inner pipe: psig
- N = Normal load on model due to airload: 16
- D = Net loadwise force on model due to thrust and airload: 16
- L = Side force on model: 16
- M = Pitching moment on model: 16
- M = Rolling moment on model: 16
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

7.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 HORIZONTAL TUBE

7-1-1 TUBE IN BENDING

SECTION PROPERTIES OF THE TUBE:

Size: 7" x 3/16" - ID = 6.625"

Sectional area:
\[ A = \frac{\pi}{4} (7^2 - 6.625^2) = 11.94 \text{ in}^2 \]

Moment of inertia:
\[ I = \frac{\pi}{64} (7^4 - 6.625^4) = 23.3 \text{ in}^4 \]

Section modulus:
\[ Z = \frac{I}{120} (7 - 6.625) = 6.65 \text{ in}^3 \]

The max support reactions under both static and aerodynamic loading occur with the incidence of the model at 45°.

45° CASE.

**Bending moment under static load**

**Bending moment at the center line**:

\[ M = -(340 \times 40) + (40 \times 20) = -13600 + 800 = -12800 \text{ in-lb} \]

**Bending moment under model airflow**

Vertically: \( 533.1 \times 40 = 21320 \text{ in-lb} \)  
Horizontally: \( 126.1 \times 40 = 5040 \text{ in-lb} \)

REF. SECTION 4-3.5, APPENDIX A.
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.

7-1 HORIZONTAL TUBE

7-1-1 TUBE IN BENDING

45° CASE - cont'd.

Since airloads relieve the static loads, the critical loads occur with the tunnel open.

Then: max. bend. stress in the tube:

\[
\sigma_b = \frac{M}{2} + \frac{12F_{ho}}{6.65} = 7660 \text{ PSI}
\]

M.S. \[\frac{55000}{7660} \approx 7\]

-10° CASE

This case is to be considered the bending moments from static load add to bending moment from airload (330 - 144) = 186 = Pa.

Static load:

\[
M = (190 \times 4) - (40 \times 20) = 7440 - 800 = 6640 \text{ in-lb}
\]

Airload:

\[
\begin{align*}
\text{Vertical:} & \quad 109.31 \times 40 = 4370 \text{ in-lb} \\
\text{Horizontal:} & \quad 13.59 \times 40 = 544 \text{ in-lb}
\end{align*}
\]

Total Bending moment:

\[
M_t = \sqrt{(6640 + 4370)^2 + 544^2} = 11024 \text{ in-lb}
\]

Max bending stress:

\[
\sigma_b = \frac{M}{2} \frac{11024}{6.65} = 6640 \text{ PSI}
\]

M.S. \[\frac{55000}{6640} \approx 8.3\]
1.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1.1 HORIZONTAL TUBE

7-1.2. FLANGES ON 7.00" TUBE.

Bending Moment:

\[ 340 \times 5 = 1700 \text{ in} \cdot \text{lb} \text{ \text{unfactored}} \]

Shear force:

\[ 474 - 144 = 340 \text{ in} \text{lb} \text{ \text{unfactored}} \]

Bolt strength in tension:

Ref. AN-C-5

AN-6: \( \frac{3}{8} \) "DIA: \( 10100 \text{ lb} \)
AN-S: \( \frac{7}{16} \) "DIA: \( 6500 \text{ lb} \)

Bolt strength in shear:

AN-6: \( \frac{3}{8} \) "DIA: \( 8870 \text{ lb} \)
AN-S: \( \frac{5}{16} \) "DIA: \( 5750 \text{ lb} \)

Centroid of bolt cluster in tension:

\[
\frac{(10100 - 6500)}{(10100 + 7 	imes 6500)} = .263''
\]

Distribution of tensions due to bending in the bolt cluster.

The flange pressure in the compression side is assumed concentrated at the bolts.

\[ T = \frac{S}{S} \]

Force on bolt i:

\[ F_i = M \frac{d_i S_i}{2} \sigma \]

Direct tension:

\[ F_{iT} = T \frac{S_i}{S} \]
### Stress Analysis of 1/12 Scale Hovering & Transition Model

#### 7-0 Stress Analysis - Model Support Structure

##### 7-1 Horizontal Tube

##### 7-1-2 Flanges on 7.00" Tube - Cont'd

<table>
<thead>
<tr>
<th>BOLT</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>3.881</td>
<td>2.661</td>
<td>-0.263</td>
<td>3.199</td>
<td>-6.419</td>
<td>-3.199</td>
<td>-2.661</td>
<td>2.661</td>
</tr>
<tr>
<td>(d^2)</td>
<td>15.1</td>
<td>7.1</td>
<td>-0.025</td>
<td>10.12</td>
<td>19.2</td>
<td>10.12</td>
<td>0.025</td>
<td>7.1</td>
</tr>
<tr>
<td>Sd</td>
<td>39.2</td>
<td>17.3</td>
<td>-1.75</td>
<td>28.7</td>
<td>28.7</td>
<td>28.7</td>
<td>17.3</td>
<td></td>
</tr>
<tr>
<td>(S_d^2)</td>
<td>152.5</td>
<td>46.8</td>
<td>-171</td>
<td>65.3</td>
<td>127.0</td>
<td>65.3</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td>(S_d/\sqrt{\pi d^2})</td>
<td>0.778</td>
<td>0.344</td>
<td>-0.0347</td>
<td>0.0413</td>
<td>-0.0570</td>
<td>-0.0413</td>
<td>-0.0347</td>
<td>0.0344</td>
</tr>
<tr>
<td>(S/\sqrt{\pi d^2})</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td>1.17</td>
<td></td>
</tr>
</tbody>
</table>

\[ F_{dn} = 161.0 \quad F_{lt} = 250.0 \quad F_{total} = 411.0 \]

\[ \sum S_d^2 = 504.642 \quad \sum S = 55.6 \]

Total Bending moment: \(1700 + (1372 \times 269) = 1700 + 369 = 2069 \) in-lb

Bolt in Shear:

Total shear strength available: \(8280 + (7 \times 5750) = 8280 + 40250 = 48530 \) lb

Shear on AN-6 bolt: \(33g \times \frac{8280}{48530} = 57.4 \) lb unfactored

Shear on AN-5 bolt: \(33g \times \frac{5750}{48530} = 40.1 \) lb unfactored

Allowable tension on bolt:

Ref. AN-3-5

\[ \gamma = 6 \sqrt{1 - \left(\frac{57}{60}\right)^2} = 10 \times 100 \sqrt{1 - \left(\frac{57}{60}\right)^2} = 10 \times 100 \times \sqrt{1 - (0.0960)^2} \]

Effect of shear in negligible.
STRESS ANALYSIS OF \( \frac{1}{8} \) SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 HORIZONTAL TUBE

7-1-2 FLANGES ON 7.06" TUBE - CONT'D.

Margin of Safety on Bolts:

\[
\text{AN-6}: \quad M.S. = \frac{10100}{4411} - 1 = 5.14
\]

\[
\text{AN-5}: \quad M.S. = \frac{6500}{231.5} - 1 = 6.03
\]
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 HORIZONTAL TUBE

7-1-2 FLANGES ON 7.00" TUBE - CONT'D.

Margin of Safety on bolts:

\[
\begin{align*}
\text{AN-6} & : \quad \text{M.S.} = \frac{10,000}{4 \times 411} = 5.14 \\
\text{AN-5} & : \quad \text{M.S.} = \frac{6,500}{4 \times 231.5} = 6.03
\end{align*}
\]

WELD:

Assume the load of AN-6 bolt taken by 2" of ½" weld.

\[
\text{Weld area: } 2 \times 2.5 = 5.0 \text{ in}^2
\]

Allowable UTS of weld metal: 51,000 PSI (Ref. AN-C.5)

\[
\begin{align*}
\text{Weld Stress: } & \quad \frac{411}{0.5} = 822 \text{ PSI unfactored} \\
\text{M.S.} & = \frac{32,000}{4 \times 822} = 8.71
\end{align*}
\]
7.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE
7-1-3 - MAIN SUPPORT BEARINGS

MAIN STRUTS BEARINGS:
SKF: BALL BEARING - N° 6238-M.
Ref. SKF Catalog No 551 - STATIC STRENGTH: RADIAL 53000 lbf
               DYNAMIC :  V = 14000 lbf

Max applied load: \( \sqrt{333.1^2 + 126.1^2} = 356 \text{lbf} \) - Ref. A.3

\[ M.S. \frac{53000}{4 \times 356} - 1 = \]

Static load on bearings: tunnel stagna 352 lbf - Ref. A.3.

BEARING HOUSING:

MOUNTING BOLTS:
3 BOLTS: \( \frac{1}{2}'' \) DIA. INTERNAL WRENCHING,
NAS bolts in tension: 23500 lbf per bolt
Total strength available: 23500 x 3 = 70500 lbf

\[ M.S. \frac{211500}{4 \times 356} - 1 = \]

> 10

LUG:
MATERIAL: SAE 1020 STEEL

Stress as per Milen & Horlet method:
Tension & bearing

[Diagram of lug with dimensions and section AA]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-3 MAIN SUPPORT BEARINGS

LUG - CONT'D.

Tension:
Ratio: \( \frac{\text{Width}}{\text{I.D.}} = \frac{7.25 \times 2}{13.58} = 1.083 \)

Coeff: \( K_t = 0.99 \) from graph 2:12

Tensile stress in the ring: \( f_t = \frac{P}{K_t A} = \frac{356 \times 4}{0.99 \times 2.5 \times 2.5} = 1260 \text{ PSI} \)

Bearing:
Ratio: \( \frac{\text{edge distance}}{\text{I.D.}} \)

In this case: concentric lugs:

\( \frac{\text{Ratio edge distance}}{\text{I.D.}} = \frac{\text{Width}}{2 \times \text{I.D.}} = \frac{1.083}{2} = 0.5415 \)

Coeff: \( K_{br} = 0.10 \) from graph 2:13.

Bearing stress in the ring: \( f_{br} = \frac{P}{K_{br} A} = \frac{356 \times 4}{0.10 \times 2.5 \times 2.5} = 10200 \text{ PSI} \)

Characteristics of material:

AN-S-11. Ref. AVRO DESIGN MANUAL - Sect II - 3.2.4.4

UTS: 55,000 PSI
YTS: 36,000 PSI

CHARACTERISTICS OF MATERIAL:

MARGINS OF SAFETY:

Tension: \( \frac{55,000}{1260} - 1 = 10 \)

Bearing: \( \frac{90,000}{10200} - 1 = 7.8 \)
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

7-6 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE
7-1-4 - PRESSURE HOLDING LINK.

BALANCE SIDE

BALL BEARING HOUSING

TUNNEL WALL SIDE

ALL WELDS: 1/8" FILLETS.

1/4" STEEL ROD

1/4" STEEL ROD
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7-0  STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4  PRESSURE HOLDING LINK

LENGTH IN TENSION: 24.40"
MIN. DIA. AT END OF THREAD: .233"
UNFACTORED LOAD: 1372 lb TENSION  
FULLY FACTORED LOAD: 1372 x .8 = 5490 lb

Sectional area: \( \frac{.233^2 \times \pi}{4} = .0487 \text{ in}^2 \)

Tensile stress: \( \frac{5490}{.0487} = 113800 \text{ psi} \)

The rod is made of SAE 4130 steel @ 185,000 psi

\( \frac{185000}{113800} - 1 = -0.03 \)

Actual M.S. = 3.97

Rod elongation under load: \( \frac{1372 \times .03}{.0487 \times 30 \times 10^6} = .0862" \)

BALL BEARINGS CAPACITY

Ref. SKF CATALOG No. 551

EE-2 - Static: 216 lb radial
Dynamic: 130 lb radial

51100 - Static: 2500 lb axial
Dynamic: 1730 lb axial

SKF EE-2 BALL BEARING
SKF 51100 THRUST BEARING
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4 PRESSURE HOLDING LINK: cont'd.

SKF - BALL GEARINGS:

According to SKF catalogue No. 551 - page 21: "Static Carrying Capacity". The failing load of ball bearings is usually higher than 8 x static load indicated in the tables.

Hence, for the thrust bearing F = 5,000 lb, the failing load is approx: 2,500 x 8 = 20,000 lb

\[
\frac{20,000}{1372} = 13.5
\]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.
7-1-4 - PRESSURE HOLDING LINK.

END BRACKETS.

BALANCE SIDE:

Each frame takes 1/3 of the load.

Each frame is fully fixed on the bearing housing and can also be considered as fully fixed on the take-off since it is welded to two rings.

Hence, load in the frame: 

\[
1370 \times \frac{4}{3} = 1830 \text{ lb fully fixed.}
\]

Max bending moment: 

\[
1830 \times 2.8 = 5160 \text{ in-lb}
\]

Section modulus of frame at small end:

\[
\frac{1.55 \times 1.15}{6} = 0.080 \text{ in}^3
\]

Bending stress:

\[
\frac{5160}{0.080} = 64500 \text{ psi}
\]

M.S. 

\[
\frac{51600}{64500} = 0.07
\]

WELD FILLERS:

2 fillers, .125" x 1.75" shearing: 5160 in-lb bending + 1830 lb direct shear.

Ref. AN-C-5: Shear strength of welded joint: 32000 psi.

Weld area: 

\[
2 \times 0.125 \times 1.75 = 0.437 \text{ in}^2
\]

Direct shear stress: 

\[
\frac{1830}{0.437} = 4180 \text{ psi}
\]

Section modulus of weld in shear: 

\[
2 \times \frac{1.75^2 \times 0.125}{6} = 0.1272 \text{ in}^3
\]
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 - 4 PRESSURE HOLDING LINK

END BRACKETS - cont'd

BALANCE SIDE - cont'd

Shear stress due to bending in the weld:

max. \( \frac{2560}{1.272} = 20150 \) PSI

Max shear stress in the weld:

\[ \sqrt{20150^2 + 4190^2} = 20600 \] PSI

M.S. \( \frac{32000}{20600} \) = 0.55

TUNNEL WALL SIDE -

Each arm takes \( \frac{1}{3} \) of the load

Each arm is fully fixed in the center piece and has some degree of fixing on the tube. It will be assumed that the tube provides a fixing about equal to half that of the center piece.

Here: load on each arm: \( 1372 \times \frac{2}{3} = 881.33 \) lb. full load

Max Bending Moment:

\[ 1150 \times \frac{2}{3} \times 3.15 = 1980 \] in lb.

Section modulus of the arm:

\[ \frac{1.5^2 \times 0.187}{6} = 0.0701 \] in³

Max. bending stress:

\[ \frac{1980}{0.0701} = 28000 \] PSI

M.S. \( \frac{55000}{28000} \) = 0.05
STRESS ANALYSIS OF 7/12 SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4 PRESSURE HOLDING LINK

END BRACKETS - CONT'D

TUNNEL WALL SIDE - CONT'D

WELD FILLETS:

2 fillets: $0.125 \times 0.75''$ taking: $3840$ with bending
+ $1840 \frac{1}{2}$ direct shear.

Ref. AN.6.5: Shear strength of welded joint: $32000$ PSI

Weld area: $2 \times 0.125 \times 0.75 = 0.437 \text{ in}^2$

Direct shear stress: $\frac{1840}{0.437} = 4180$ PSI

Section modulus of weld in shear: $2 \frac{1.75^3 \times 0.105}{6} = 12.73$ mm^3

Shear stress due to bending in the weld:
max: $\frac{3840}{1.872}$

Max shear stress in the weld: $\sqrt{32000^2 + 4180^2} = 30500$ PSI

\[ M.S. \quad \frac{32000}{30500} - 1 = 0.05 \]
Max load on this member is 250 ft when \( \alpha = 45^\circ \) and tunnel stopped.

Hence: load normal to the arm and fully factored:

\[
\frac{250 \times 4}{12} = 707.1\text{ lb}
\]

Compression in the arm:

\[
\frac{250 \times 4}{12} = 707.1\text{ lb}
\]

Bending Moments:

\[
M_c: 707 \times (6 + 2.5 - 1.25) = 707 \times 7.25 = 5120 \text{ inlb}
\]

\[
M_a: 707 \times (6 + 2.5 - 1.25) = (707 \times 12) = 5120 - 8490 = -3360 \text{ inlb}
\]

\[
H_b: 707 \times (6 + 2.5 - 4.15) = (707 \times 3.7) = 2075 - 3090 = -2785 \text{ inlb}
\]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE
7-2-1 INCIDENCE CONTROL ARM - BENDING

SECTION A & C
Sectional area: \( 2.5 \times 2 - 2.85 \times 1.813 = 5 - 4.08 = 0.92 \text{ in}^2 \)
Section modulus: \( \frac{2.5^2 \times 2 - 2.85^2 \times 1.813}{6} = \frac{13 - 9.22}{6} = 0.63 \text{ in}^3 \)

SECTION B
Sectional area: \( 8.3 \times 3 - 8.05 \times 2.813 = 24.3 - 23.4 = 0.9 \text{ in}^2 \)
Section modulus: \( \frac{8.3^2 \times 3 - 8.05^2 \times 2.813}{6} = \frac{207 - 183}{6} = 4 \text{ in}^3 \)

Bending stresses:
Section C: \( \frac{5120}{0.63} = 8140 \text{ PSI} \)
Section B: \( \frac{27125}{4} = 6781 \text{ PSI} \)

Compressive stresses:
Section C: \( \frac{707}{0.92} = 770 \text{ PSI} \)
Section B: \( \frac{707}{1.5} = 472 \text{ PSI} \)

Total max stresses:
Section C: \( 8140 + 770 = 8910 \text{ PSI} \)
Section B: \( 6781 + 472 = 7253 \text{ PSI} \)
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2 - INCIDENCE CONTROL ARM.

7-2-1 - BENDING

MARGIN OF SAFETY

\[
\text{Section } C: \quad \frac{55000}{890}\quad -1 = \quad 5.18
\]

\[
\text{Section } B: \quad \frac{55000}{7.432}\quad -1 = \quad 7.40
\]

WELD FILLETS - AT SECTION B.

The stresses are the same as those calculated at section B.

The strength of the weld metal is 5/1000

\[
\text{M.S.:} \quad \frac{5/1000}{7.432}\quad -1 = \quad 5.87
\]

7-2-2

ATTACHMENT LINK TO BALANCE STRUT.

\[\frac{1}{2}\text{ AN steel bolts.}\]
\[\frac{2}{4}\text{ AN steel bolts.}\]
\[\frac{1}{8}\text{ weld fillets}\]

\[6\text{" DIA}\]
\[1.125\text{" DIA}\]
\[.25\text{" THK}\]
\[.125\text{" reinforcing}\]

\[6\text{" reinforcing}\]

\[2.5\text{" plate}\]
STRESS ANALYSIS OF ½ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE
7-2 INCIDENCE CONTROL ARM

7-2-2 ATTACHMENT LINE - CONT'D

Circular section in bending + compression at bottom of link
1.125" dia. SAE 1020 steel.

Bending moment: \( 707 \times 6 = 4242 \text{ in}^3 \)

Section modulus: \( \frac{\pi}{4} D^3 = \frac{0.0984 \times 1.125 ^3}{4} = \frac{0.0984 \times 1.641}{2} = 0.14 \text{ in}^3 \)

Sectional area: \( \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 1.125^2 = 1.0 \text{ in}^2 \)

Bending stress: \( \frac{4242}{1.14} = 3700 \text{ PSI} \)

Compression stress: \( \frac{707}{1.0} = 707 \text{ PSI} \)

Total max. comp. stress: \( 30200 + 707 = 31007 \text{ PSI} \)

\( M.I. = \frac{55000}{31007} - 1 = 0.77 \)

WELD FILLETS:
2 FILLETS: ½" wide.

Consider the fillets as rings having ½" width and a mean dia. of 1.125"
\( D = 1.25" \quad d = 1.00" \)

Sectional area: \( \frac{\pi}{4} (0.5^2 - 0.1^2) = \frac{\pi}{4} (1.25^2 - 1^2) = \frac{\pi}{4} \times 0.56 = 0.440 \text{ in}^2 \)

Section modulus: \( \frac{\pi}{32} \left( \frac{D^4 - d^4}{D} \right) = 0.0984 \left( \frac{1.25^4 - 1^4}{1.25} \right) = 0.0984 \times 2.44 = 0.234 \text{ in}^3 \)

Hence, for both sections:
\( A = 0.44 \times 2 = 0.88 \text{ in}^2 \)
\( Z = 0.234 \times 2 = 0.468 \text{ in}^3 \)
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7-2 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2.2 INCIDENCE CONTROL ARM

ATTACHMENT LINK - CONT'D

WELD FILLETS - CONT'D

Bending stress in the fillet: \( \frac{4242}{12k} = 23100 \text{ PSI} \)

Compressive stress in the fillet: \( \frac{707}{.88} = 804 \text{ PSI} \)

Total max comp. stress: \( 23100 + 804 = 23904 \text{ PSI} \)

\[ \frac{51000}{23904} = 1.10 \]

7-2.3 BASE PLATE

Shear per 3/8 bolt:

\[ \frac{707}{2} = 353.5 \text{ in} \]

Tension on aft bolt:

\[ \frac{4242}{2} \times \frac{3}{15} = 702 - 1410 - 176 = 1234 \text{ lbs} \]

Strength of AN 3 steel bolt in shear: \( 2070 \text{ lbs} \) (AN 3.5)

\[ \frac{2070}{353.5} = 5.85 \]

Strength of AN - H steel bolt in tension: \( 4080 \text{ lbs} \) (AN 5.5)

\[ \frac{4080}{1234} = 3.3 \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

7.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7.2 INCIDENCE CONTROL ARM

7.2-3 ATTACHMENT LINK - cont’d

BASE PLATE - cont’d.

Section in bending is assumed as shown: length 1.26”, thickness .3125”

Section modulus:
\[ \frac{3125^2 \times 1.2}{6} = 0.195 \text{ in}^3 \]

Bending Moment: \(1234 \times 0.6 = 740 \text{ in} \times \text{lb} \)

Max bending stress: \( \frac{740}{0.195} = 38000 \text{ PSI} \)

\[ M.S. = \frac{55000}{57000} = 1 \]

7.2-4 LOCAL REINFORCEMENT OF THE CONTROL ARM

Bending moment at section AA:
\(1234 \times 1.06 = 501 \text{ in} \times \text{lb} \)

Consider a section in bending 1.25” long, made of 2 .125” plates:

Section modulus:
\[ \frac{125 \times 0.125^2}{6} = 0.01354 \text{ in}^3 \]

Bending stress: \( \frac{501}{0.01354} = 37000 \text{ PSI} \)

\[ M.S. = \frac{55000}{57000} = 1 \]
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

7.2.4
LOCAL REINFORCEMENTS - CONT'D.

SHEAR STRESS IN FILLET No. 1

Area of fillet in shear: \(0.125 \times 2.00 = 0.25 \text{ in}^2\)

Shear on this section: \(1.5 \frac{W}{b} = 1.5 \frac{1234}{25} = 74.16 \text{ ksi} \) fully fact.

Shear stress in the weld:

\[
\frac{74.16}{0.25} = 29600 \text{ PSI}
\]

M.S. \(\frac{32000}{29600} - 1 = 0.083\)

Note: The length of weld has been taken as 1.10 along the length + 0.70 across the back.

SHEAR STRESS IN FILLET No. 2

It is assumed that 1/4 of the load is introduced in the 3/4" weld by the upper 1/4" cap. The other half through the reinforcing bracket. The effect of moments will be accounted for by assuming that the whole load is introduced through only one oblique side 3" long.

Weld area: \(3.0 \times 0.25 = 0.75 \text{ in}^2\)

Fully factored load: \(\frac{1234}{2} = 617 \text{ ksi}\)

Shear stress in the weld: \(\frac{617}{0.75} = 823.33 \text{ PSI}\)

M.S. \(\frac{31000}{823.33} - 1 = 0.88\)
7-3: TAPERED SECTION OF VERTICAL ARM.

7-3-1 UPPER FLANGE.

Considering the same case as for the gauge (section 5), and resolving at the upper flange.

-10° case in the streamwise case.

Load per bolt due to vertical load:
\[
\frac{561}{8} = 70.2 \text{ in.}
\]

Total shear in the bolts:
\[
\sqrt{29.2^2 + 10^2} = 37.45
\]

Shear per bolt:
\[
\frac{5.2}{8} = 0.65 \text{ in. per bolt}
\]
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.

7-3 -

TAPERED SECTION OF VERTICAL ARM - CONT'D.

7-3-1 UPPER FLANGE

Load on the bolts due to moments.
The bolts are stressed as cluters under tension & compression.

Longitudinal moment:

Load on bolt A:
$$\frac{M \times 5.45}{4(4.75 \times 3.47)} = 0.025 \frac{M}{4} = 0.025 \times 148.5 = 108^\circ$$

Load on bolt B:
$$\frac{M \times 5.45}{4(4.75 \times 3.47)} = 0.025 \frac{M}{4} = 0.025 \times 148.5 = 108^\circ$$

Transverse moment:

Load on bolt A:
$$\frac{M \times 3.45}{4(3.45 \times 1.25)} = 0.054 \frac{M}{13.46} = 0.054 \times 1010 = 53.4^\circ$$

Load on bolt B:
$$\frac{M \times 3.45}{4(3.45 \times 1.25)} = 0.054 \frac{M}{13.46} = 0.054 \times 1010 = 53.4^\circ$$

Total max. load in bolt A:
$$A = 108 + 53.4 = 161.4^\circ$$

Total max. load in bolt B:
$$B = 108 + 53.4 = 161.4^\circ$$

Say 172^\circ from direct load on previous page.

Total unfactored load on one $\frac{1}{12}$ AN bolt:
$$172 + 70.2 = 242.2^\circ$$

With factor of 1.5:
$$242.2 \times 1.5 = 363.3^\circ$$

Strength of bolt in tension:
Ref. AN C-15: 6500^\circ

$$M.S. = \frac{6500}{965.8} = 6.7$$
STRESS ANALYSIS OF 1/3 SCALE HOVERING & TRANSITION MODEL

7-3-2 CRUCIFORM BRACKET

MODEL SUSPENSION ROD ATTACHMENT

Steel bar: 1.50" x 0.125"

8.625 x .141 tube.

This bracket is intended to have the same strength as the rod in tension.

Strength of the rod: taking strength of equivalent

\[
\frac{1}{16} \text{ AN bolt at 125,000 PSI} \quad \text{Ref. AN-C-5: 2160 lb say 2200 lb}
\]

Each bar of the cruciform bracket takes \(\frac{1}{2}\) the load: i.e. 1100 lb

Max bending moment on the bar:

\[
\frac{1100 \times 8.484}{4} = 2210 \text{ in-lb}
\]

Section modulus of bar:

\[
\frac{1.5^2 \times 0.125}{6} = 0.066 \text{ in}^3
\]

Bending stress:

\[
\frac{2210}{0.066} = 33,250 \text{ PSI}
\]

M.S. \[
\frac{55,000}{33,250} - 1 = 0.160
\]
STRESS ANALYSIS OF ½ SCALE NOVEMBER 4 TRANSITION MODEL

7-5. STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3. TAPERED SECTION OF VERTICAL ARM

7-3.2 CRUCIFORM BRACKET.

WELD FILLETS ON HUB.

- \( \frac{1}{2} \)" fillets: 1.25 x 1.5 in., taking 2210 in.² bending + 550 in.² direct shear.

Weld section area: \( 2 \times 1.25 \times 1.5 = 3.75 \text{ in.}^2 \)

Direct shear stress: \( \frac{550}{3.75} = 1470 \text{ PSI} \)

Section modulus of weld in shear: \( \frac{2 \times 1.5^2 \times 1.25}{6} = 0.937 \text{ in.}^3 \)

Shear stress due to bending: \( \frac{2210}{0.937} = 2390 \text{ PSI} \)

Total max shear stress: \( \sqrt{2390^2 + 1470^2} = 26650 \text{ PSI} \)

\[ M.S. = \frac{32000}{26650} - 1 = 0.20 \]
TAPERED SECTION OF VERTICAL ARM -

BRACKETS ATTACHING DRAG CAGE -

Stirring of the lower bracket will cover the upper bracket.

Bending Moment at root:
152 \times 2.25 = 342 \text{ in} \cdot \text{lb} \quad (\text{in} \cdot \text{lb})

Section in bending: 2 - \frac{1}{2}" steel plate.
2 - sections: 1.20" x .25"

\[ \frac{Z}{I} = \frac{0.5 (1.20 \times 0.25)}{12} = 0.12 \text{ in}^3 \]

Bending Stress: fully factored:
\[ \frac{342}{0.12} = 11400 \text{ psi} \quad (\text{psi}) \]

\[ \frac{55000}{11400} - 1 = 3.82 \]

Load on attachment screw:
\[ \frac{1}{2} \times 342 \times \frac{4}{5} = 1370 \text{ lb} \quad (\text{lb}) \]

Strength of \( \frac{3}{16} \) AN screw in tension: Ref. AN-0.5: 2160 lb

\[ \frac{2160}{1370} - 1 = 0.57 \]
STRESS ANALYSIS OF \( \frac{1}{12} \) SCALE HOVERING & TRANSITION MODEL

7-0  STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3:  TAPERED SECTION OF VERTICAL ARM.

7-3-4

MODEL ATTACHMENT.

The load can be assumed to pass entirely into the bolts closest to the gauge attachment.

Thus, the attachment can be covered by considering the tensile load, taking the load of the 800-gage.

2 AN SCREWS - \( \frac{1}{4} \) IN. DIA. STEEL.
MAX Tensile Strength : By \( \text{AN-1-S} \):
\[ 4030 \times 2 = 8060 \text{ lbf} \]

Factored load: \( 800 \times 4 = 3200 \text{ lbf} \)

\[ M.S. \frac{8060}{3200} - 1 = \]

1.55

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STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

B-1
HORIZONTAL TUBE.
B-1-1 BENDING.

Section properties of the tube:

Size: 10" x .121"
ID: 9.718"

Sectional area: \( A = \frac{\pi}{4} (10^2 - 9.718^2) \) = 353 in\(^2\)

Moment of inertia: \( I = \frac{\pi}{64} (10^4 - 9.718^4) \) = 54 in\(^4\)

Section modulus: \( Z = \frac{I}{Z} \) = 10.8 in\(^3\)

Stress under static load + aircrash:

Bending moment under static loads:

\[ H = (839.27 \times 40) - (43.85 \times 20) - (20 \times c) = 9560 - 1052 - 120 = 8388 \text{ in} \times \text{lb} \]
STRESS ANALYSIS OF \( \frac{1}{2} \) SCALE HOVERING & TRANSITION MODEL

\[ B-0 \quad \text{STRESS ANALYSIS - FAIRING.} \]

\[ B-1 \quad \text{HORIZONTAL TUBE} \]

\[ B-1-1 \quad \text{BENDING.} \]

Bending moment under airload:

\[ M = 173.6 \times 40 - 25 \frac{40^2}{2 \times 12} = 6940 - 1660 = 5274 \text{ in} \cdot \text{lb} \]

Total bending moment on the section:

\[ M_t = \sqrt{8388^2 + 5274^2} = 9870 \text{ in} \cdot \text{lb} \quad (225) \]

Bending stress: max:

\[ \sigma = \frac{9870}{10.8} = 910 \text{ PSI} \quad (647) \]

\[ 1.5 \times \frac{55000}{3600} - 1 = \]

\( >10 \)

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AIRCRAFT
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

B-6
STRESS ANALYSIS - FAIRING

B-1
HORIZONTAL TUBE

B-1-2
FLANGES ON 10" TUBE

FLANGE LOADING.

STATIC LOADS - VERTICAL

Bending moment at flange section:

\[
(239.27 \times 28) - (43.85 \times 12) = 6700 - 527 = 6173 \text{ in} \cdot \text{lb unfactored}
\]

Shear force:

\[
239.27 - 43.85 = 195.42 \text{ lb unfactored}
\]

AIRLOADS - HORIZONTAL

Bending moment at flange section:

\[
(173.6 \times 28) - \frac{28^2}{12 \times 2} = 4960 - 815 = 4145 \text{ in} \cdot \text{lb unfactored}
\]

Shear force:

\[
173.6 - \frac{28}{12} = 173.6 - 2.33 = 171.3 \text{ lb unfactored}
\]

TOTAL BENDING MOMENT:

\[
\sqrt{6173^2 + 4145^2} = 7380 \text{ in} \cdot \text{lb unfactored}
\]

Total shear force:

\[
\sqrt{195.42^2 + 171.3^2} = 286.16 \text{ lb unfactored}
\]
**STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL**

**B-0**  
**STRESS ANALYSIS**  
**FAIRING**

**B-1**  
**HORIZONTAL TUBE**

**B-1-2.**  
**FLANGES ON 10" TUBE**

Bolt strength in tension:
Ref: AN-C-5.
AN-5  5/16" OIA : 8500 lbf

Bolt strength in shear:
AN-5  5/16" OIA : 5750 lbf

Determination of tensions due to bending in the bolt cluster

\[ F = \frac{M d_i}{E d_k^2} \]

Considering only the bolt having greatest tension,

\[ E d_k^2 = 5.6^2 \left[ 2 + 4 \sin 60^\circ + 4 \sin 20^\circ \right] \]

\[ F = \frac{M}{5.6 \left[ 2 + 4 \sin 60^\circ + 4 \sin 20^\circ \right]} \]

\[ F = 7380 \times 0.0298 = 220 \text{ lbf} \text{ maximum} \]

Shear per bolt: \( \frac{220}{12} = 18.33 \text{ lbf per bolt} \text{ maximum} \)

Such low shear does not practically reduce the tensile strength.

\[ M.S. = \frac{6500}{4 \times 220} = 6.4 \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

B-0  STRESS ANALYSIS - FAIRING
B-1  HORIZONTAL TUBE
B-1-E  FLANGES ON 10" TUBE

WELDS.

Assume max load on bolt to be taken by 2" of 1/4" weld.

Weld area:  2 x .25 = .50 in²

Allowable U.S.S. of weld metal 32,000 PSI (Ref. AN-C-5)

Weld stress:  \frac{220}{.50} = 440 PSI unfactored.

\[ M = \frac{32,000}{4 \times 440} = 7.10 \]
**STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL**

**B-0**  
**STRESS ANALYSIS - FAIRING.**

**B-2**  
**VERTICAL FAIRING**

**B-2-1**  
**LOADING.**

**AREA:**

\[
\frac{(3.11 \times 3.11) - (1.80 \times 1.022)}{2} = \frac{9.81 - 9.44}{2} = 0.34 \text{ in}^2
\]

Side load on fairing:

\[C_a @ 5^\circ \approx 0.50\]

Total load at 30 ft:

\[0.50 \times 0.94 \times 30 = 13.4 \text{ lb} \text{ unfaired.}\]

Aft load on fairing:

\[C_d @ 5^\circ \approx 1.50\]

Total load at 30 ft:

\[1.50 \times 0.94 \times 30 = 40.5 \text{ lb} \text{ unfaired.}\]

Fully factored loads: \((N=4)\)

Side load:

\[13.4 \times 4 = 53.6 \text{ lb} \text{.}\]

Fray load:

\[10.5 \times 4 = 42.2 \text{ lb} \text{.}\]

Omitting CP at 25% chord and \(\frac{1}{2}\) span:

Moments at root:

**SIDE MOMENT:**  
\[18.7 \times 53.6 = 1000 \text{ inlb}\]

**AFT MOMENT:**  
\[18.7 \times 42.2 = 602 \text{ inlb}\]

These moments are considered as taken by groups of six or as shown in sketch.

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**CHECKED BY:**  
J. Smith

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**AIRCRAFT:**
8.0 STRESS ANALYSIS - FAIRING.

8.2 VERTICAL FAIRING.

8.2.2 VERTICAL FAIRING ATTACHMENT.

Loads on groups of rivets:

RIVETS AA: \( \frac{10000}{9} = 111.14 \)

RIVETS BB: \( \frac{6020}{32} = 187.87 \)

Bearing strength of 7/16" rivets in 0.064" 35.2 N alloy.

In the absence of exact data regarding the max. allowable bearing stress on 35.2 N, this stress is taken as being twice the UTS by comparison with other similar soft alloys.

\[ \text{UTS} = 20000 \text{ PSI (Ref. Engineering Manual)} \]

\[ \text{UTS} = 2 \times 20000 = 40000 \text{ PSI} \]

Bearing strength on 0.064" (AN-5-5) for \( \frac{D}{d} = 2.0 \):

\[ \frac{1020}{100000} = 0.0102 \]

The 1120 lb load is to be taken by rivets at 2.00" pitch, and a length of 12" will be inserted to take this load. Hence 6 rivets having a total strength of: \( 6 \times 408 = 2448 \) lb.

\[ M.S. \frac{2448}{1120} - 1 = \]
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

8-0 STRESS ANALYSIS - FAIRING
8-3 ATTACHMENT TO STRUT FAIRINGS

B-3-1 LOADING.

NOTE: Bolt "A" join flanges on both sides and are blocked tight on a tube space.

Flanges offset to load carrying plate:
inner flange: 0.95"
outer flange: 1.50"

APPLIED LOADS:
On the inner side, where loading is max.
240 lb Vertically down.
174 lb Horizontally aft.
10.5 lb Side load due to Vertical fairing.

NOTE: The side load is taken on the Port side only.

FULLY FACTORED APPLIED LOADS: n = 4.0
960 lb Vertically down.
696 lb Horizontally aft.
322 lb Side load.

NOTE: - Loads on the outer side are smaller than on the inner side.
- As a cover up, only load on the inner side will be considered.

DECLASSIFIED
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

8-0 STRESS ANALYSIS - FAIRING

8-3 ATTACHMENT TO STRUT FAIRINGS

8-3-1 LOADING.

NOTE: Butt "A" join.
flanges on both sides
and are blocked light in a tube spars.

Flanges offset to load
_carried plate:
inner flange: 1.25"
outer flange: 1.50"

APPLIED LOADS:

On the inner side, where loading is max.
240 lb Vertically down.
175 lb Horizontally aft.
80.5 lb Side load due to vertical fairing

NOTE: The side load is taken on the Port side only.

FULLY FACTORED APPLIED LOADS  n = 1.0

960 lb Vertically down.
696 lb Horizontally aft.
322 lb Side load.

NOTE: Loads on the outer side are smaller than on the inner side.

As a case up steering, only load on the inner side will be
considered.

DECLASSIFIED
Stress Analysis of 1/12 Scale Hovering & Transition Model

8-3.2 Load Carrying Steel Plate

Max. Vertical Load:
\[ 960 + 322 \times \frac{20.14}{5} = 960 + 1300 = 2260 \text{ lb} \]

Load per bolt due to 2260 lb:
\[ \frac{2260}{7} = 323 \text{ lb} \]

Load per bolt due to side load:
\[ \frac{696}{7} = 99.4 \text{ lb} \]

Load on bolts due to moment of side load:
- Moment: \( 696 \times 20.14 = 14000 \text{ in} \cdot \text{lb} \)
- Load on bolt 1:
  \[ \frac{14000}{\sqrt{(7.8^2 + 5.2^2 + 26)^2}} = 189.4 \]
- Load on bolt 2:
  \[ 73.9 \times 5.2 = 384 \text{ lb} \]
- Load on bolt 3:
  \[ 73.9 \times 2.6 = 192 \text{ lb} \]

Total load on bolt 1:
\[ \sqrt{(323 + 577)^2 + 99.4^2} = 905 \text{ lb} \]

Strength of bolt in shear: Ref. AN-C-5: 2126 lb
- M.S.:
  \[ \frac{2126}{905} - 1 = 1.34 \]

Steel plate: Strength of 1” strip under tension at UTS 55000 psi
- 1” x 0.025 x 5700 = 4375 lb

Assuming a 1” strip carries the load to bolt 1.

M.S.:
\[ \frac{4375}{905} - 1 = 3.75 \]
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

B-0 STRESS ANALYSIS - FAIRING
B-3 ATTACHMENT TO STRUT FAIRINGS

B-3-3.
BEARING FLANGES

Load per bolt due to:
322 1/16 322/6 = 53.7 1/16

Tension in upper bolt due to moment of vertical load:
960/11.0 x 1/2 = 43.6 1/16

Tension in side bolt due to moment of horizontal load:
696/15.6 x 1/3 = 14.9 1/16

Max tension on one bolt:
53.7 + 43.6 + 14.9 = 112.2 1/16

Total shear strength of the assembly (bearing not critical) Ref. AN-C-5
(6 x 3680) + (14 x 962) = 22100 + 13050 = 35150 1/16

Shear per bolt: \[
\frac{3680}{35150} = 0.108 V
\]

Total shear force: \[
\sqrt{960^2 + 696^2} = 1182 1/16
\]

Shear per bolt: 1182 x 0.108 = 128 1/16

Strength of 1/4 AN steel bolt (AN-C-5) Min. shear: 4050 1/16

M.S.
STRESS ANALYSIS OF $\frac{1}{2}$ SCALE HOVERING & TRANSITION MODEL

8.0 STRESS ANALYSIS - FAIRING

8.3 ATTACHMENT TO STRUT FAIRINGS.

8.3-3.
BEARING FLANGES - CONT'D.

FLANGE IN BENDING UNDER LOAD OF CORNER BOLT:

Bolt Tension: 112.2 lb
Moment arm: 4.00"
Section in bending: 0.25" x 8"
Section modulus: $\frac{0.25 \times 8}{2} = 1.0$ in$^3$

Bending stress: $\frac{112.2 \times 4.00}{1.0} = 5480$ PSI

M.S. $\frac{55000 - 1}{5400} = 9.2$
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL.

8-0 STRESS ANALYSIS - FAIRING.

8-3 ATTACHMENT TO STRUT FAIRING.

8-3.4 LOADS RESOLVED AT ATTACHMENT TO STRUT FAIRING.

LOADING REQUIRED FOR DESIGN BY WPAFB OF ATTACHMENT FLANNE TITLE 4.20 SK 30250 - FAIRING ASS'Y ATTACHMENT TO STRUT FAIRING.

UNFACTORED LOADS.

DECLASSIFIED

WRITTEN BY
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1st Lt. T. Chappell

DATE
Sept 18, 1977

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AIRCRAFT

AVRO LA 3110
9-0 DEFLECTIONS

9-1 NOMINAL MINIMUM CLEARANCES

FIG. 11

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WRITTEN BY
G. Jacques

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DATE
Sept. 1957

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AIRCRAFT
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

3-0  DEFL ections

3-2  GAGE SECTION DEFLECTION

The gages are designed as per report: AVRO/SPG/TR-87.

GAGE A  -  800

<table>
<thead>
<tr>
<th>OUTER DIA.</th>
<th>WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00&quot;</td>
<td>6.25&quot;</td>
</tr>
<tr>
<td>Operating</td>
<td>40,000 PSI</td>
</tr>
<tr>
<td>Stress</td>
<td>13.63</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.220</td>
</tr>
</tbody>
</table>

GAGE B & C  -  350

<table>
<thead>
<tr>
<th>OUTER DIA.</th>
<th>WIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00&quot;</td>
<td>5.00&quot;</td>
</tr>
<tr>
<td>Operating</td>
<td>40,000 PSI</td>
</tr>
<tr>
<td>Stress</td>
<td>18.20</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.165</td>
</tr>
</tbody>
</table>

GAGE DEFLECTION AND ROTATION OF MODEL

GAGE A: \( \sum_{800} = 0.0243" \) \( \frac{\sum_{800}}{800} = 2.66 \times 10^{-5} \) \( \text{in} \);

GAGE B & C: \( \sum_{350} = 0.0260" \) \( \frac{\sum_{350}}{350} = 7.42 \times 10^{-5} \) \( \text{in} \);

Rotation of model under 1004 applied at center.

Load on gage A: \( 100 \times 350 = 35 \) 
Load on gage B & C: \( 100 \times 325 = 32.5 \)

Gage A deflection: \( 2.66 \times 35 \times 10^{-5} = 0.0932" \)
Gage B deflection: \( 7.42 \times 32.5 \times 10^{-5} = 0.241" \)

Deflection angle of the model: \( \frac{0.241 - 0.0932}{6.3} = 0.000235 \) rad.

Rotation of the model in degrees: \( 0.0134 \) per 1004
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

9-0 DEFLections
9-3 DEFLECTION OF MODEL SUPPORT STRUCTURE
9-3-1 DEFLECTION OF MODEL MOUNT UNDER STATIC LOAD. 1 - VERTICAL.

\[ E = 30 \times 10^6 \text{ psi} \]
\[ I = 23.35 \times 10^{-6} \]

\[ EI = 30 \times 10^6 \times 23.35 = 7 \times 10^8 \]

\[ P \]
\[ 200 + 10.95 + 1.36 + 22.70 + 59.5 + 35.2 = 330.55 \]
\[ \text{say} \ 350 \text{ lb} \]

DEFLECTION UNDER UDL. P.

\[ J_1 = \frac{5}{384} \frac{P \cdot L^4}{EI} = \frac{0.1332 \times 80^4}{7 \times 10^8} P = 0.00768 P + 7.68 \times 10^{-2} P \]

DEFLECTION UNDER CONCENTRATED LOAD P.

\[ J_2 = \frac{Pl^2}{48EI} = \frac{P \cdot 80^3}{48 \times 7 \times 10^8} = 1.525 \times 10^{-5} P \]

TOTAL DEFLECTION:

\[ J = J_1 + J_2 = 7.68 \times 10^{-2} P + 1.525 \times 10^{-5} P \]

\[ J = 7.68 \times 10^{-2} \times 1.16 + 1.525 \times 10^{-5} \times 350 = 0.0089 + 0.00034 = 0.01424'' \]

DECLASSIFIED
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

9-0  DEFLECTIONS

9-3  DEFLECTION OF MODEL SUPPORT STRUCTURE

9-3-2  DEFLECTION OF MODEL MOUNT UNDER A DRAG LOAD AT MODEL CENTER.

HORIZONTAL

The incidence control arm has a variable moment of inertia along its length.

Deflection calculated by integrating twice \( \frac{d^2 \delta}{dx^2} \) along the length of the beam.

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>( l )</td>
<td>4.7</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>( M )</td>
<td>49.9 H</td>
<td>12.48 H</td>
<td>0</td>
</tr>
<tr>
<td>( I )</td>
<td>11.5 in^4</td>
<td>1114 in^4</td>
<td>0.852 in^4</td>
</tr>
<tr>
<td>( \frac{M}{E1} )</td>
<td>14.46 in^3 H</td>
<td>1.87 ( 10^{-8} ) H</td>
<td>0</td>
</tr>
<tr>
<td>( \frac{I}{E1} )</td>
<td>271.5 in^3 H</td>
<td>0.62 ( 10^{-8} ) H</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ \int \frac{M}{E1} dx = 3.26 \times 10^{-8} H = \Delta \]

\[ \int \frac{I}{E1} dx = \frac{5.10}{10^8} \times \frac{1}{E1} \]

\[ 1.10^2 = 5.0 \times 10^8 \left( \frac{M}{E1} \right) \]

\[ 1.00 \times 10^{-5} \int \frac{M}{E1} \]
9.0  DEFLECTIONS

9.3  DEFLECTION OF MODEL SUPPORT STRUCTURE.

9.3.2  DEFLECTION OF MODEL MOUNT UNDER A DRAG LOAD AT MODEL CENTER—CONT'D.

HORIZONTAL.

\[ \Delta_1 = 3.26 \times 10^{-5} \text{ in} \]
\[ \Delta_2 = 3.26 \times 10^{-5} \times \frac{50}{H} = 3.39 \times 10^{-5} \text{ in} \]

BENDING DEFLECTION OF VERTICAL MEMBER.

\[ \Delta_3 = \frac{H \ell^2}{3EI} \]

where \( \ell = 50 \) in and \( I = 33.75 \) in\(^4\)

\[ \Delta_3 = H \frac{50^2}{3 \times 30 \times 10^5 \times 33.75} = 4.12 \times 10^{-5} \text{ in} \]

TOTAL HORIZONTAL DEFLECTION OF THE MODEL CENTER:

\[ 1.525 \times 10^{-5} \text{ in} + 3.39 \times 10^{-5} \text{ in} + 4.12 \times 10^{-5} \text{ in} = 9.035 \times 10^{-5} \text{ in} \]

Say: \( 10^{-4} \text{ in} = \Delta \)

Thus, for a drag load of \( 2 \times 10^{-4} \), the deflection is

\[ 2 \times 10^{-4} + 2 \times 10^{-2} = 2 \times 10^{-2} = 0.02 \text{ in} \]
9.0 DEFLECTIONS

3.4 DEFLECTION OF FAIRING

9.4-1

DEFLECTION OF FAIRING TUBE UNDER STATIC LOAD. VERTICAL

\[ E = 30 \times 10^6 \text{ psi} \]
\[ I = 54 \text{ in}^4 \]
\[ EI = 16.2 \times 10^9 \]

DEFLECTION UNDER UDL \( P \)

\[ \Delta_1 = \frac{5}{384} \cdot \frac{P \cdot L^4}{EI} = \frac{10 \times 80^3}{16.2 \times 10^9} P = 3.71 \times 10^{-5} P \]

DEFLECTION UNDER CONCENTRATED LOAD \( P \)

\[ \Delta_2 = \frac{P \cdot L^3}{48 \cdot EI} = \frac{P \cdot 80^3}{48 \times 16.2 \times 10^9} = 7.34 \times 10^{-5} P \]

TOTAL DEFLECTION: \( \Delta = \Delta_1 + \Delta_2 = 3.71 \times 10^{-5} P + 7.34 \times 10^{-5} P \)

\[ \Delta = 3.71 \times 10^{-5} \times 125 + 7.34 \times 10^{-5} \times 75 = .00468 + .000558 \]

\[ = .005238" \]
9-0. DEFLECTIONS
9-4. DEFLECTION OF FAIRING
9-4.2.
DEFLECTION OF FAIRING TUBE UNDER AIR LOAD - HORIZONTAL.

The characteristics are similar to the static load case
with a UCL 25 lb; 2.08 \% say, 2.10 \%
and a drag load of 80.5" from the fairing of the vertical arm.

Hence, deflection:

\[ U = 3.71 \times 10^{-3} \times 2.10 + 7.34 \times 10^{-6} \times 80.5 = 7.79 \times 10^{-3} + 5.92 \times 10^{-4} = 0.008382" \]
9-0  DEFLECTIONS

9-5. CONCLUSION.

In view of the clearance provided, the deflection under load of this structure is insignificant.

We can see that the smallest clearance is .10" just above the surface of the model. In the static condition, the model mount sinks .0142" while the fairing sinks .0052" hence the relative motion is:

\[ 0.0142 - 0.0052 = 0.0090" \]

Thus, approximately 10% of the clearance provided.

Considering the effect of model lift, a critical case is the -10° case with a total down load of 546 lbs i.e. an extra 346 lbs on the static case which would induce an additional deflection:

\[ 1.525 \times 10^{-5} \times 346 = 0.00527" \]

Then, the relative motion becomes:

\[ 0.009 + 0.00527 = 0.01427" \] about 14% of the clearance provided.

All other clearances are larger hence less critical than the above.
In this section, the symbols and sign convention used in the rest of the report have been replaced by those of report AVRO/SPG/1477 "Test Specification for \( \frac{1}{12} \) Scale Hovering and Transition Model".

In 10-1-1, the basic gage equations from section 6-3 have been repeated using the new symbols. It should be noted that these equations apply only when the model suspension rod is engaged. When the rod is disengaged, the load distribution on the gages changes to that calculated on 6-1-3 page.

The basic equations from 10-1-1 can be simplified for calibration purposes by noting that:
1/ angle \( \phi = 0 \)
2/ reunion and sections are off.

The reduced equations are given in 10-1-2.
### STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

#### 10-0 CALIBRATION

#### 10-1 GAGE EQUATIONS FOR CALIBRATION.

#### 10-1-1 BASIC GAGE EQUATION.

**Ref. Section 6-1.3 # 6-3**

<table>
<thead>
<tr>
<th>Gage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>$-0.196 W(1+i\cos\alpha)$</td>
<td>$-0.182 W(1-i\cos\alpha)$</td>
<td>$-0.182 W(1+i\cos\alpha)$</td>
<td>$- W \sin \alpha$</td>
</tr>
<tr>
<td>Pressure</td>
<td>$4.67(P_1 - P_0)$</td>
<td>$4.60(P_2 - P_0)$</td>
<td>$-4.05(P_3 - P_0)$</td>
<td>$0$</td>
</tr>
<tr>
<td>Suction</td>
<td>$2.17(P_1 - P_0)$</td>
<td>$2.658(P_2 - P_0)$</td>
<td>$2.658(P_3 - P_0)$</td>
<td>$0$</td>
</tr>
<tr>
<td>Normal Load</td>
<td>$-0.196 N$</td>
<td>$-0.182 N$</td>
<td>$-0.182 N$</td>
<td>$0$</td>
</tr>
<tr>
<td>Drag Load</td>
<td>$-0.750 (F-W_{min})$</td>
<td>$+0.750 (F-W_{max})$</td>
<td>$2.000 (F-W_{min})$</td>
<td>$0$</td>
</tr>
<tr>
<td>Side Load</td>
<td>$0$</td>
<td>$-0.626 Y$</td>
<td>$+0.626 Y$</td>
<td>$0$</td>
</tr>
<tr>
<td>Pitching Mx</td>
<td>$-0.1575 M_p$</td>
<td>$+0.07875 M_p$</td>
<td>$+0.07875 M_p$</td>
<td>$0$</td>
</tr>
<tr>
<td>Rolling Mx</td>
<td>$0$</td>
<td>$+0.130 M_r$</td>
<td>$-0.130 M_r$</td>
<td>$0$</td>
</tr>
</tbody>
</table>

Positive gage load is tension.

**Note:**

- Pressure $(P_1 - P_0)$
- $(P_2 - P_0)$ in PSI.

**Total load on each gage is the sum of the corresponding column.**

**Note:** Above values are valid as long as the total normal load does not exceed $+22.78 W$.

Normal loads of this magnitude are not expected to occur during tests.

---

**DECLASSIFIED**

**Written by**

G. Froscavanc

**Checked by**

D. Fords

**Date**

Sept. 1957

**Issue**

Aircraft
STRESS ANALYSIS OF ½ SCALE HOVERING & TRANSITION MODEL

10-0  CALIBRATION
10-1  GAGE EQUATIONS FOR CALIBRATION
10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS.

VERTICAL LOAD AT WHICH VERTICAL SUSPENSION ROD WILL DISCONNECT.

From Section 5-1-3: Rod deflection: $f_r = 2.42 \times 10^{-5} W$

Gage system deflection: $f_g = 1.895 \times 10^{-5} W$

From the equation: $\Delta W = W_i + 1.278 W_i = 2.278 W_i$

where $W_i$ is the weight of the model and $\Delta W = N$.

we have

$N = 2.278 \times 800 = 1822.4 \text{ lb}$

MAX. & MIN. LOADS APPLICABLE ON THE SYSTEM TO REACH RATED GAGE LOADS

NORMAL LOAD $N$.

GAGE A: Equations:

$-800 \leq \frac{-0.35(N-800)}{196} \leq 800 \text{ tons}$

$-800 \leq \frac{-0.196 N}{N \geq 456} \leq 800 \text{ tons}$

Gage load at $N = 456 \text{ lb}$

$G_1 = \frac{-0.35 \times (456-800)}{196} = -35 \times 256 = -89.6 \text{ lb}$

$G_2 = -0.196 \times 456 = -89.6 \text{ lb}$

at Min. Gage load:

$G = -0.196 N$

$N = \frac{-800}{-0.196} = 4090 \text{ lb}$.

at Max. Gage load:

$G = \frac{-0.35(N-800)}{196}$

$N = \frac{-800/-0.35 + 800}{2485 \text{ lb}}$
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL.

10-0 CALIBRATION

10-1 GAGE EQUATIONS FOR CALIBRATION

10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS.

MAX. & MIN. LOADS APPLICABLE ON THE SYSTEM TO REACH RATED

GAGE LOADS - CONT'D.

GAGE B & C

Equation: \[-350 \leq -0.325(N-200) \leq 350\]

\[-350 \leq -0.182N \quad \text{if} \quad N \leq 456 \leq 350\]

Gage load at: \(N = 456 \:\text{lbf}\)

\[G_1 = -0.325(456-200) = -0.325 \times 256 = -83.2 \:\text{lbf}\]

\[G_2 = -0.182 \times 456 = -83.2 \:\text{lbf}\]

at Min. Gage Load:

\[G = -0.182N\]

\[\therefore \quad N = \frac{-350}{-0.182} = 1925 \:\text{lbf}\]

at Max. Gage Load:

\[G = -0.325(N-200)\]

\[\therefore \quad N = \frac{350 + 200}{-0.325} = 1375 \:\text{lbf}\]

PITCHING MOMENT \(M_p\)

GAGE A:

Equation: \[0.1575 \quad M_p = G_a \pm 800 \:\text{lbf in}\]

\[\therefore \quad M_p = \frac{800}{0.1575} = 5060 \:\text{lbf in}\]

GAGE B & C:

Equation: \[0.07175 \quad M_p = G_b = \pm 350 \:\text{lbf in}\]

\[\therefore \quad M_p = \frac{\pm 350}{0.07175} = \pm 4840 \:\text{lbf in}\]
**10-0 Calibration**

**10-1 Gage Equations for Calibration**

**10-1-2 Gage Equations & Max. Applied Loads.**

Max. & Min. loads applicable on the system to reach rated gage loads - cont'd.

**Rolling Moment Mr.**

Gage B & C only.

Equation: \( \pm 130 \text{ Mr} = G \)

\[
\frac{350}{1.10} = \pm 2690 \text{ in-lb}
\]

**Summary**

The max. and min. loads and moment that can be applied on the system must not exceed those which will produce the rated load of the weaker gage. Thus, gage B & C are limiting these loads and moments to the values underlined in the text and summarized below:

- \( F \): Front-off \( \pm 150 \text{ lb} \)
- \( Y \): Side \( \pm 50 \text{ lb} \)
- \( N \): Up \( 1275\text{ lb} \), Down \( -1425\text{ lb} \)
- Mr: Pitching Mr \( \pm 4440 \text{ in-lb} \)
- Mr: Rolling Mr \( \pm 2690 \text{ in-lb} \)

**Note:** \( F \) & \( Y \) are limited by design considerations rather than gage strength.
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL.

10-0  CALIBRATION

10-1  GAGE EQUATIONS FOR CALIBRATION:

10-1.2  GAGE EQUATIONS & MAX. APPLIED LOADS

GAGE EQUATIONS IN TERMS OF F, Y, N, MP & MR FOR \( \alpha = 0 \)

Under calibration loads, \( P, B \) and \( \alpha = 0 \), then eq. given in 10-1.1 become:

**GAGE A**

\[-800 \leq -0.35(N+W) + 0.76 F - 0.1575 Np \leq 800 \quad \text{(not disengaged)}\]

\[-800 \leq -136 N + 0.76 F - 0.1575 Np \leq 800 \quad \text{(not engaged)}\]

**GAGE B & C**

\[-350 \leq -0.325(N+W) + 0.38 F + 0.626 Y + 0.07875 Np \pm 0.130 Mr \leq 350 \quad \text{(not disengaged)}\]

\[-350 \leq -0.182 N + 0.38 F + 0.626 Y + 0.07875 Np \pm 0.130 Mr \leq 350 \quad \text{(not engaged)}\]

**GAGE D**

\[-150 \leq F \leq 150\]

MAX VALUES OF APPLIED LOADS & MOMENTS

<table>
<thead>
<tr>
<th>F</th>
<th>Fore/Aft</th>
<th>+150 4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Side</td>
<td>+50 4%</td>
</tr>
<tr>
<td>N</td>
<td>Up/Down</td>
<td>+1275 /4 to -1925 /4</td>
</tr>
<tr>
<td>Mp</td>
<td>Pitching Mr.</td>
<td>+440 4%</td>
</tr>
<tr>
<td>Mr</td>
<td>Rolling Mr</td>
<td>+2690 4%</td>
</tr>
</tbody>
</table>

**NOTE:**
1. Above loads (max.) apply singly when all other loads = 0
2. \( N \) may be sum of normal loads, pressure and suction loads.
3. Gage readings will not differentiate between rolling Mr due to \( Y \) and Mr.

**WRITTEN BY**  G. Jacquemin

**CHECKED BY**  

**DATE**  Sept. 1957

**ISSUE**  

**AIRCRAFT**  

AVRO EA 3110

SECRET  DECLASSIFIED
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION

10-1 GAGE EQUATIONS FOR CALIBRATION

10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS

GAGE EQUATIONS & LIMITS - ASSUMING \( W = -200 \) lbf

GAGE A

\[-800 \leq -35(N-200) \]
\[-.76 F \]
\[-.1575 M_p \]
\[N = 1275 \]
\[F = -150 \]
\[M_p = -6940 \]

\[-800 \leq -196 N \]
\[-.76 F \]
\[-.1575 M_p \]
\[N = -1985 \]
\[F = -150 \]
\[M_p = -6940 \]

GAGE B & C

\[-350 \leq -3325(N-200) \]
\[+.38 F \]
\[+.626 Y \]
\[+ .07875 M_p \]
\[N = 1275 \]
\[F = -150 \]
\[Y = -50 \]
\[M_p = -6940 \]
\[\pm .13 M_p \]
\[M_p = -6940 \]

\[-350 \leq -182 N \]
\[+.38 F \]
\[+.626 Y \]
\[+ .07875 M_p \]
\[N = -1985 \]
\[F = -150 \]
\[Y = -50 \]
\[M_p = -6940 \]
\[\pm .13 M_p \]
\[M_p = -6940 \]

GAGE D

\[-150 \leq F \]
\[F = -150 \]
\[F = -150 \]
STRESS ANALYSIS OF 1/3 SCALE HOVERING & TRANSITION MODEL

10-0  CALIBRATION

10-2-0  CALIBRATION PROCEDURE.

The equations in page give the relation between gage loading and the applied loads N, F, Y and the moments Mx, My. These equations will hold only when there is no other interaction between the gages. The purpose of calibration is to find out any such interactions which may exist and provide means of adjusting these equations accordingly.

The calibration tests will be carried out in 4 series:

Series 1 - Each load or moment applied singly.
Series 2 - Loads N, F, Y in combination
Series 3 - Loads N, F, Y, Mx, My in combination
Series 4 - Cases representing expected loading as calculated in the stress analysis report.

SERIES 1 - Each load or moment applied singly

Table 1 & 2 indicate the loads to be applied on the calibration rig. These loads should be applied in steps from 0 to max. to 0 and from 0 to min. to 0.

SERIES 2 & 3  Combined loading.

The general principle used for calibrating under combined loading is a system where the gage load is held at a definite value and the applied loads and moments adjusted in various combination to produce the same gage load. Thus, by using values of the applied loads and moments, which should theoretically give a chosen gage load, it will be possible to estimate the error in the...
Stress Analysis of 1/2 Scale Hovering & Transition Model

10-0  CALIBRATION

10-2-0  CALIBRATION PROCEDURE - CONT'D.

gage reading at various gage loading levels. A minimum
of 5 different combinations should be tested at each gage
level for both 2 or more applied loads or moments,
combinations.

Series 2 - All possible combinations of $N, F, T_0$
are shown graphically on chart 3 & 4 for gage A
and on charts 5 & 6 for gage B & C.

Series 3 - All possible combinations of $N, F, Y,
$T_0$ & $M_x$ are shown graphically on charts 7 & 8
for gages B & C.

It should be noted that gage A is not theoretically
affected by $Y$ or $M_x$. However, it will be necessary to
follow its reading during calibration of gages B & C.

SERIES 4 - Stalling Cases.

This series is an attempt to represent approximately
the conditions of the model tests. It is felt that this series
of calibration tests will give some information on the behaviour
of the balance in a range close to that one may expect
in operation. Loads to be applied in the calibration rig for
each cases stated in this report are given in Table 3.
### Stress Analysis of ½ Scale Nacelle & Transition Model

#### 10-2 Calibration

**10-2.1** Gage Equations for Calibration

**10-2.2** Gage Equations & Max Applied Loads

#### Gage Calibration

**Graphical Solution**

---

**Example:**

\[ N = -600 \text{ kN} \quad F = 100 \text{ kN} \quad H_2 = 2000 \text{ kN} \]

*The gage is 5/10^-6 tension*
STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION
10-2 CALIBRATION RIG.
10-2-1 DESCRIPTION.

FIG. 12
CALIBRATION RIG.

AT EACH POINT 1, 2, 3 & 4, WE MAY HAVE AN OUTBOARD LOAD, AN UP LOAD, A DOWN LOAD OR A COMBINATION OF THE THREE.
## Stress Analysis of 1/2 Scale Hovering & Transition Model

### 10.0 Calibration

### 10.2 Calibration Rig

### 10.2.2 Loads on Calibration Rig

#### Table 1

Distribution of Loads & Moments on Loading Points:

<table>
<thead>
<tr>
<th>LOAD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
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<tr>
<td></td>
<td>OUT</td>
<td>UP</td>
<td>DOWN</td>
<td>OUT</td>
</tr>
<tr>
<td>(F_{150})</td>
<td>F</td>
<td></td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>(F_{10})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Y_{150})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Y_{90})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N_{1375})</td>
<td>(N_4)</td>
<td>(N_4)</td>
<td>(N_4)</td>
<td>(N_4)</td>
</tr>
<tr>
<td>(N_{1925})</td>
<td>(N_4)</td>
<td>(N_4)</td>
<td>(N_4)</td>
<td>(N_4)</td>
</tr>
<tr>
<td>(M_r_{2690})</td>
<td></td>
<td>(M_r_{40})</td>
<td>(M_r_{40})</td>
<td>(M_r_{40})</td>
</tr>
<tr>
<td>(M_r_{1500})</td>
<td>(M_r_{40})</td>
<td></td>
<td>(M_r_{40})</td>
<td>(M_r_{40})</td>
</tr>
<tr>
<td>(M_p_{-4440})</td>
<td>(M_p_{40})</td>
<td>(M_p_{40})</td>
<td>(M_p_{40})</td>
<td>(M_p_{40})</td>
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</tbody>
</table>
### TABLE 2

#### SIMPLE CASE - ONE LOAD ALONE

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<tr>
<td>( F = 150 )</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F = -150 )</td>
<td></td>
<td></td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>( Y = 50 )</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Y = -50 )</td>
<td></td>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>( N = 1275 )</td>
<td>318.5</td>
<td>318.5</td>
<td>318.5</td>
<td>318.5</td>
</tr>
<tr>
<td>( N = -1925 )</td>
<td>481.25</td>
<td>481.25</td>
<td>481.25</td>
<td>481.25</td>
</tr>
<tr>
<td>( M_r = 2690 ) lb-in.</td>
<td></td>
<td>67.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M_r = -2690 ) lb-in.</td>
<td></td>
<td></td>
<td>67.25</td>
<td></td>
</tr>
<tr>
<td>( M_p = 4440 ) lb-in.</td>
<td>III</td>
<td>III</td>
<td>III</td>
<td>III</td>
</tr>
<tr>
<td>( M_p = -4440 ) lb-in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Above load \( F \) will bring gage D to its rated load.
Above load \( N \) will bring gages B & C to their rated loads.
Above \( M_r \), \( M_r \) and \( M_p \) all exceed their rated loads.
Above \( M_r \) and \( M_p \) all exceed their rated loads.
## Stress Analysis of 1/2 Scale Hovering & Transition Model

### Table 3

<table>
<thead>
<tr>
<th>Case</th>
<th>Applied Load</th>
<th>Hovering</th>
<th>Horizontal</th>
<th>Thrust</th>
<th>Transition 20°</th>
<th>Transition 30°</th>
<th>Transition 35°</th>
<th>Transition 45°</th>
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<tbody>
<tr>
<td>1</td>
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<td>Hi</td>
<td>47.1</td>
<td>121.5</td>
<td>7.55</td>
<td>6.95</td>
<td>5.55</td>
<td>3.8</td>
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<tr>
<td>2</td>
<td>Fh</td>
<td>Hi</td>
<td>3.8</td>
<td>14.5</td>
<td>27</td>
<td>24.5</td>
<td>20</td>
<td>3.8</td>
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<tr>
<td>3</td>
<td>Mr</td>
<td>Hi</td>
<td>3.8</td>
<td>14.5</td>
<td>27</td>
<td>24.5</td>
<td>20</td>
<td>3.8</td>
</tr>
</tbody>
</table>

**Notes:**
- **Load Cases:** With no rolling moment or side load.
- **Movement:** Up, Down, Out, In.
APPENDIX A - CALCULATION OF WEIGHT

A-1 - WEIGHT OF MODEL

A-1.1 GENERAL

Volume of an annulus: Sectional area \times path of the CG.

\[ V = a \times b \times 2\pi r \]

\[ W = V \times b \times 2\pi r \]

Using Simpson's rule we can fix
\[ a = 0.25 \]
\[ b = 0.25 \text{ in} \]

Here: the term \[ 2\times a \times b \times 2\pi r = 2\times 0.25 \times 0.25 \times 2\pi = 0.445 \]

Hence: the weight of one element: \[ dW = 0.445 \text{ br} \]

and the total weight of one annular part is

\[ W = 0.445 \times \text{ br} \]

Values of \text{ br} are tabulated for each part.
APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-2 PART I
LOWER INTAKE & EXHAUST.
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-3 PART II LOWER RAMP.
### Stress Analysis of 1/2 Scale Hovering & Transition Model

#### Weight of Model Components

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<th>Part II</th>
<th>Part III</th>
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<td>rb</td>
</tr>
<tr>
<td>a</td>
<td>in</td>
<td>in</td>
</tr>
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Form 1385
### Stressed Analysis of 1/2 Scale Hovering & Transition Model

#### Part IV

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</tr>
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</table>

\[ \sum_{i=1}^{n} r_i b_i = 163.55 \text{ lb} \]

**Total Weight of Model:** 104.5 + 73.5 = 178 lb
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4-1-5 WEIGHT OF MODEL COMPONENTS

Weight of ribs:

Side area: \( \frac{7.5}{2} \left( \frac{.82 + 1.45}{2} \right) + \left( 1.45 \times 1.45 \right) + \frac{.625}{2} \left( .65 + .82 \right) = \)

\( 8.5 + 1.378 + .46 = 10.328 \text{ in}^2 \)

Weight per rib: \( .293 \times 10.328 \times .30 = .887 \text{ lb} \)

Total weight of ribs: \( .887 \times 24 = 21.30 \text{ lb} \)

4-1-6 TOTAL WEIGHT OF MODEL.

TOTAL WEIGHT OF MODEL WITHOUT DEDUCTION OF HOLES:

\( 177.8 + 21.30 = 199.1 \text{ lb} \)

The holes will remove about 10%. However, instrumentation inside the model will add to the total and we can expect other variations due to tolerances etc.

TOTAL WEIGHT OF THE MODEL IS TAKEN AT: 200 lb
APPENDIX A - CALCULATION OF WEIGHT.

A-2 - WEIGHT OF MODEL SUPPORT STRUCTURE.

A-2-1 - MAIN TUBES.

Weight of steel pipe: Ref. ARMCO Welded Steel Pipe Catalog.

<table>
<thead>
<tr>
<th>O.D.</th>
<th>WALL THK.</th>
<th>WEIGHT/ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in</td>
<td>.141&quot;</td>
<td>8.80 lb</td>
</tr>
<tr>
<td>8.625&quot;</td>
<td>.141&quot;</td>
<td>12.24 lb</td>
</tr>
</tbody>
</table>

Tube 7 x 3/16 is available from stock: Item: MT 1015 cold drawn seamless tube.

Weight per foot at .205 lb/ft^3

\[
0.205 \times 12 \times \frac{\pi}{4} \left( 7^2 - 6.625^2 \right) = 13.32 \text{ lb/ft}
\]
APPENDIX A - CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-1 MAIN TUBES

Weight of horizontal main tube: 13.32 \( \frac{72}{12} \) = 80 \( \frac{\text{lb}}{\text{in}} \)

Weight of 5 \( \frac{1}{2} \) vertical tube: 12.74 \( \frac{48 + 8}{12} \) = 59.5 \( \frac{\text{lb}}{\text{in}} \)

Weight of 6\" vertical tube: 8.80 \( \frac{48}{12} \) = 35.30 \( \frac{\text{lb}}{\text{in}} \)

Tapered entry to 6\" tube: assume approx. equal to 1\% of tube 6 \( \frac{1}{2} \) OD x .0141 wall: 9.74 \( \frac{\text{lb}}{\text{in}} \) say 10 \( \frac{\text{lb}}{\text{in}} \)

Weight of cascade: assume 2 \( \frac{\text{lb}}{\text{in}} \)

End rings: 2 \( \times \) 2.03 \( \times \) .375 \( \times \) \( \frac{\pi}{2} \) \( (9^2 - 7^2) \) = 5.33 \( \frac{\text{lb}}{\text{in}} \)

Total weight of model mounting not including incidence arm and gear mounting:

80 + 59.5 + 35.2 + 10 + 2 + 5.33 = 192 \( \frac{\text{lb}}{\text{in}} \)

Weight of vertical tubes: 59.5 - 35.2 = 94.7 \( \frac{\text{lb}}{\text{in}} \)
APPENDIX A  - CALCULATION OF WEIGHT

A-2  WEIGHT OF MODEL SUPPORT STRUCTURE

A-2.2  LOAD GAGES ASS'Y.

---

**UPPER PLATE**

Area: measured on drawing: 37.68 in²

Weight of plate: \( \frac{283 \times 0.375 \times 37.68}{12} = 4.0 \) lb

---

**LOWER PLATE**

Area: measured on drawing: 28.18 in²

Weight of plate: \( \frac{283 \times 0.375 \times 28.18}{12} = 3.00 \) lb
APPENDIX A - CALCULATION OF WEIGHT
A-2 WEIGHT OF MODEL SUPPORT STRUCTURE
A-2-2 LOAD GAGES ASS'Y - CONT'D.

Tubes:
- Larger tube: Weight: $0.283 \times 2.0 \frac{\pi}{4} (7.2^2 - 7.0^2) = 1.33 \frac{lb}{ft}$
- Smaller tube: Weight: $0.283 \times 2.5 \frac{\pi}{4} (4.5^2 - 4.1^2) = 0.62 \frac{lb}{ft}$

Drag gage brackets:
- Weight estimated at 1/2 lb

Total weight:
$$4 + 3 + 1.33 + 0.62 + 1 = 9.95 \frac{lb}{ft}$$

Add 10% for welds, bolts, etc...
$$9.95 \times 1.1 = 10.95 \frac{lb}{ft}$$

WEIGHT OF RING GAGES.

CASE A: 800 lb RATED LOAD.

$$W = 0.283 \left[ \frac{\pi}{4} (D^2 - d^2) b + 2 b_p e \ell_F + 2 b_p e \ell_P \right]$$

Substituting $d = D - 2t$

$$W = 0.283 \left[ \pi b (D - t) + 2 b_p e \ell_F + 2 b_p e \ell_P \right]$$

$$= 0.283 \left[ \pi \times 6.05 \times 0.22 (3 - 2.2) + (2 \times 0.50 \times 0.02 \times 0.55) + (2 \times 0.50 \times 0.20 \times 1.50) \right]$$

$$= 0.436 \frac{lb}{ft}$$
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

4-2-2 LOAD GAGE ASS'Y

WEIGHT OF RING GAGES - CONT'D

GAGES B & C : RATED LOAD: 1350 lb

\[ W = 0.283 \left[ \frac{1}{2} bc (D-c) + 2 b f \left( \frac{L_f}{2} + 0.5 \right) \right] \]

\[ = 0.283 \left[ \frac{1}{2} \times 0.50 \times 165 \times (3.0 - 0.165) + \left( 2 \times 0.25 \times 0.027 \times 0.55 \right) + \left( 2 \times 0.50 \times 0.26 \times 0.150 \right) \right] \]

\[ = 298 \frac{lb}{\text{per gage}} \]

\[ - 596 \frac{lb}{\text{for the 2 gages}} \]

GAGE D - : RATED LOAD : 150 lb

\[ W = 0.283 \left[ \frac{1}{2} bc (D-c) + 2 b f \left( \frac{L_f}{2} + 0.5 \right) \right] \]

\[ = 0.283 \left[ \frac{1}{2} \times 0.10 \times 10 \times (2.0 - 0.10) + \left( 2 \times 0.25 \times 0.035 \times 0.35 \right) + \left( 2 \times 0.175 \times 0.375 \times 0.50 \right) \right] \]

\[ = 103 \frac{lb}{\text{per gage}} \]

TOTAL WEIGHT OF GAGES:

\[ 1436 + 596 + 103 = 1141 \frac{lb}{\text{total}} \]

add 10% for bolts, leads, wiring, etc:

\[ 1141 \times 1.1 = 1261 \frac{lb}{\text{total}} \]

Total weight of vertical pieces:

\[ 94.7 + 11.0 + 6.3 = 102.0 \frac{lb}{\text{total}} \]
APPENDIX A - CALCULATION OF WEIGHT
A-2 WEIGHT OF MODEL SUPPORT STRUCTURE
A-2-3 WEIGHT OF ATTACHMENT TO BALANCE STRUTS.

BALL BEARING: SKF 6238-11

Weight of balls: \( W = \frac{70^3}{6} \) = 14.68 lb

Carter race:
Mean dia: \( 13.5 \times 0.75 = 12.38 \) in

Sectional area: \( 2.16 \times 0.75 = 1.62 \) in²

Weight: \( 1.283 \times 12.38 \times 1.62 \) = 23.18 lb

Inner race:
Mean dia: \( 7.48 + 0.75 = 8.23 \) in

Sectional area: \( 2.16 \times 0.75 = 1.62 \) in²

Weight: \( 1.283 \times 8.23 \times 1.62 \) = 16.95 lb

Weight of bearing: 14.68 + 17.12 + 10.95 = 42.75 lb

Note: By not removing the weight of the groove, that of the retainer is not taken care of.
APPENDIX A - CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-3 ATTACHMENT TO BALANCE STRUTS... CONT'D.

BEARING HOUSING.

Side area:

\[
\left( \sqrt{14.5 \times 6.6} + \left( \frac{7.25 \times 1}{2} \right) - \left( \frac{12.38 \times \pi}{2} \right) \right) = 124.8 + 83 - 141 = 66.8 \text{ sq in}
\]

Weight:

66.8 x 0.5 x 285 = 94.3 lb

Retention ring:

2.85 x \pi x \frac{1}{4} (12.38^2 - 12.625^2) = 1.70 lb

Total weight:

97.8 + 1.70 = 99.5 lb

* NOTE: Dimension 8.6" is now 17.28". However, a number of large holes have been cut in the rectangular part of this component. Exact weight has not be computed again.
APPENDIX A — CALCULATION OF WEIGHT
A-2 — WEIGHT OF MODEL SUPPORT STRUCTURE
A-2-3
ATTACHMENT TO BALANCE STRUTS — CONT’D.

TUBE, FLANGE & OTHER RINGS.

Tube length: 21.50".  \( 7 \times \frac{1}{16} \) Tube. Steel:

weight: \( 13.32 \) lb per ft

Tube weight: \( 13.32 \times \frac{21.5}{16} = 23.9 \) lb

Flange: 5.33 \( \frac{1}{4} \) (Ref. page 6 - )

Ball bearing mounting ring: assumed: 12 \( \frac{1}{4} \)

End ring: assumed: 6 \( \frac{3}{4} \)

Total weight: 23.9 + 5.33 + 12 + 6 = 47.23 \( \frac{1}{2} \)

add 10% for weld, bolts, etc:

\[ 47.23 \times 1.10 = 52 \frac{1}{2} \]
APPENDIX A - CALCULATION OF WEIGHT

A-2 - WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-4 - INCIDENCE CONTROL ARM.

---

**FLANGES**

Total length of tapered flanges: \(31.7 + 18.3 = 64''\)

Weight of tapered flange: \(64 \times 2.5 \times 125 \times 283 = 5.67 \text{ lb}\)

Total length of constant width flange: \((12 + 1.5) \times 2 = 27''\)

Weight of constant width flange: \(27 \times 2 \times 125 \times 283 = 1.91 \text{ lb}\)

**WEB**

Rectangular part: Side area: \((2.5 - .25) \times (12 + 1.5) = 30.4 \text{ in}^2\)

weight: \(70.4 \times 125 \times 283 = 1.6 \text{ lb}\)

Trapezoidal part: Side area: \((8.85 + 2.25) \times \frac{48 - 12 - 4.31}{2} = 163.5 \text{ in}^2\)

weight: \(163.5 \times 125 \times 283 = 3.65 \text{ lb}\)

Weight of web: \((163.5 + 30.4) \times 1.17 \times 283 = 10.06 \text{ lb}\)

Total weight of arm: \(10.25 + 1.91 + 5.67 = 17.83 \text{ lb}\)

Then \(z = \frac{(33 \times 14.32) + (6 \times 3.71)}{17.83} = 28''\)

Weight of rear balance arm connecting link: \(\approx 3.5 \text{ lb}\)

Total weight of arm: \(17.83 + 3.5 = 21.35 \text{ lb}\) say \(21.50 \text{ lb}\)

add 10% for welds: \(23.70 \text{ lb}\) say \(24.0 \text{ lb}\)

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**WRITTEN BY**

G. Jacques

**CHECKED BY**

**DATE**

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**AIRCRAFT**
APPENDIX A - CALCULATION OF WEIGHT

A-3 - WEIGHT OF FAIRING

A-3 - 1
FAIRING - OUTER SECTION

![Diagram of fairing with dimensions and labels]

Weight of 10" tube: Ref. Barnes catalog 14.81 lb

\[
\text{Weight of tube: } 14.81 \times \frac{25}{12} = 30.3 \text{ lb}
\]

Weight of steel ring: 
\[
\frac{1.25 \times 0.25}{(1.25^2 - 1.0^2)} = 2.44 \text{ lb}
\]

Weight of brass ring: 
\[
\frac{0.36 \times 1.75}{(1.75^2 - 1.0^2)} = 6.53 \text{ lb}
\]

Total weight: 
30.3 + 2.44 + 6.53 = 39.87 lb

Add 10% for rivets, bolts, etc.

39.87 \times 1.10 = 43.85 lb
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-2 FAIRING - CENTER SECTION - CYLINDRICAL PART.

Weight of tube: Ref. ARMCO CATALOG. Size 10 x .141. $\frac{14.01}{12} \times \frac{12}{12} = 14.01$ lb.

Weight of unused tube: $14.01 \times \frac{24}{12} = 29.62$ lb.

Weight removed by cut, ang. $\frac{165^\circ}{360} = \frac{5.10}{12}$ lb.

Total weight of tube: $29.62 - 5.10 = 24.52$ lb.

Weight of rings: $2 \times .283 \times \frac{\pi}{4} (12^2 - 10^2) \times \frac{25}{2} = 487$ lb.

Weight of side strip: $4 \times .283 \times 1.0 \times .25 \times 23.5 = 6.65$ lb.

Total weight of component: $24.52 + 487 + 6.65 = 36.04$ lb.

Add 10% for welds, bolts, etc.: $36.04 \times 1.1 = 39.7$ lb.
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-2 FAIRING - CENTER SECTION - REAR ARM FAIRING.

MATERIAL: MILD STEEL - .10" THK.

Developed length of streamlined part: 82"
Lateral area of developed part: \((82 \times 9.0) = 738\) in²


Arm fairing:
- Side: \(6.0 (2 \times 22.5 + 10) = 294\) in²
- Bottom: \(22.5 \times 6 = 135\) in²

Edge: 1.0" wide; total length measured in dug: 105"
- Area: 105 in²

Cover plates:
- Front plate: \(\frac{1}{2}\) circle; rad. 3.0"; 12 in²
- Rear plate: \(\frac{25 \times 12}{2} = 150\) in²
\(25 \times 6 = 150\) in²

Total area of plate: \(659.5 + 294 + 135 + 105 + 150 + 150 = 1493.5\) in²

Weight of plate: \(0.283 \times 10 \times 1493.5 = 42.3\) lb

Add 10% for welds, bolts, etc.:
\(42.3 \times 1.1 = 46.50\) lb
APPENDIX A - CALCULATION OF WEIGHT

A.3 WEIGHT OF FAIRING.

A.3.2 FAIRING - CENTER SECTION - ALUMINUM PART.

MAT: 24 ST. AL. ALL .064" THK @ .10 lb/in^3

Developed length of contour: 82"

Lateral area of sheet:

\[ 82 \times 40 = 3280 \text{ in}^2 \]

Volume:

\[ 3280 \times 0.064 = 210 \text{ in}^3 \]

Weight of sides:

\[ 210 \times 0.10 = 21 \frac{1}{2} \]

Bottom part:

Approx area:

\[ 10 \times \frac{22}{2} = 110 \text{ in}^2 \]

Weight:

\[ 0.10 \times 0.064 \times 110 = 70 \frac{1}{2} \]

Total weight of aluminum fairing:

\[ 21 + 70 = 21.70 \text{ lb} \]
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-3 ATTACHMENT TO BALANCE STRUTS - FAIRING -

![Diagram of stress analysis components]

**LOWER BORDER**

- **Material**: 3/16 steel
- **Thickness**: 0.055" (1.4 mm)
- **Width**: 0.775" (1.97 cm)
- **Mean Length**: 24" (61 cm)

Weight: \( 0.283 \times 0.055 \times 0.775 \times 24 = 2.5 \text{ lb} \)

**UPPER BORDER**

- **Material**: 1/8 steel
- **Thickness**: 0.0625" (1.6 mm)
- **Width**: 0.775" (1.97 cm)
- **Mean Length**: 31.2" (79 cm)

Weight: \( 0.283 \times 0.0625 \times 0.775 \times 31.2 = 1.93 \text{ lb} \)

**Stiffening Channels**

- **Thickness**: 0.088" (2.2 mm)
- **Developed Width**: 2.0" (5 cm)
- **Length**: 19" (48.3 cm)

Weight: \( 0.283 \times 0.088 \times 2.0 \times 19 = 2.99 \text{ lb} \)
APPENDIX A - CALCULATION OF WEIGHT
A-3 WEIGHT OF FAIRING
A-3-1 ATTACHMENT TO BALANCE STRUTS - FAIRING - CONT'D

LOWER COVER PLATE. .064" R.A ST.
Thicknes: .064" width: 5.5" mean length: 11.6" x 2

Weight .10 x .064 x 5.5 x 23.2 = .81 lb

FRONT & REAR SHEETING. .058" STEEL
Thicknes: .058" developed width: 16.8" length: 19"

Weight 2 x .283 x .058 x 16.8 x 19 = 10.5 lb

SIDE SHEETING. .072" STEEL
Thicknes: .072" side area: \((4\times.072) = (14.4\text{ in}^2)\) = 169\text{ in}^2

Weight 2 x .283 x .072 x 169 = 6.9 lb

FAIRING TUBE BEARING.

MAT. STEEL.
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING.

A-3.3 ATTACHMENT TO BALANCE STRUTS - FAIRINGS - CONT'D.

FAIRING TUBE BEARING - CONT'D.

Plate: Thickness: 

Size: \((12 \times 13) = \frac{\pi}{4} (0.50)^2 = 0.79 \text{ ft}^2\)

Weight: \(0.283 \times 0.30 \times 0.79 = 0.625 \text{ lb}\)

Cylinder:

Weight: \(0.283 \times \frac{\pi}{4} (0.50^2 - 0.10^2) \times 1.50 = 6.02 \text{ lb}\)

Retainer ring:

Weight: \(0.283 \times \frac{\pi}{4} (0.50^2 - 0.10^2) \times 0.25 = 1.622 \text{ lb}\)

Retainer ring - external:

Weight: \(0.283 \times \frac{\pi}{4} (0.30^2 - 0.10^2) \times 0.157 = 1.33 \text{ lb}\)

Total weight: \(0.625 + 6.02 + 1.622 + 1.33 = 10.60 \text{ lb}\)

Add 10% for bolts, welds, etc.

\(10.60 \times 1.10 = 11.65 \text{ lb}\)

TOTAL WEIGHT OF FAIRING:

\(10.60 + 1.93 + 2.99 + 0.10 + 10.5 + 6.9 + 13.23 = 39.46 \text{ lb}\)

Add 10% for welds, bolts, etc.

\(39.46 \times 1.10 = 43.41 \text{ lb}\)
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-4
TUBES BETWEEN TUNNEL WALLS & BALANCE STRUT.

EXTERNAL TUBE: 14.81 lb
Weight: \( \frac{90}{12} \times 14.81 = 111.16 \) lb

INTERNAL TUBE: 13.32 lb
Weight: \( \frac{70}{12} \times 13.32 = 77.7\frac{1}{2} \) lb

TOTAL WEIGHT OF TUBES:
111.16 + 77.7 = 188.7 lb

Assume \( \frac{1}{2} \) the total weight is applied on the strut, fairing + 10 lb for miscellaneous parts:
94.35 + 10 = 104.35 lb, say 105 lb

Declassified