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STRESS ANALYSIS OF 1/12 SCALE HOVERING AND TRANSITION MODEL

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Written by:

G. Jacquemin
Avro Aircraft Limited

Approved by:

D. C. Ferguson
Sr. Stress Engineer
Special Projects Group
Avro Aircraft Limited

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INDEX OF REFERENCES.

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/SPG/TR 98 : TEST SPECIFICATIONS FOR THE $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

GENERAL REFERENCES.

- AN-C-5. - MARCH 1955-
- THEORY OF PLATES & SHELLS - S. TIMOSHENKO.
- RESISTANCE DES MATERIAUX APPLIQUÉE A L'AVIATION - P. VALLAT.
PUBLISHED BY : MENARD - EDITEURS - 8 RUE DES REGANS - TOULOUSE - FRANCE.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

1-0 SUMMARY

The strength and stiffness of the $\frac{1}{12}$ scale hovering and transition model, its supporting structure and fairings are analyzed.

The stressing of all parts except the ring load gages is carried out with an ultimate load factor of 4.

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.

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2-0 INTRODUCTION

As a part of the system 606 A test program, a $\frac{1}{12}$ scale model of the P.V. 704 aircraft has been designed for installation in the 20' diameter Maine Memorial Wind Tunnel at Wright-Patterson Airforce 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 $\frac{1}{12}$ scale Hovering and transition model. The development of loads, and the stressing of the model, model support structure and fairings are contained in this report.

The model is circular in plan form: 35.3" DIA, 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 the the balance is not affected by the supply pressures, these pipes come into the tunnel in a horizontal plane to supply the vertical pipes supporting the model.

The wind tunnel balance is a three components balance measuring lift, pitching moment and drag. However, due to the distances involved compared with the size of the model and the relatively light aerodynamic and heavy tare 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

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

2-0 INTRODUCTION - CONT'D.

is provided near the model.

This second balance employs ring type load gages to measure drag forces and pitching and rolling moment. 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.

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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 struts. 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 fairings.

Additionnal streamlining 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 dish-shaped steel turnings joined together to form a hollow circular wing; and three 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 sizes of the final openings

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3-0 DESCRIPTION OF INSTALLATION

3-2 MODEL - CONT'D.

The peripheral outlets are 336 holes : .242" dia. distributed along a circle of rad. 16.825". They are covered with segment plates having holes of dia. ranging in steps from .242" to .120" dia. Plates are also provided to close the holes completely.

The propulsive outlets are 48 holes : 1.40" dia distributed along a circle of rad. 15.80". 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 arrangement of propulsion and control being provided by changing the plates.

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 .228". 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 ramp and is attached to the outer 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

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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 turning is attached to the center supply tube by a suspension rod and to center turning by six soldered tubes. These tubes also direct some of the high pressure air through a central nozzle in the lower turning to simulate the aircraft Viper 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.

Hovering 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 4 ring 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

3-0 DESCRIPTION OF INSTALLATION -

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 suction.

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 arm 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 belows 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-bearings 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 parts of this 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 struts fairings. 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 struts 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 independant of

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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 tubes and the fairings when changing the angle of attack of the model.

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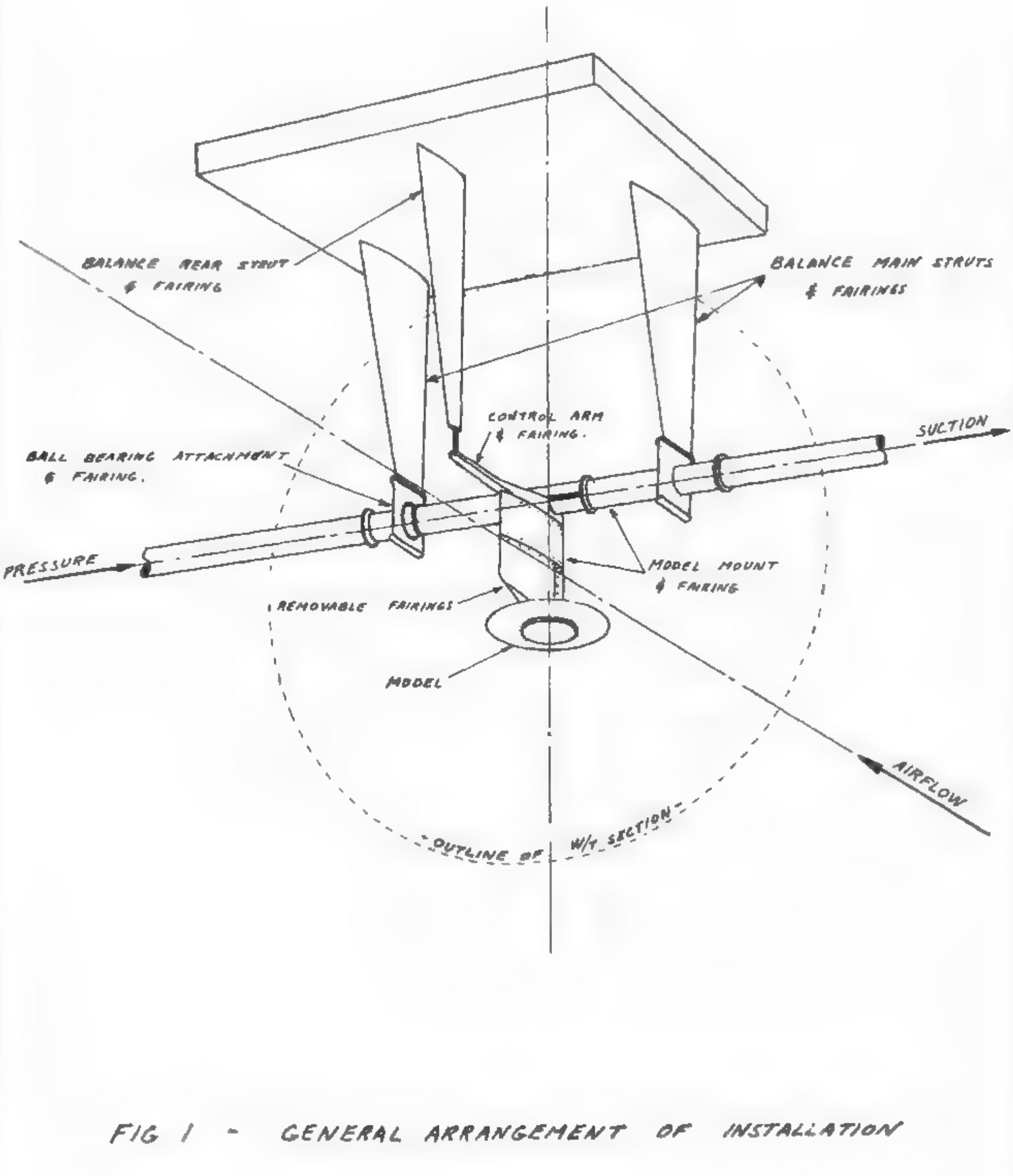

FIG 1 - GENERAL ARRANGEMENT OF INSTALLATION

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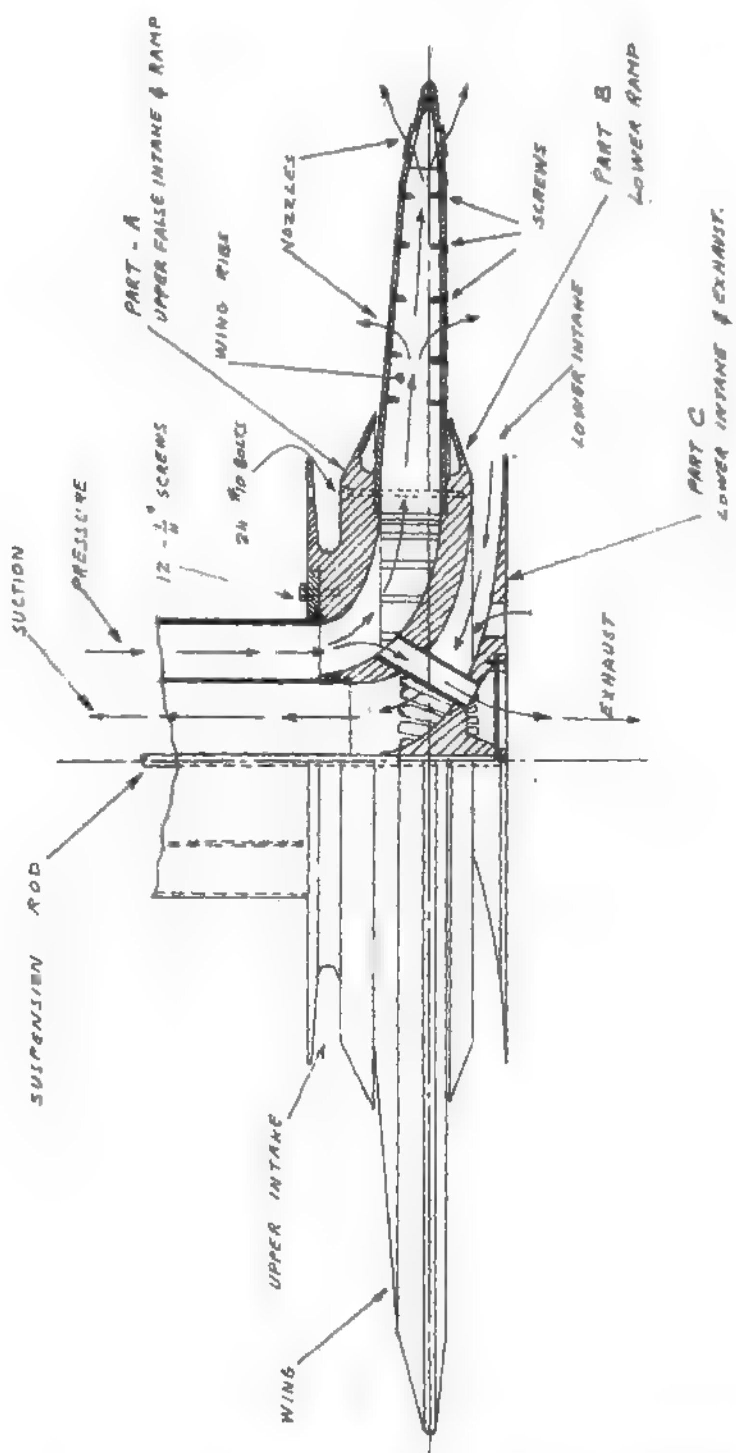

FIG - 2 - 1/12 SCALE HOVERING AND TRANSITION MODEL

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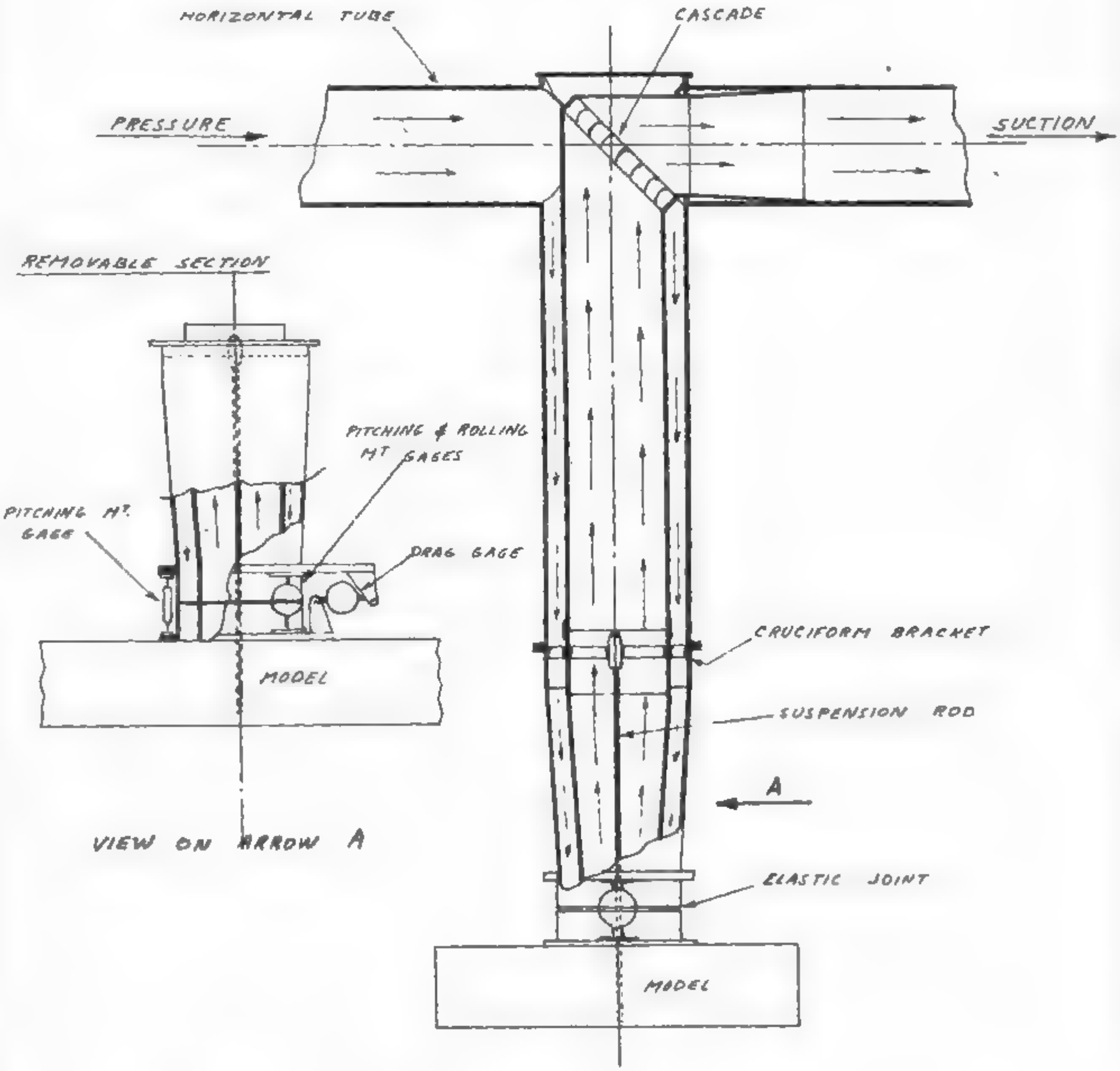

FIG-3 - DETAILS OF MODEL SUPPORT - A

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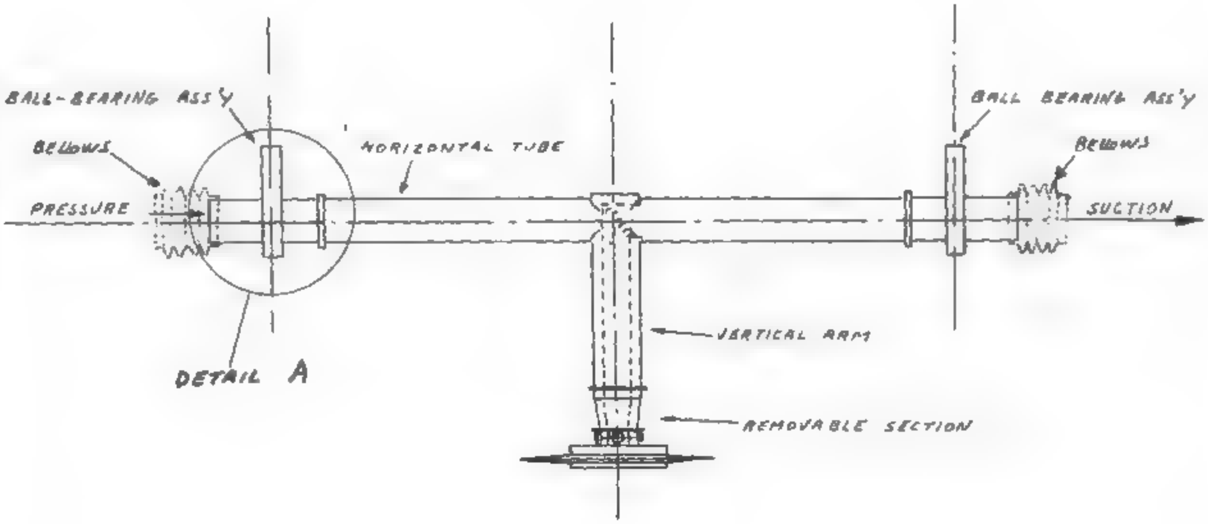

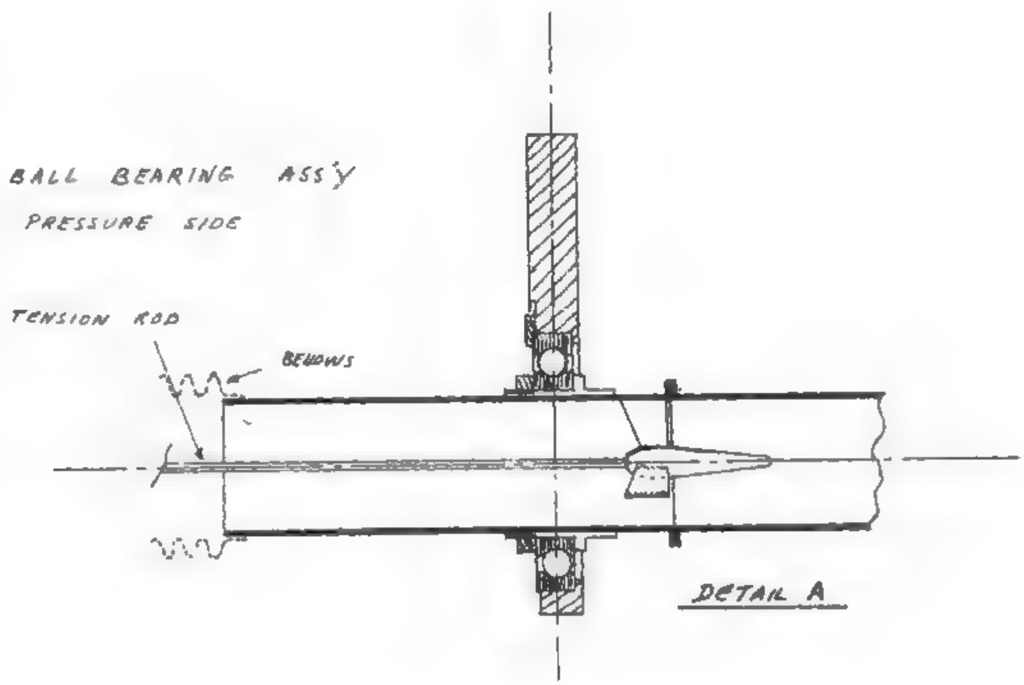

FIG. 4 - DETAILS OF MODEL SUPPORT - B

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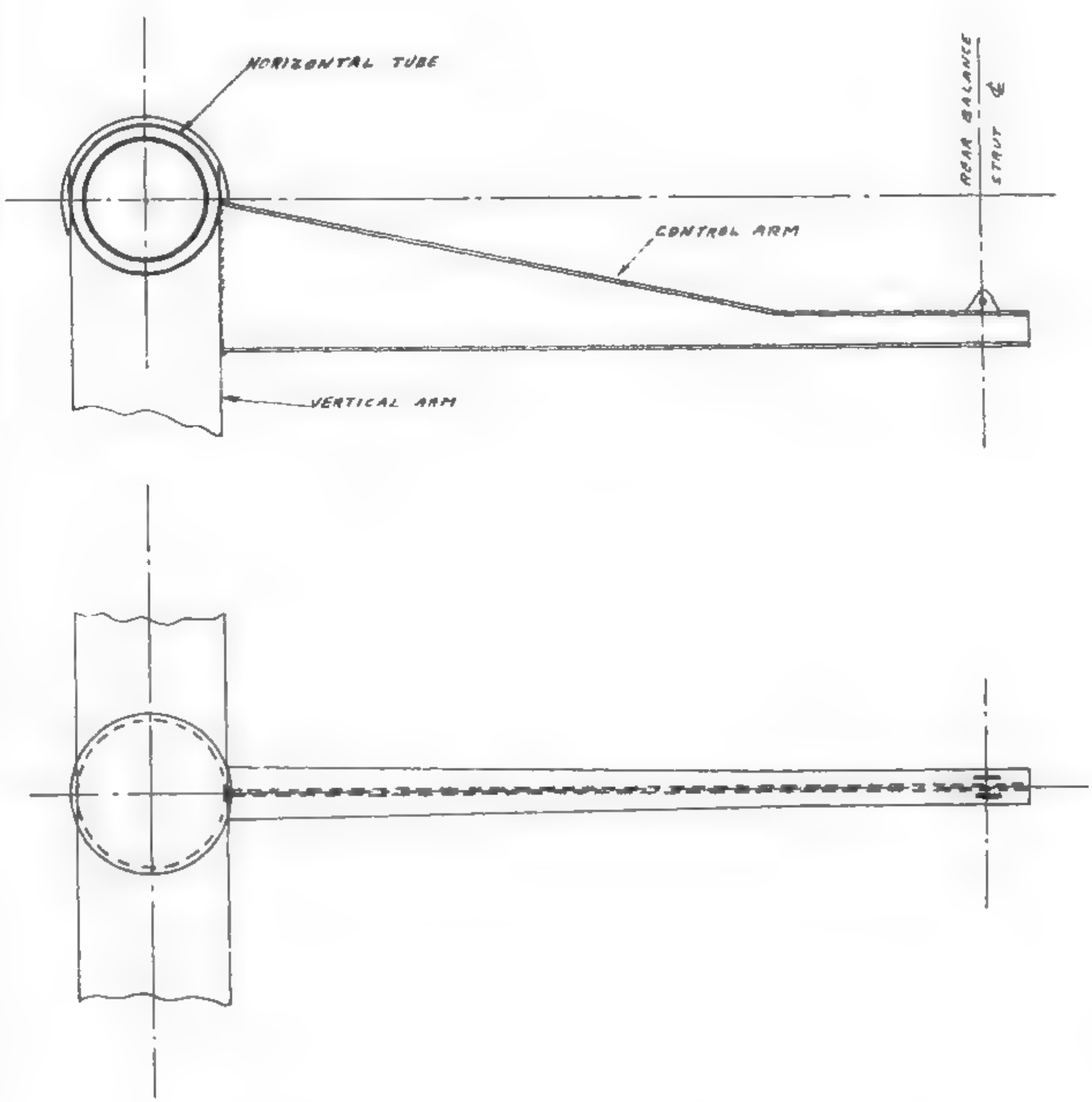

FIG. 5 - CONTROL ARM

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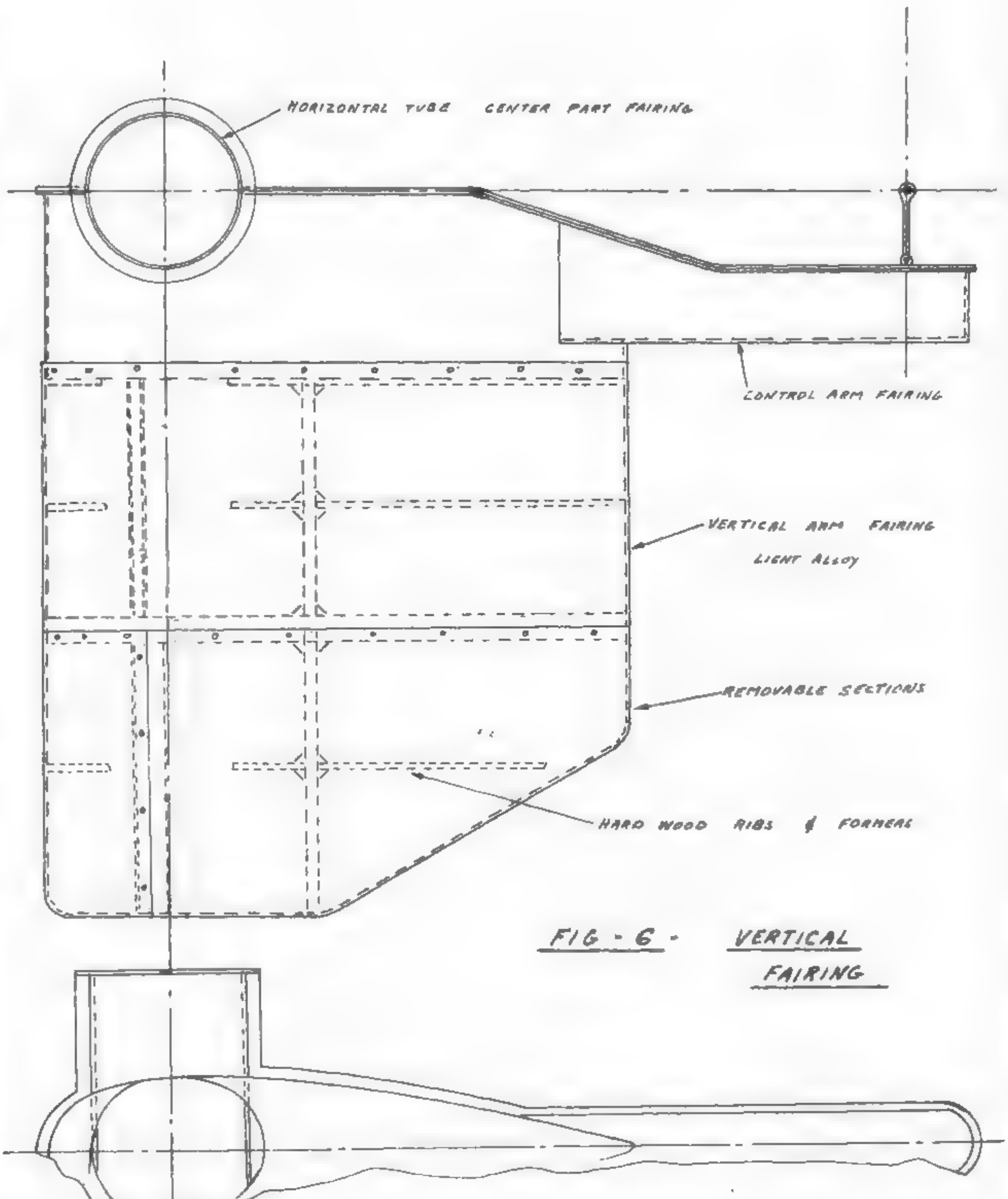

FIG - 6 - VERTICAL FAIRING

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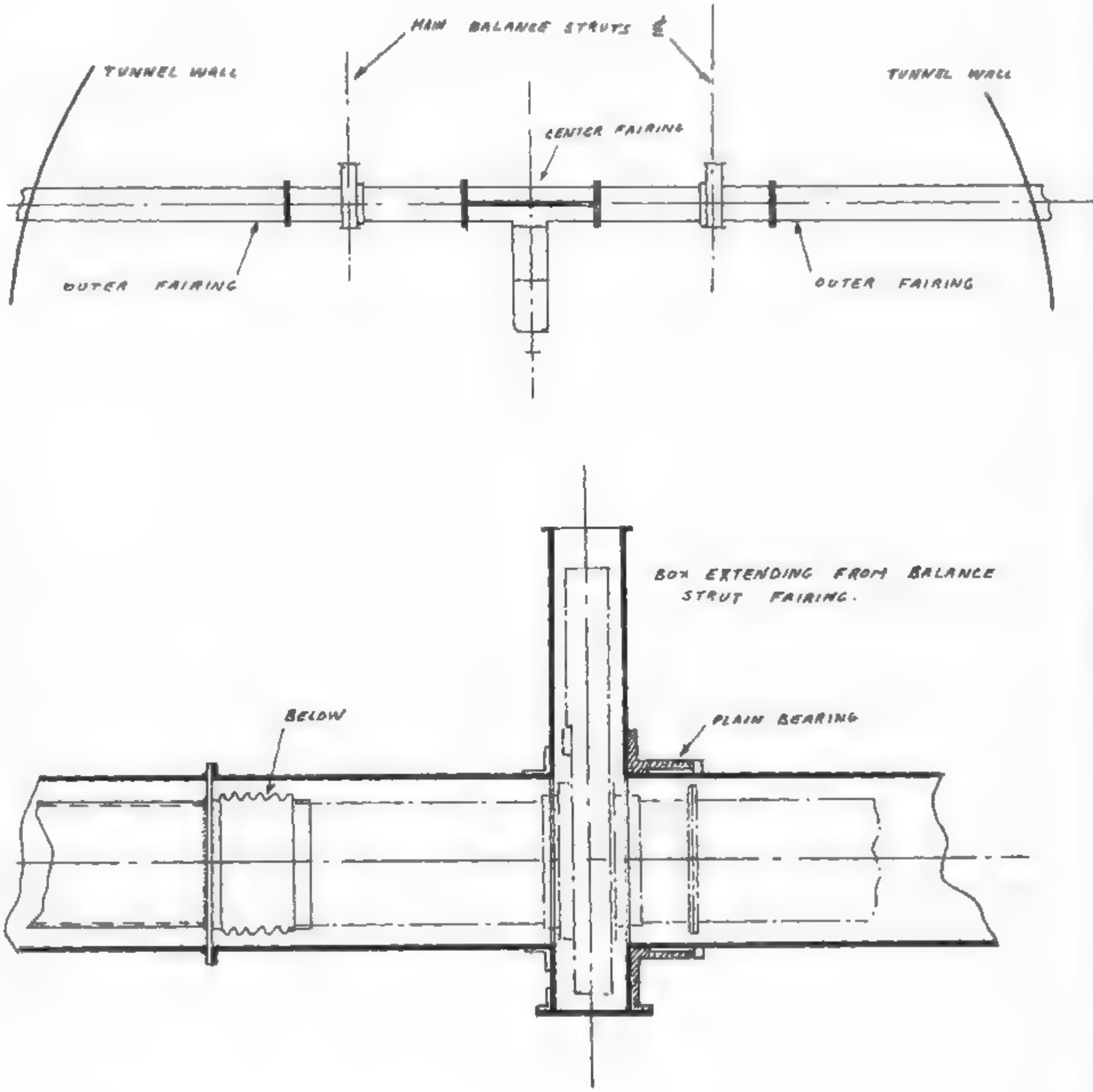

FIG - 7 - HORIZONTAL FAIRING.

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- STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

4-0 LOAD ANALYSIS

4-1 LOADING CONSIDERATIONS -

4.1.1 General

The model forces are taken by the ring load measuring gages and transfered through the model support to the 3 balance struts.

The fairing loads, both static and aerodynamic are taken by the 3 balance strut fairings.

4.1.2 Loads on the model

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

Jet reaction. In the hovering cases, the jet reaction is entirely directed downward. In the flying cases, 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 relieved 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 suctions 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 delivery 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 α varying between $-10°$ & $45°$ with a preferential range from $-10°$ to $20°$. The tunnel is to

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

4-0 LOAD ANALYSIS.

4-1 LOADING CONSIDERATIONS - CONT'D.

be operated at $q = 30$ PSF 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 thus allowing the use of smaller ring load measuring gages at the model attachment.

Since accurate values of C_L, C_D & C_m are not available, these parameters have been taken on the high side in order to ensure that the stressing of the model will amply 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 airdrag. 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 on the ring load measuring gages which are stressed for their operating conditions as per report AVRO/SPG/TR 87.

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4-0 LOAD ANALYSIS.

4-2 MODEL LOADS

4-2-1 LOADING CASES

HOVERING CASES

α	T	q PSF	LIFT $E_L = \frac{L}{T}$	MOMENT $E_M = \frac{M}{Tb}$	SIDE LOAD $E_S = \frac{S}{T}$
0°	FULL	0	2.0	0	0
20°	FULL	0	2.0	.15	.30

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

TRANSITION CASES

α	T	P	q PSF	C_L	C_D	$C_{m\,c/2}$
-10°	0	FULL	30	-.30	.08	-.60
0°	0	0	30	.05	.05	-.20
0°	FULL	FULL	0			
20°	0	FULL	30	2.1	.60	.18
35°	0	FULL	30	2.8	1.20	.32
45°	0	FULL	18	3.0	1.70	* .98

* As determined from assumed distribution

Values of C_L, C_D & $C_{m\frac{c}{2}}$ are based on estimates from previous testing

SYMBOLS

T : THRUST. P : SUPPLY PRESSURE

q : TUNNEL DYNAMIC PRESSURE

E_L, E_M, E_S : THRUST EFFICIENCIES IN HOVERING CASES

C_L, C_D, $C_{M\frac{c}{2}}$: AERODYNAMIC COEF.

NOTE. TRANSITION CASES WERE SELECTED FOR MOST ADVERSE LOADS ON THE GAGES RATHER THAN ACTUAL TEST CASES.

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4-0 LOAD ANALYSIS

4-2-1 LOADING CASES

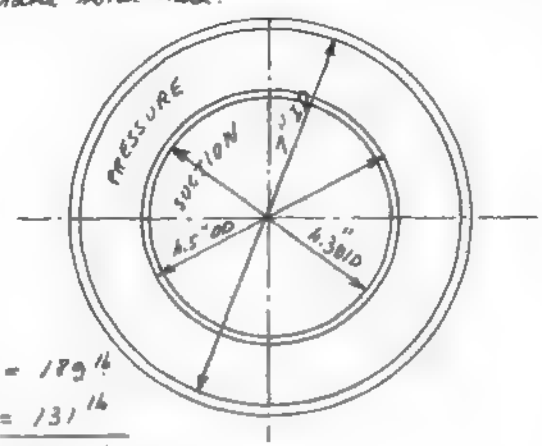
LOADS DUE TO INTERNAL PRESSURE:

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

*. based on: - simulated hot thrust with cold nozzle area
- pressure loss in jet flow circuit = 5x dynamic head based on ave. 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: $\frac{\pi}{4} 4.3^2 = 14.5 \text{ in}^2$

PRESSURE AREA: $\frac{\pi}{4}(7^2 - 4.5^2) = 22.6 \text{ in}^2$



LOADS DUE TO PRESSURE.

Force due to static pressure: $(22.96 - 14.7)\,22.5 = 189^{lb}$
Force due to momentum flow: $= 131^{lb}$
net force 320^{lb}

LOADS DUE TO SUCTION

Force due to static pressure $= (4.98 - 14.7)\,14.5 = -138^{lb}$
Force due to momentum flow: $= 104^{lb}$
net force: -34^{lb}

net load on model: $320 - 34 = 286^{lb}$

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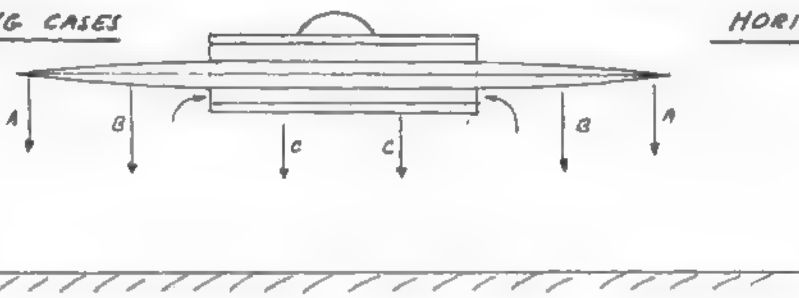
4.0. LOAD ANALYSIS

4.2.2. HOVERING CASES

HORIZONTAL



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

Lift provided by C : 11 lb

Ground efficiency $\frac{L}{T}$ = 2.0

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

– 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 undersurface.

Wing area: $35.33^2 \frac{\pi}{4} = 978 \text{ in}^2$

Pressure: $\frac{161}{978} = .165$ PSI

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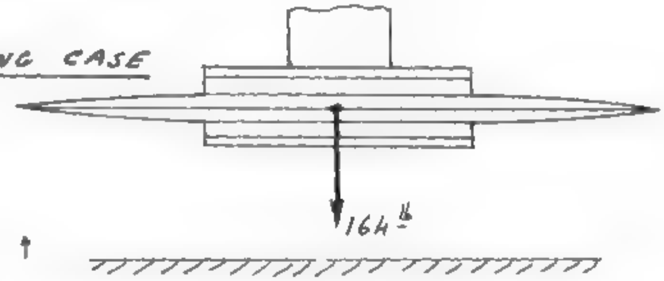
4·0 LOAD ANALYSIS

4·2·2 HOVERING CASE

HORIZONTAL
NET LOADS



LIFT : 322 lb ↑
WEIGHT : 200 lb ↓
PRESS : 286 lb ↓

NET LOAD : $200 + 286 - 322 = 164$ lb ↓

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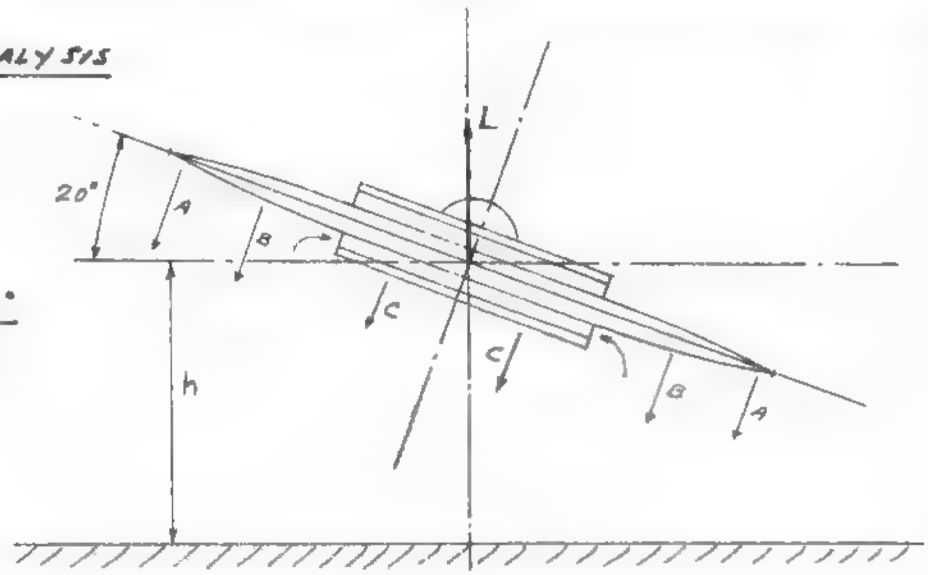
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-2 - HOVERING CASE

HOVERING AT 20°

AIR LOADS



Efficiencies

LIFT IN GROUND.	$E_L = \frac{L}{T} = 2.0$	$\therefore L = 2T$	Ref: AVRO/SPG/TR 29
MOMENT	$E_M = \frac{M}{Tb} = .15$	$\therefore M = .15\,Tb$	AVRO/SPG/TR 33
SIDE LOAD	$E_S = \frac{S}{T} = .30$	$\therefore S = .30\,T$	

Lift provided by A or B or A+B . 150 lb
Lift provided by C . 11 lb } 161 lb

Total lift on the model. 2 × 161 = 322 lb normal to the floor.
In the absence of more accurate data lift distribution will be taken as for hovering case at $\alpha = 0°$.

Moment : .15 × 161 × 35.3 = 853 in-lb

Side load : .30 × 161 = 48.3 lb in any direction in the plane of the floor.

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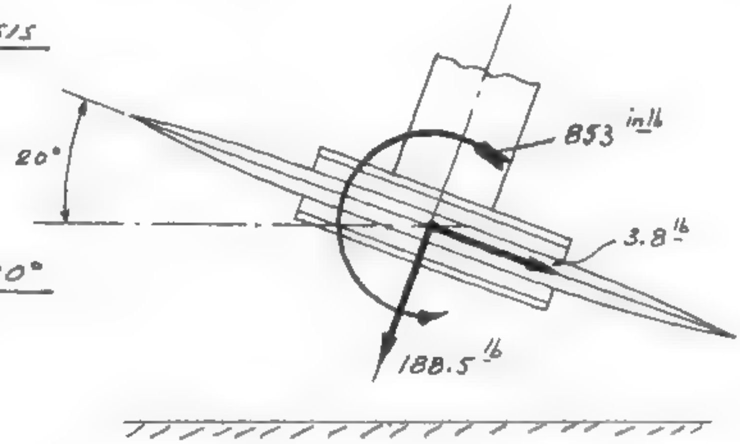
4-0 LOAD ANALYSIS

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 : 200 lb normal to the floor ↓

PRESSURE : 286 lb normal to the model ↓

Total force normal to the model.

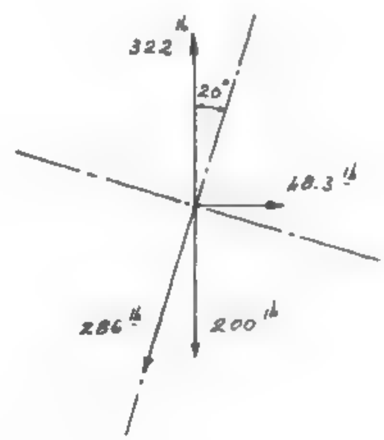
$286 + 200 \cos 20° - 322 \cos 20° + 48.3 \sin 20° =$

$286 + 188 - 302 + 16.5 = 188.5$ lb ↓

Total force parallel to the model:

$200 \sin 20° - 322 \sin 20° + 48.3 \cos 20° =$

$68.4 - 110 + 45.4 = 3.8$ lb ↘



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4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE

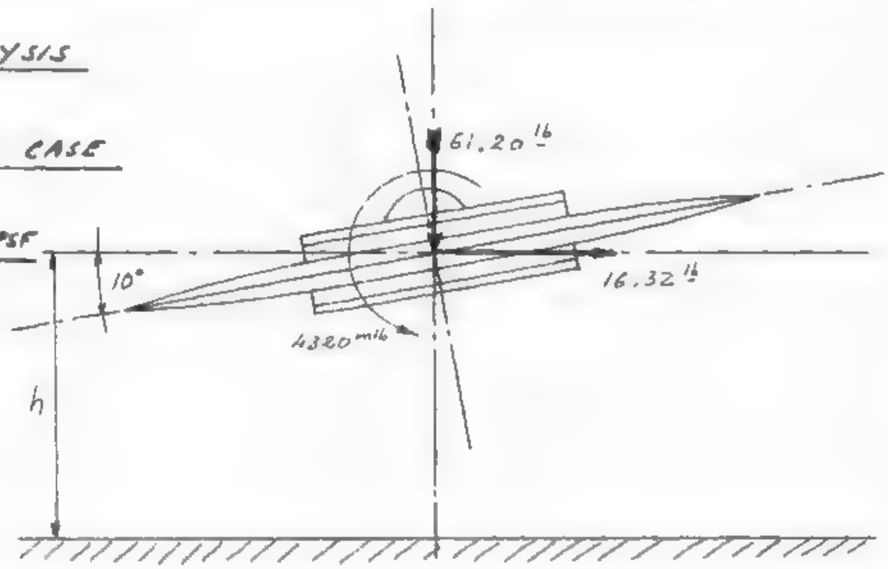
-10° CASE - q = 30 PSF

AIR LOADS

C_L : -.30

C_D .08

C_M -.60



Tunnel q 30 PSF

Wing area 6.8 ft²

Wing chord · 2.94 ft

LIFT: $-.30 \times 6.8 \times 30 = -61.20$ lb

DRAG: $.08 \times 6.8 \times 30 = 16.32$ lb

MOMENT: $-.60 \times 2.94 \times 6.8 \times 30 = -360$ ft lb $= -4320$ in lb

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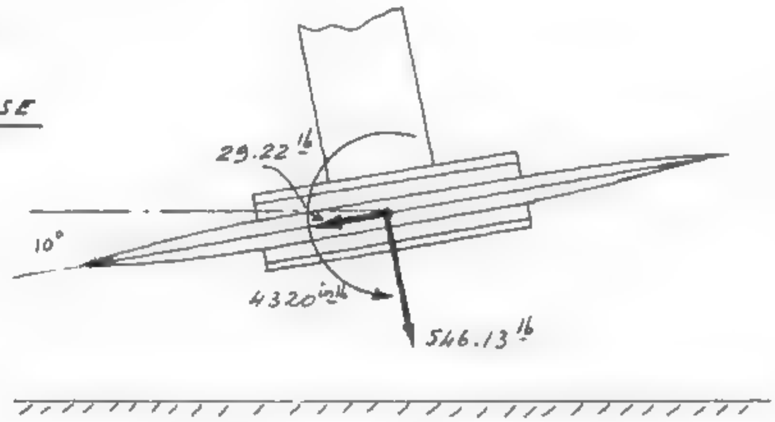
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE

10° CASE – q = 30 PSF

NET LOADS



LIFT: – 61.20 lb ↓

DRAG: 16.32 lb →

MOMENT: 4320 in-lb ↺

WEIGHT 200 lb ↓

PRESSURE: 286 lb ↘

TOTAL FORCE NORMAL TO THE MODEL:

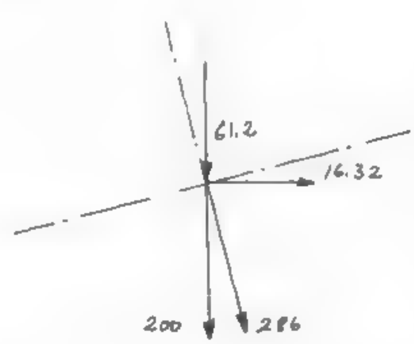
$$286 + 200 \cos 10^\circ + 61.8 \cos 10^\circ + 16.32 \sin 10^\circ =$$

$$286 + 197 + 60.30 + 2.83 = 546.13 \text{ lb}$$

TOTAL FORCE PARALLEL TO THE MODEL:

$$-200 \sin 10^\circ - 61.20 \sin 10^\circ + 16.32 \cos 10^\circ =$$

$$-34.7 - 10.6 + 16.08 = -29.22 \text{ lb}$$



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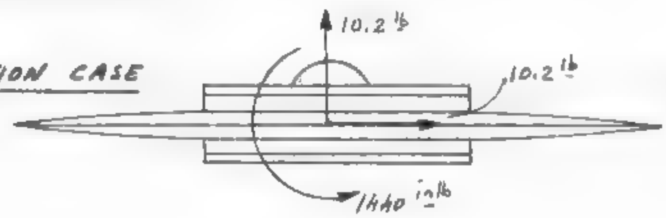
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE



ZERO THRUST : $\alpha = 0$
AIR LOADS

$C_L = .05$
$C_D = .05$
$C_{M_{\bar{c}/4}} = -.20$

Tunnel q = 30 PSF
Wing area 6.8 ft²

LIFT : $.05 \times 6.8 \times 30 = 10.2$ lb

DRAG : $.05 \times 6.8 \times 30 = 10.2$ lb

MOMENT : $2.94 \times -.20 \times 6.8 \times 30 = -120$ ft lb $= -1440$ in lb

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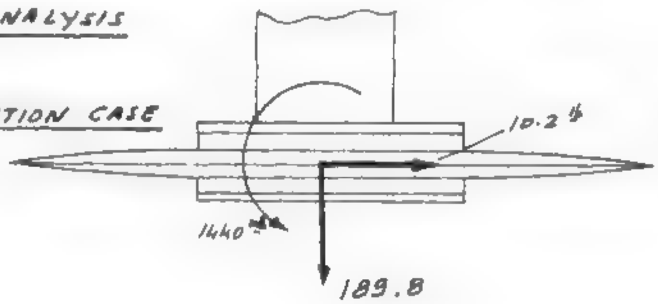
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 - LOAD ANALYSIS

4.2.3 TRANSITION CASE



ZERO THRUST : α = 0

NET LOADS

LIFT : 10.2 lb ↑

DRAG : 10.2 lb →

MOMENT: 1440 in lb ↺

WEIGHT : 200 lb ↓

TOTAL FORCE NORMAL TO MODEL:

+ 200 − 10.2 = 189.8 lb

TOTAL FORCE PARALLEL TO MODEL:

10.2 lb

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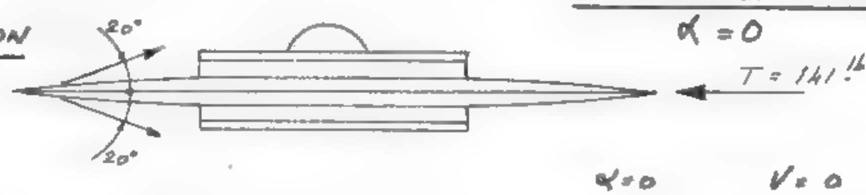
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

MAX. THRUST CASE.

$\alpha = 0$

4-2-3 TRANSITION CASE



Thrust: 150 cos 20° = 141 lb

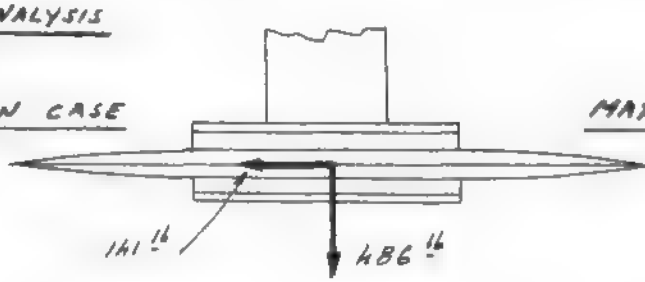
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

4·0 LOAD ANALYSIS

4·2·3 TRANSITION CASE

MAX THRUST CASE α = 0

NET LOADS



THRUST : 141 lb ←

WEIGHT : 200 lb ↓

PRESSURE : 286 lb ↓

TOTAL FORCE NORMAL TO MODEL

200 + 286 = 486 lb ↓

TOTAL FORCE PARALLEL TO MODEL

141 lb ←

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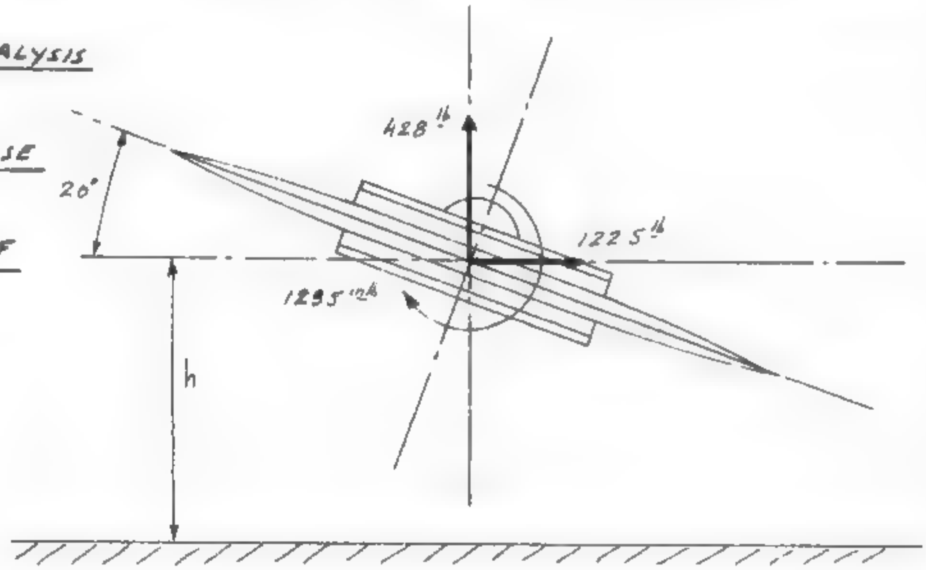
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4.0 - LOAD ANALYSIS

4.2.3 TRANSITION CASE

20° CASE - q = 30 PSF
AIRLOADS



C_L : 2.1
C_D : .60
$C_{M_{c/3}}$: .18

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

LIFT 2.1 × 6.8 × 30 = 428 lb

DRAG : .60 × 6.8 × 30 = 122.5 lb

MOMENT : .18 × 6.8 × 30 × 2.94 = 108 ft lb = 1295 in lb

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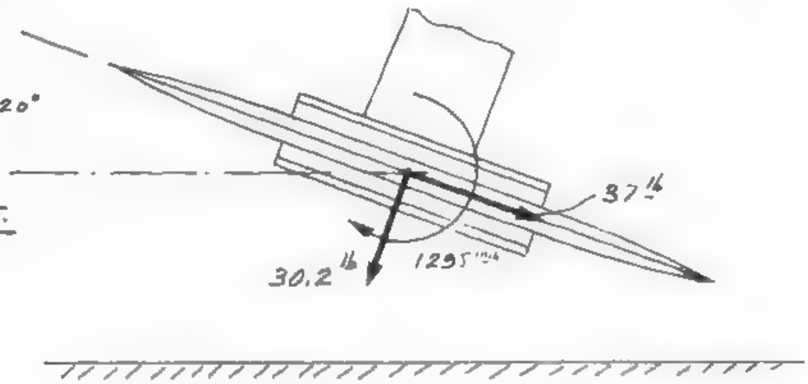
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4.0 LOAD ANALYSIS

4.2.3 TRANSITION CASE

20° CASE – q = 30 PSF.

NET LOADS



LIFT : 428 lb ↑

DRAG : 122.5 lb →

MOMENT : 1295 in-lb

WEIGHT : 200 lb ↓

PRESSURE : 286 lb ↙

TOTAL FORCE NORMAL TO THE MODEL:

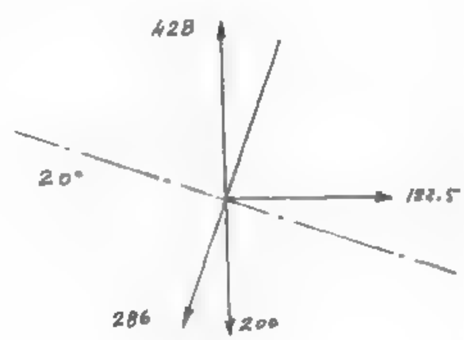
$$286 + 200 \cos 20° - 428 \cos 20° - 122.5 \sin 20° =$$

$$286 + 188 - 402 - 41.8 = 30.2^{lb} \downarrow$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200 \sin 20° - 428 \sin 20° + 122.5 \cos 20° =$$

$$68.4 - 146.4 + 115 = 37^{lb} \rightarrow$$



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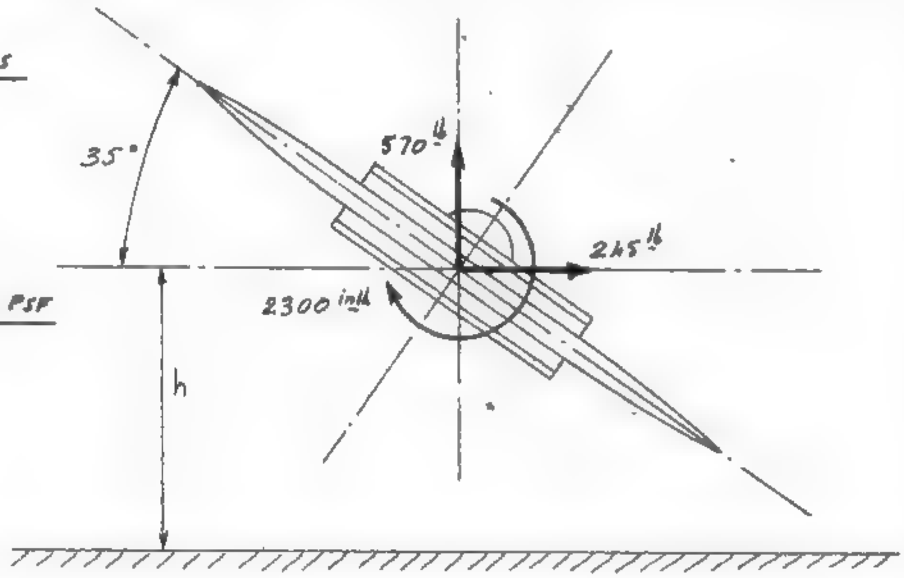
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL



4-0- LOAD ANALYSIS

4-2-3 - TRANSITION CASE

35° CASE - q = 30 PSF

AIRLOADS

C_L : 2.8

C_D : 1.20

$C_{M_{\bar{c}/2}}$: .32

Tunnel q : 30 PSF

Wing area : 6.8 ft² Wing chord: 2.94 ft

LIFT: 2.8 x 6.8 x 30 = 570 lb

DRAG: 1.20 x 6.8 x 30 = 245 lb

MOMENT: .32 x 6.8 x 30 x 2.94 = 192 ftlb = 2300 inlb

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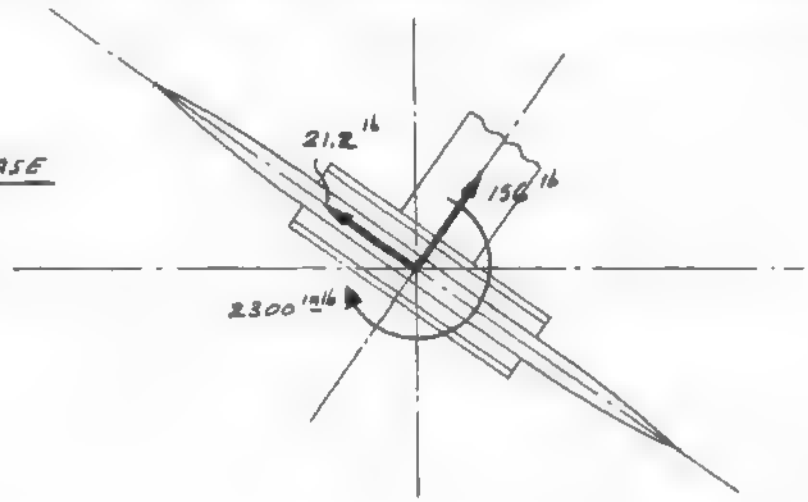
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL -

4.0 LOAD ANALYSIS

4.2.3 TRANSITION CASE

35° CASE - q = 30 PSF.

NET LOADS



LIFT : 570 lb ↑

DRAG : 245 lb →

MOMENT: 2300 in-lb

WEIGHT : 200 lb ↓

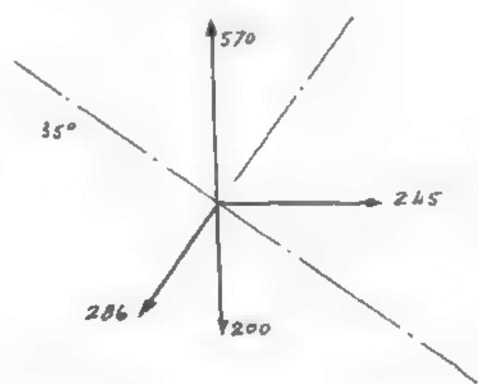
PRESSURE: 286 lb ↙

TOTAL FORCE NORMAL TO THE MODEL:

$$286 + 200\cos 35° - 570\cos 35° - 245\sin 35° =$$
$$286 + 164 - 466 - 140 = -156 \text{ lb} \uparrow$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200\sin 35° - 570\sin 35° + 245\cos 35° =$$
$$104.8 - 327 + 201 = -21.2 \text{ lb} \leftarrow$$



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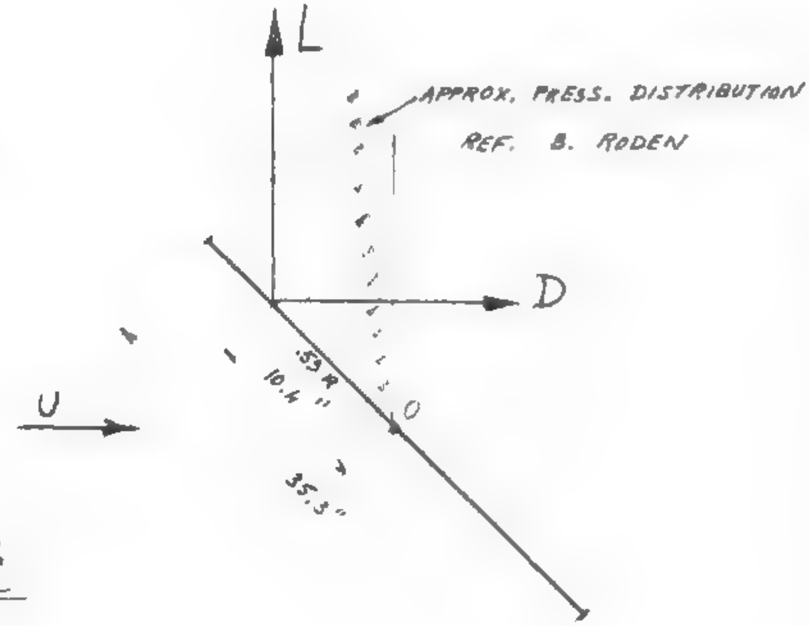
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE



45° CASE - q = 30 PSF

AIRLOADS

$C_L = 3.0$

$C_D = 1.7$

Wing area: 6.8 ft²

TUNNEL AT 30 q

LIFT.

$3.0 \times 6.8 \times 30 = \underline{612^{lb}}$

DRAG.

$1.7 \times 6.8 \times 30 = \underline{347^{lb}}$

Assuming press. distribution as shown
Center of Pressure

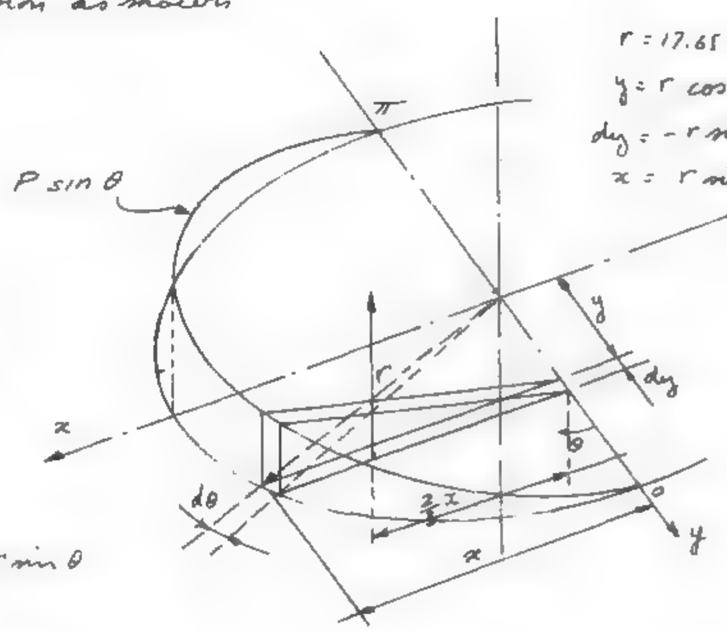
$\bar{X} = \frac{M}{V}$

$r = 17.65''$

$y = r\cos\theta$

$dy = -r\sin\theta\, d\theta$

$x = r\sin\theta$



Volume element:

$dV = \frac{1}{2} x\, dy\, P\sin\theta$

$dV = -\frac{P}{2} r^2 \sin^3\theta\, d\theta$

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

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

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

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

$$M = \int_{\pi}^{0} -\frac{P}{3}\, r^3 \sin^4\theta \, d\theta$$

$$\therefore \quad X = \frac{-\int_{\pi}^{0} \frac{P}{3}\, r^3 \sin^4\theta \, d\theta}{-\int_{\pi}^{0} \frac{P}{2}\, r^2 \sin^3\theta \, d\theta} = \frac{2}{3}\, r \, \frac{\int_{\pi}^{0} \sin^4\theta \, d\theta}{\int_{\pi}^{0} \sin^3\theta \, d\theta} = \frac{3}{16}\pi r = .59\, r.$$

$V = \frac{2}{3} P r^2$ where V is component normal to the disc

$\therefore \quad X = .59 \ \frac{35.3}{2} = 10.4''$

Moment of lift & drag about center of model

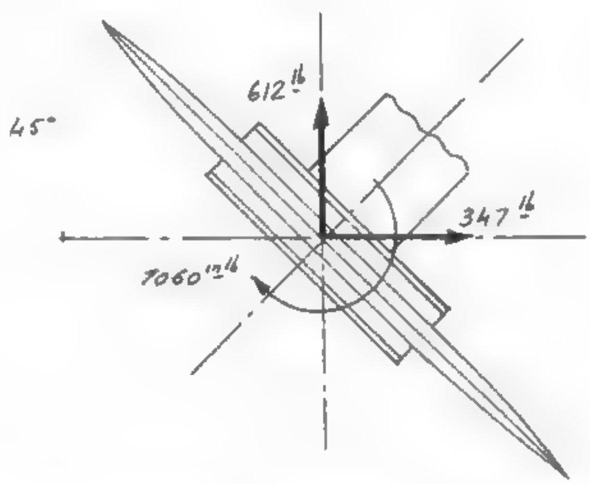
$(612 + 347)\ \frac{10.4}{\sqrt{2}} = \underline{\underline{7060 \text{ in lb}}}$

Component normal to surface of disc:

$V = (612 + 347)\ \frac{1}{\sqrt{2}} = 678\ \text{lb}$ (959) $\quad \therefore \ P = \frac{3}{2}\ 678 \times \left(\frac{1}{\frac{35.3}{2}}\right)^2 = 3.26\ \frac{\text{lb}}{\text{in}^2}$

Component in the plane of the disc

$(612 - 347)\ \frac{1}{\sqrt{2}} = 187.5\ \text{lb}$ (265)



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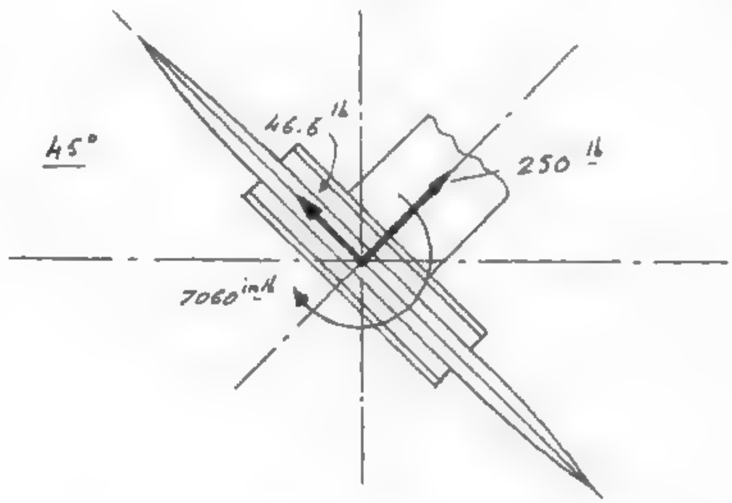
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-3 TRANSITION CASE

45° CASE - q = 30 PSF.

NET LOADS



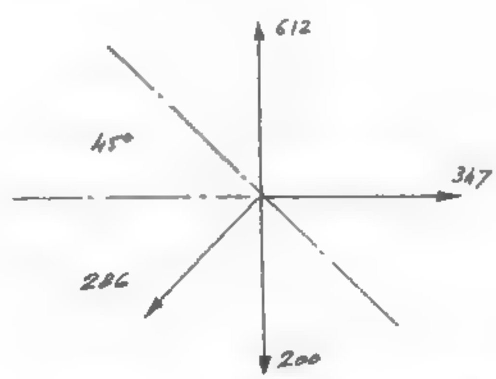
LIFT: 612 lb ↑
DRAG: 347 lb →
MOMENT: 7060 in lb
WEIGHT: 200 lb ↓
PRESSURE: 286 lb ↓

TOTAL FORCE NORMAL TO THE MODEL:

$$286 - 612 \cos 45° + 200 \cos 45° - 347 \sin 45° =$$
$$286 - 433 + 141.4 - 245 = -250\ lb$$

TOTAL FORCE PARALLEL TO THE MODEL

$$200 \sin 45° - 612 \sin 45° + 347 \cos 45° =$$
$$141.4 - 433 + 245 = -46.6\ lb$$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

4.0 LOAD ANALYSIS

4.2.3 TRANSITION CASE

45° CASE - q = 30 PSF.

Determination of $C_{M\frac{c}{2}}$ at $\alpha = 45°$

The moment about the center of the model is : 7060 in-lb
This moment is due to aerodynamic forces alone. Hence the value of $C_{M\frac{c}{2}}$ is.

$$C_{M\frac{c}{2}} = \frac{M}{\bar{c} S q} = \frac{\frac{7060}{12}}{\frac{35.3}{12} \times 6.8 \times 30} = \frac{7060}{7200} = +.98$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

4-0 LOAD ANALYSIS

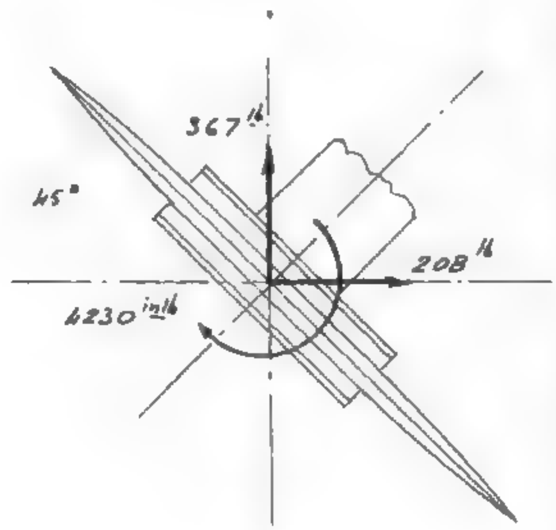
4-2-3 TRANSITION CASE-

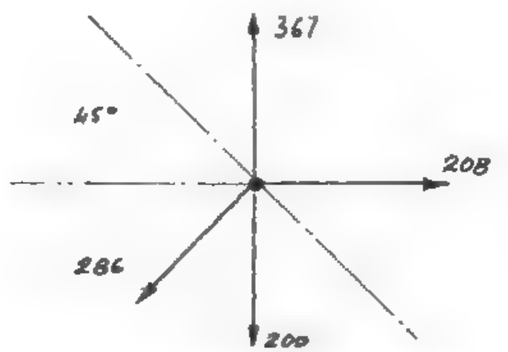
CASE 45°- TUNNEL OPERATING AT 18 q.

Lift. $612 \times \frac{18}{30} = 367^{lb}$

Drag: $347 \times \frac{18}{30} = 208^{lb}$

Moment: $7060 \ \frac{18}{30} = 4230^{in\,lb}$





FORCE NORMAL TO THE MODEL

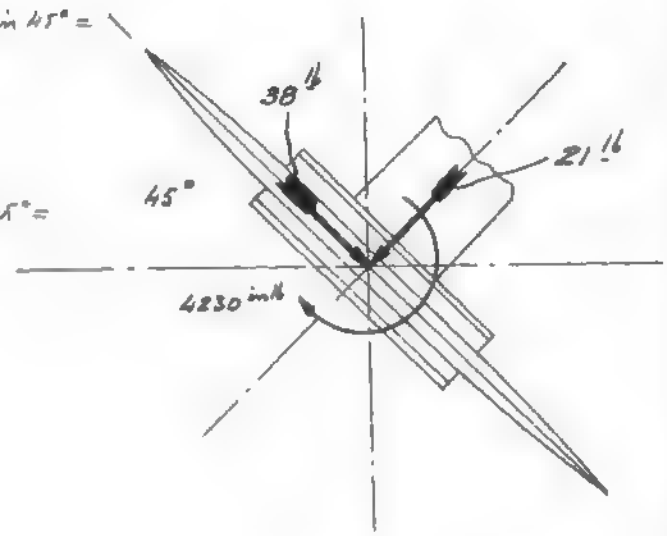
$286 + 200 \cos 45° - 367 \cos 45° - 208 \sin 45° =$

$286 + 141 - 259 - 147 = +21^{lb}$

FORCE PARALLEL TO THE MODEL

$200 \sin 45° + 208 \sin 45° - 367 \sin 45° =$

$141 + 147 - 259 = 38^{lb}$



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-0 LOAD ANALYSIS

4-2-4 SUMMARY OF CRITICAL LOADING CASES -

The critical case is the transition case for $\alpha = -10°$ which give 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 $\alpha = 35°$.

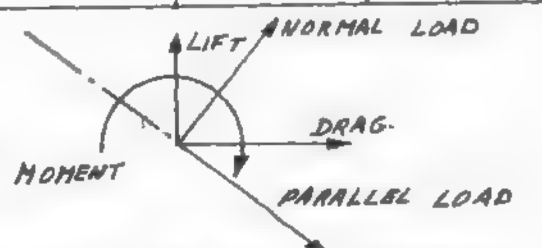
The hovering cases are not critical so; only the transition cases will be used to check the model support structure.

SUMMARY OF LOADING ON THE MODEL

LOADING CASES	AIR LOADS: LIFT lb	AIR LOADS: DRAG lb	MOMENT in lb	NET LOADS: NORMAL LOAD lb	NET LOADS: PARALLEL LOAD lb
HOVERING - $\alpha = 0°$	322 ↑			164 ↓	
HOVERING - $\alpha = 20°$	322 ↑	48.3 →	853 ↺	188.5 ↓	3.8 →
TRANSITION $\alpha = -10°$	61.2 ↓	16.32 →	4320 ↺	546.13 ↓	29.22 ←
" ZERO THRUST	10.2 ↑	10.2 →	1440 ↺	189.8 ↓	10.2 →
" MAX. THRUST				486 ↓	141 ←
" $\alpha = +20°$	428 ↑	122.5 →	1295 ↻	30.2 ↓	37 →
" " $+35°$	570 ↑	245 →	2300 ↻	156 ↑	21.2 ←
" " $+45°$ *	367 ↑	208 →	4230 ↻	21 ↓	38 →

* $q = 18$ PSF.

+VE SIGNS



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STRESS ANALYSIS OF ½ SCALE HOVERING & TRANSITION MODEL -

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.

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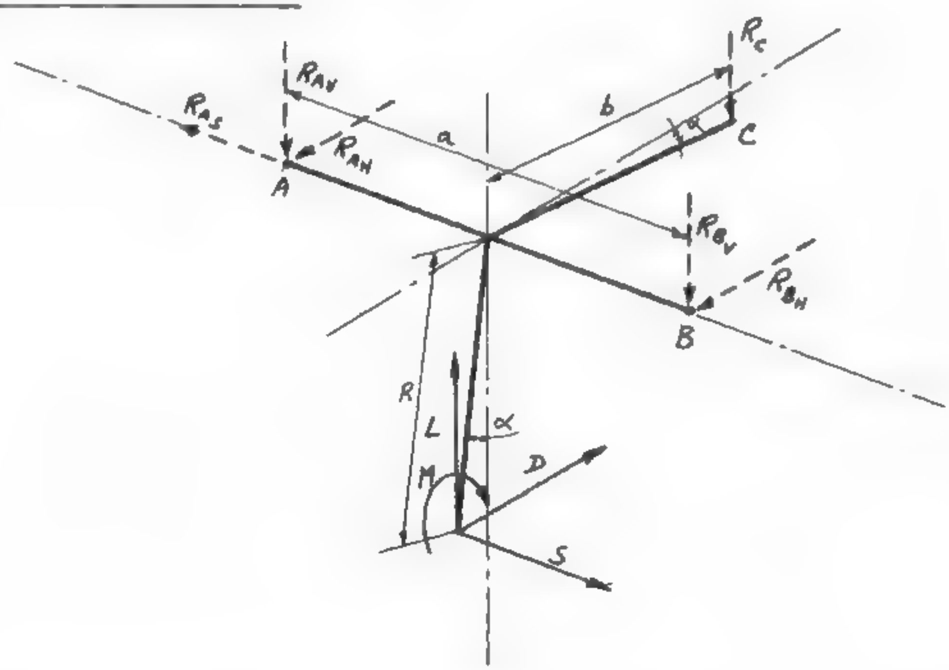
STRESS ANALYSIS OF $\frac{1}{13}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-2 MODEL LOADS & REACTIONS

EQUATIONS OF EQUILIBRIUM.



$$R_{A_V} = \frac{L}{2} + \frac{M}{2b} - \frac{SR}{a}\cos\alpha + \left[\frac{LR\sin\alpha - DR\cos\alpha}{2b\cos\alpha}\right] = \frac{L}{2} + R\left[\frac{L}{2b}\tan\alpha - \frac{D}{2b} - \frac{S}{a}\cos\alpha\right] + \frac{M}{2b}$$

$$R_{B_V} = \frac{L}{2} + R\left[\frac{L}{2b}\tan\alpha - \frac{D}{2b} + \frac{S}{a}\cos\alpha\right] + \frac{M}{2b}$$

$$R_C = -\frac{R}{b}\left[L\tan\alpha - D\right] - \frac{M}{b}$$

$$R_{A_H} = \frac{D}{2} - \frac{SR}{a}\sin\alpha$$

$$R_{B_H} = \frac{D}{2} + \frac{SR}{a}\sin\alpha.$$

$$R_{A_S} = S$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-2 MODEL LOADS & REACTIONS

EQUATIONS OF EQUILIBRIUM - CONT'D.

We have. $a = 80''$ $b = 48''$ $R = 50''$

furthermore $S = 50^{lb}$ assumed for all cases.
and $\alpha = -10°, 0°, 20°$ & $45°$

Then, Substituting

$$R_{AV} = \frac{L}{2} + \frac{M}{96} + .522\, L \tan\alpha - .522\, D - 31.25 \cos\alpha$$

$$R_{BV} = \frac{L}{2} + \frac{M}{96} + .522\, L \tan\alpha - .522\, D + 31.25 \cos\alpha$$

$$R_C = -1.042\left[L \tan\alpha - D\right] - \frac{M}{48}$$

$$R_{AH} = \frac{D}{2} - 31.25 \sin\alpha$$

$$R_{BH} = \frac{D}{2} + 31.25 \sin\alpha$$

$$R_{AS} = 50^{lb}$$

LOADING CONDITIONS

α	$-10°$	0	0 MAX. THRUST	20°	45° q = 18 PSF.
L	-61.20	10.2	0	428	367
D	16.32	10.2	-141	122.5	208
M	-4320	-1440	0	1295	4230
$\sin\alpha$	-.1737	0	0	.342	.707
$\cos\alpha$	.985	1.0	1.0	.940	.707
$\tan\alpha$	-.176	0	0	.364	1.0

Ref. SECTION 4-2-4

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS.

4-3-2 MODEL LOADS & REACTIONS.

CALCULATION OF LOADS.

−10° CASE.

$$R_{A_V} = -\frac{61.2}{2} - \frac{4320}{96} + .522(-61.20)(-.176) - (.522 \times 16.32) - (31.25 \times .985)$$

$$= -30.6 - 45 + 5.62 - 8.52 - 30.8 = \underline{\underline{-109.30\ lb}} \uparrow$$

$$R_{B_V} = -30.6 - 45 + 5.62 - 8.52 + 30.8 = \underline{\underline{-47.70\ lb}} \uparrow$$

$$R_C = -1.042\left[-61.20 \times -.176 - 16.32\right] - \frac{-4320}{48} = +5.80 + 90 = \underline{\underline{+95.80\ lb}} \downarrow$$

Check on total vertical load: $-109.30 - 47.70 + 95.80 = 61.2\ lb$ @ 61.2. OK

$$R_{A_H} = \frac{16.32}{2} - 31.25(-.1737) = 8.16 + 5.43 = \underline{\underline{13.59\ lb}} \leftarrow$$

$$R_{B_H} = \frac{16.32}{2} + 31.25(-.1737) = 8.16 - 5.43 = \underline{\underline{2.73\ lb}} \leftarrow$$

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

$$R_{A_S} = \underline{\underline{50\ lb}} \nwarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-2 MODEL LOADS & REACTIONS.

CALCULATION OF LOADS - CONT'D

0° CASE.

$$R_{AV} = \frac{10.2}{2} - \frac{1440}{96} + .522 \times 10.2 \times 0 - .522 \times 10.2 - 31.25 \times 1.0 =$$

$$5.1 - 15 + 0 - 5.32 - 31.25 = -46.47^{lb} \uparrow$$

$$R_{BV} = 5.1 - 15 + 0 - 5.32 + 31.25 = +16.03^{lb} \downarrow$$

$$R_C = -1.042\left[10.2 \times 0 - 10.2\right] - \frac{-1440}{48} =$$

$$+10.62 + 30 = +40.62^{lb} \downarrow$$

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

$$R_{AH} = \frac{10.2}{2} - 31.25(0) = 5.1^{lb} \leftarrow$$

$$R_{BH} = \frac{10.2}{2} + 31.25(0) = 5.1^{lb} \leftarrow$$

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

$$R_{A_S} = 50^{lb} \nwarrow$$

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STRESS ANALYSIS OF $\frac{1}{12}$ 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 -

$R_{A_V} = \frac{0}{2} - \frac{0}{96} + .522 \times 0 \times 0 - .522(-141) - (31.25 \times 1)$

$= + 73.5 - 31.25 = \underline{\underline{42.25^{lb}}} \downarrow$

$R_{B_V} = 73.5 + 31.25 = \underline{\underline{104.5^{lb}}} \downarrow$

$R_C = -1.042\left[0 \times 0 - (-141)\right] - \frac{0}{48} = \underline{\underline{-147^{lb}}} \uparrow$

Check on total Vert. load: 104.5 + 42.25 − 147 = −.25 @ 0

$R_{A_H} = \frac{-141}{2} - 31.25 \times 0 = \underline{\underline{-70.5^{lb}}} \rightarrow$

$R_{B_H} = \frac{-141}{2} + 31.25 \times 0 = \underline{\underline{-70.5^{lb}}} \rightarrow$

Check on total Horizontal load: −70.5 − 70.5 = −141 lb @ −141 lb

$R_{A_S} = \underline{\underline{50^{lb}}} \nwarrow$

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4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-2 MODEL LOADS & REACTIONS

CALCULATION OF LOADS - CONT'D.

20° CASE -

$$R_{A_V} = \frac{428}{2} + \frac{1535}{96} + (.522 \times 428 \times .364) - (.522 \times 122.5) - (31.25 \times .94) =$$

$$= 214 + 16 + 81.3 - 64 - 29.4 = \underline{217.9^{lb}} \downarrow$$

$$R_{B_V} = \frac{428}{2} + \frac{1535}{96} + (.522 \times 428 \times .364) - (.522 \times 122.5) + (31.25 \times .94) =$$

$$= 214 + 16 + 81.3 - 64 + 29.4 = \underline{276.7^{lb}} \downarrow$$

$$R_C = -1.042\left[428 \times .364 - 122.5\right] - \frac{1535}{48} = -34.9 - 32 = \underline{-66.9^{lb}} \uparrow$$

Check on Total Vertical load: $217.9 + 276.7 - 66.9 = 427.7^{lb}$ @ 428

$$R_{A_H} = \frac{122.5}{2} - 31.25 \times .342 = 61.25 - 10.68 = \underline{50.57^{lb}} \leftarrow$$

$$R_{B_H} = \frac{122.5}{2} + 31.25 \times .342 = 61.25 + 10.68 = \underline{71.93^{lb}} \leftarrow$$

Check on total horizontal load: $50.57 + 71.93 = 122.5$ @ 122.5

$$R_{A_S} = \underline{50^{lb}} \nwarrow$$

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-2 MODEL LOADS & REACTIONS

CALCULATION OF LOADS – CONT'D.

45° CASE –

$$R_{A_V} = \frac{367}{2} + \frac{4230}{96} + (.522 \times 367 \times 1.0) - (.522 \times 208) - (31.25 \times .707) =$$

$$183.5 + 44 + 192 - 108.5 - 22.1 = \underline{\underline{288.9^{lb}}} \downarrow$$

$$R_{B_V} = \frac{367}{2} + \frac{4230}{96} + (.522 \times 367 \times 1.0) - (.522 \times 208) + (31.25 \times .707) =$$

$$183.5 + 44 + 192 - 108.5 + 22.1 = \underline{\underline{333.1^{lb}}} \downarrow$$

$$R_C = -1.042\left[(367 \times 1) - 208\right] - \frac{4230}{48} = -166 - 88.2 = \underline{\underline{-254.2^{lb}}} \uparrow$$

Check on total vertical load. 288.9 + 333.1 − 254.2 = 367.8 @ 367

$$R_{AH} = \frac{208}{2} - (31.25 \times .707) = 104 - 22.1 = \underline{\underline{81.9^{lb}}} \leftarrow$$

$$R_{BH} = \frac{208}{2} + (31.25 \times .707) = 104 + 22.1 = \underline{\underline{126.1^{lb}}} \leftarrow$$

Check on total horizontal load: 81.9 + 128.1 = 208 @ 208

$$R_{A_S} = 50^{lb} \nwarrow$$

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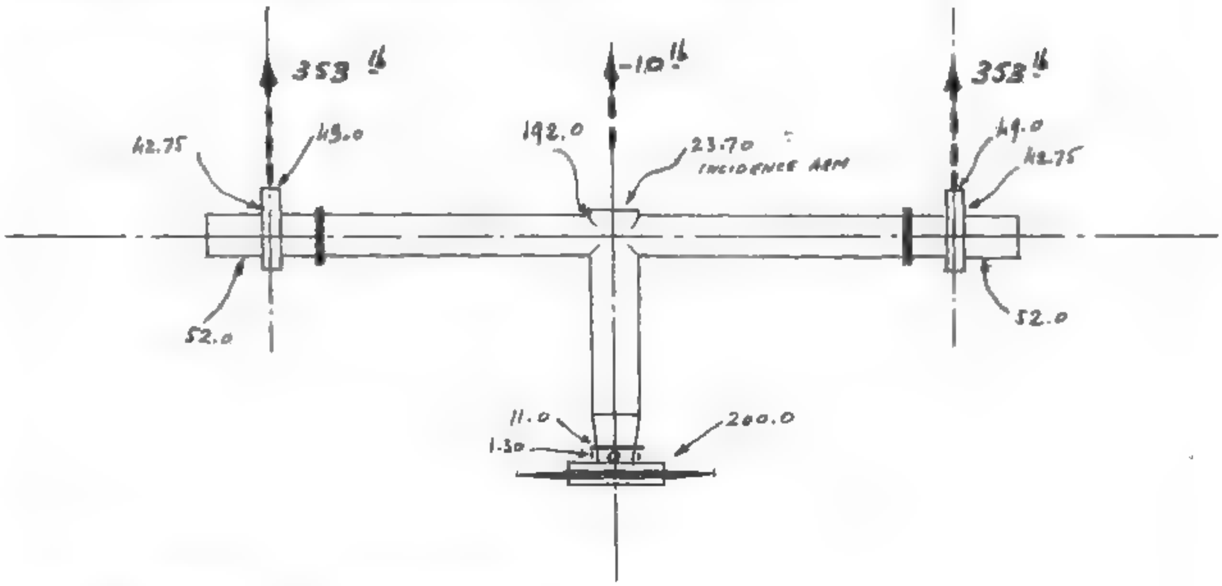
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

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 -

$200 + 1.30 + 11.0 + 192 + 24.67 + 2(49 + 42.75 + 52) =$

$200 + 1.30 + 11.0 + 192 + 24.67 + 287.5 = \underline{\underline{715.80 \text{ lb}}}$

Load on balance Struts -

Main struts:

$-\frac{715.8 - 10}{2} \approx -353 \text{ lb}$

Incidence strut:

$-24 \frac{20}{48} = -10 \text{ lb}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

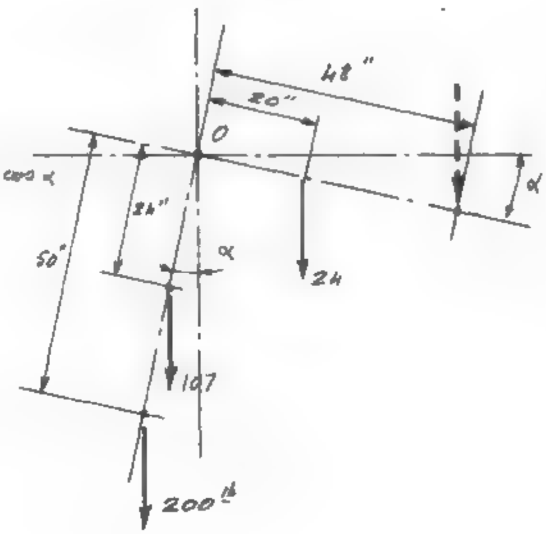
4-3 MODEL SUPPORT STRUCTURE LOADS

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

REACTION ON INCIDENCE STRUT FOR ANGLES ≠ 0.

MODEL MOUNT.

-10°:



Moment about point O.

$-(107 \times 24 \sin\alpha) - (200 \times 50 \sin\alpha) + (24 \times 20)\cos\alpha$

$= -\sin\alpha\,(107 \times 24 + 200 \times 50) + 480\cos\alpha$

$= -12570 \sin\alpha + 480\cos\alpha$

Reaction at incidence strut:

$$-\frac{12570 \sin\alpha + 480\cos\alpha}{48 \cos\alpha} = -262\tan\alpha - 10$$

Reaction when $\alpha = -10°$

$-10 + 262 \tan(-10°) = \underline{-56.2 \text{ lb}}$

Reactions on main struts:

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

+20°

Reaction at incidence strut:

$262 \tan(\alpha) - 10 = 262 \tan(20°) - 10 = \underline{85.2 \text{ lb}}$

Reactions on main struts

$$-\left(\frac{715.8 + 85.2}{2}\right) = \underline{-400.5 \text{ lb}}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ 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°

Reaction at incidence strut:

$-262 \tan\alpha + 10 = -262 \tan 45° + 10 = -252$ lb

Reactions on main struts.

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

SUMMARY OF STATIC STRUT REACTIONS–

$\alpha°$	MAIN STRUT	INCIDENCE STRUT.
-10	-329.8	-56.2
0	-353.0	-10.0
20	-400.5	-85.2
45	-483.9	-252

ALL LOADS IN lb

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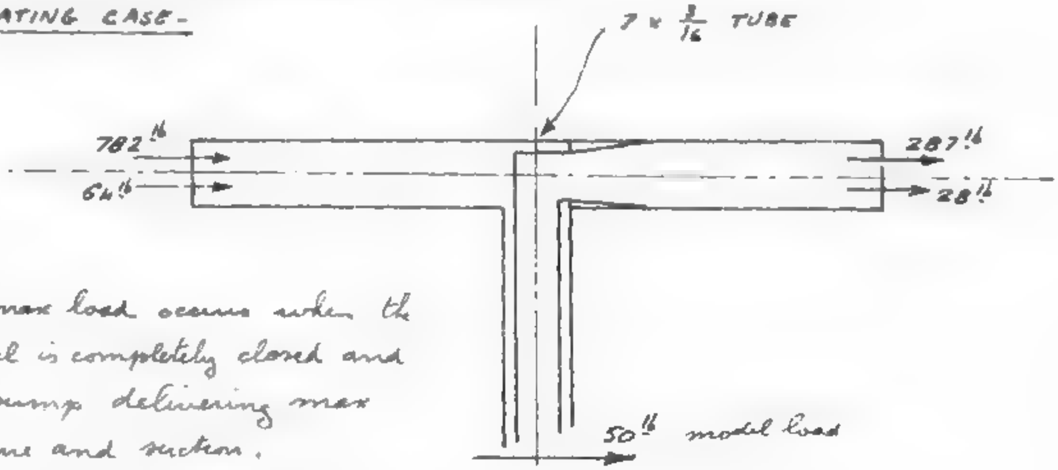
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-4 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.

hence: $782 + 64 + 28 + 287 = \underline{1211\text{ lb}}$

PRESSURE CASE:

TUBE AREA: $\left[7 - (2 \times .187)\right]^2 \frac{\pi}{4} = 34.5\text{ in}^2$

MAX. ABS. PRESSURE : 44.7 PSIa

MIN. ABS. PRESSURE : 6.34 PSIa

TOTAL LOAD: $(44.7 - 6.34)\, 34.50 + 50 = \underline{\underline{1372\text{ lb}}}$

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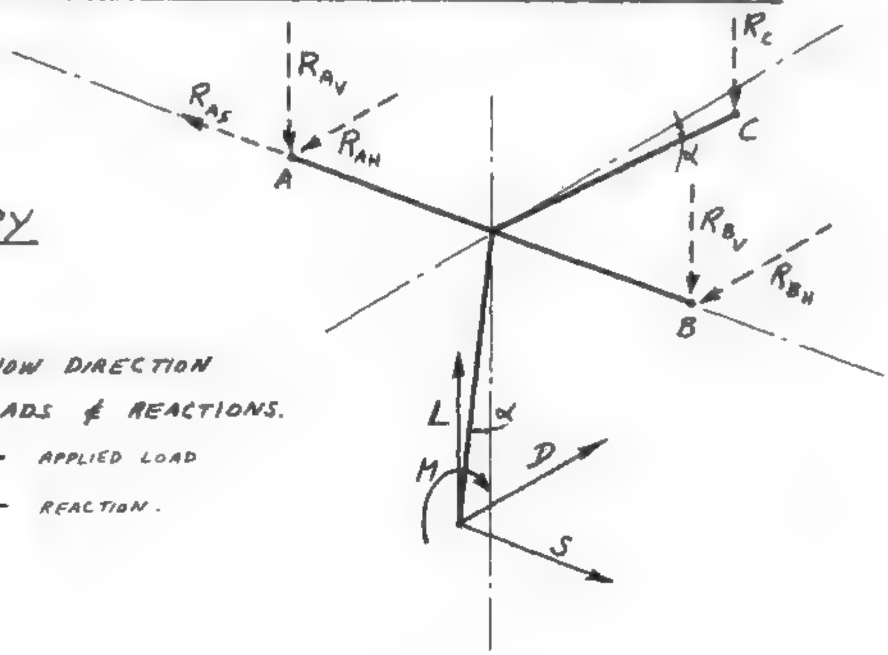
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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 +VE LOADS & REACTIONS.

——— APPLIED LOAD

– – – – REACTION.

α	−10°	0	0 MAX. THRUST.	20°	45°
R_{AV}	−109.31	−46.47	42.25	217.5	288.9
R_{BV}	−47.71	16.03	104.5	276.7	333.1
R_C	−95.82	40.62	−147	−66.9	−254.2
R_{AH}	13.59	5.1	−70.5	50.57	81.9
R_{BH}	2.73	5.1	−70.5	71.93	126.1
R_{AS}	50	50	50	50	50
R_{AS} TOTAL OPERATING.			1211		
PRESS. CASE	1372	1372		1372	1372

−VE REACTION IS A DOWN OR FORWARD LOAD ON THE STRUT

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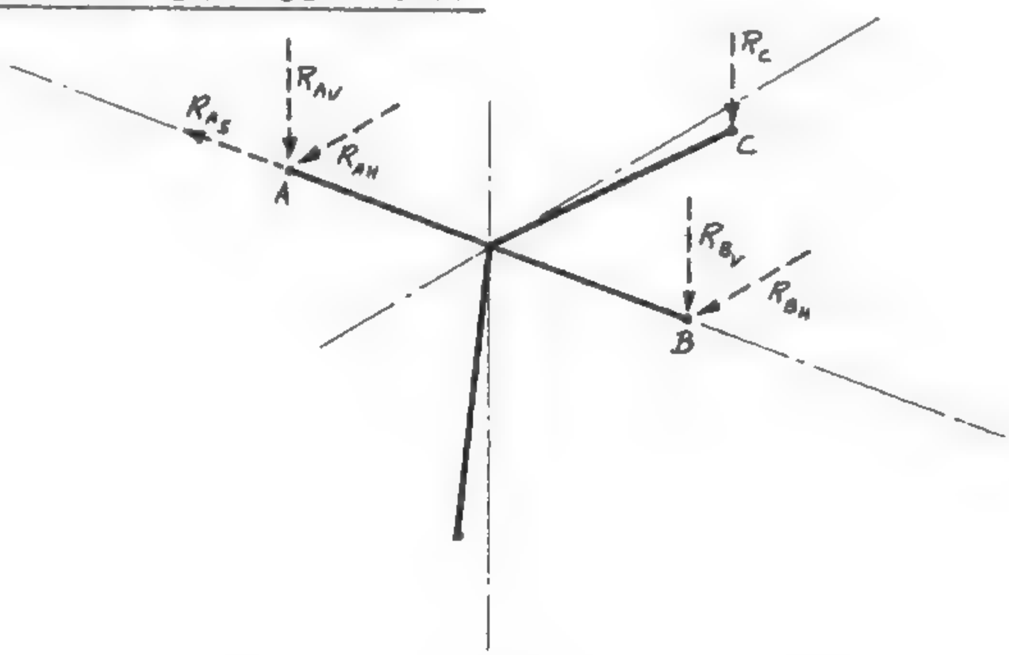
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-3 MODEL SUPPORT STRUCTURE LOADS

4-3-5 NET LOADS & REACTIONS -

NET LOADS ON BALANCE STRUTS



α	−10°	0	0 MAX. THRUST.	20°	45° 10 g.
R_{AV}	−439.11	−399.47	−310.75	−182.6	−195.0
R_{BV}	−377.51	−336.97	−248.5	−123.8	−150.8
R_C	+39.62	+30.62	−157.0	+18.3	−2.2
R_{AH}	+13.59	+5.10	−70.5	+50.57	+81.9
R_{BH}	+2.73	+5.10	−70.5	+71.93	+126.1

- REACTION R_{AS} is not shown here as it is not taken by the struts (See Fairing loads).
- Reactions R_{AV} & R_{BV} and R_{AH} & R_{BH} are interchangeable depending on the direction of the side load on the model.

- In the above table : −ve reaction is a down or forward load on the strut.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-4 FAIRING LOADS

4-4-1 LOADING CONSIDERATIONS

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 $\alpha = 5°$ have been estimated by comparison with other thick airfoils

The loads on the fairings are taken by the balance strut fairings, 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 struts are considered as simply supported beams their loading dividing between the 2 supports.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-4 FAIRING LOADS

4-4-2 LOADS DUE TO AERODYNAMIC FORCES

For a Circular Cylinder, the drag coef. $C_D \simeq 1.0$

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

$D = C_D S q = 1.0 \times .833\, q = .833\, q$

Hence: at the max speed of the tunnel: ($q = 30$ PSF)

$D = 30 \times .833 = 25$ lb/ft.

and at the reduced speed: ($q = 18$ PSF)

$D = 18 \times .833 = 15$ lb/ft.

Length of tube between balance struts: 80"

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

Thus, on balance struts fairings, the load is:

at $\underline{30\,q}$: $25\left[\frac{80}{2\times12} + \frac{150}{4\times12}\right) = 25(3.33 + 3.13) =$
$= 25 \times 6.46 = \underline{164\ \text{lb}}$ →

and load on tunnel walls.

$25\ \frac{150}{4\times12} = 25 \times 3.13 = \underline{78.2\ \text{lb}}$ →

at $\underline{18\,q}$. on strut fairings. $15 \times 6.46 = \underline{97\ \text{lb}}$ →

on tunnel wall: $15 \times 3.13 = \underline{46.9\ \text{lb}}$ →

Drag on vertical fairing

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

$C_D = .20$

Frontal area $\frac{42\times11}{144} = 3.2\ \text{ft}^2$

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4.4 FAIRING LOADS.

4.4.2 LOADS DUE TO AERODYNAMIC FORCES

Drag on vertical fairing: cont'd.

Drag force $.20 \times 3.2 \times q = .64\,q$.

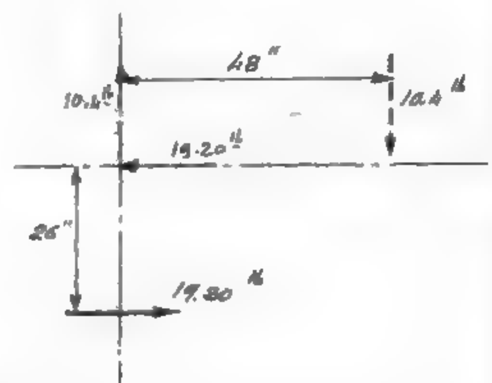
High speed case. $q = 30$ PSF. $D = .64 \times 30 = 19.20$ lb.
Low speed case. $q = 18$ PSF. $D = .64 \times 18 = 11.50$ lb.

Load on strut fairings:

$q = 30$ PSF. $\frac{19.20}{2} = 9.60$ lb. →

$q = 18$ PSF. $\frac{11.50}{2} = 5.75$ lb. →

REACTION ON INCIDENCE STRUT FAIRING.



$\alpha = 0°$.

(30 q) $19.20 \frac{26}{48} = 10.4$ lb

(18 q) $11.50 \frac{26}{48} = 6.22$ lb

$\alpha = 45°$

At this angle the airload on the fairing will be approximately balanced by that on the arm fairing. Hence the reaction will be small and can be neglected.

$\alpha = 20°$

Since the reaction at $\alpha = 0°$ is only 10 lb it will be conservative to assume the same value for $\alpha = 20°$.

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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 PSF : 164 + 9.60 = 173.6 lb

q = 18 PSF : 97 + 5.75 = 102.75 lb

ON TUNNEL WALL :

q = 30 PSF : 78.2 lb

q = 18 PSF : 46.9 lb

VERTICAL LOADS:

q = 30 PSF	ON MAIN STRUTS :	5.2 lb ↓	direction of applied load.
	ON REAR STRUT :	10.4 lb ↑	
q = 18 PSF	ON MAIN STRUTS :	3.11 lb ↓	" "
	ON REAR STRUT :	6.22 lb ↓	

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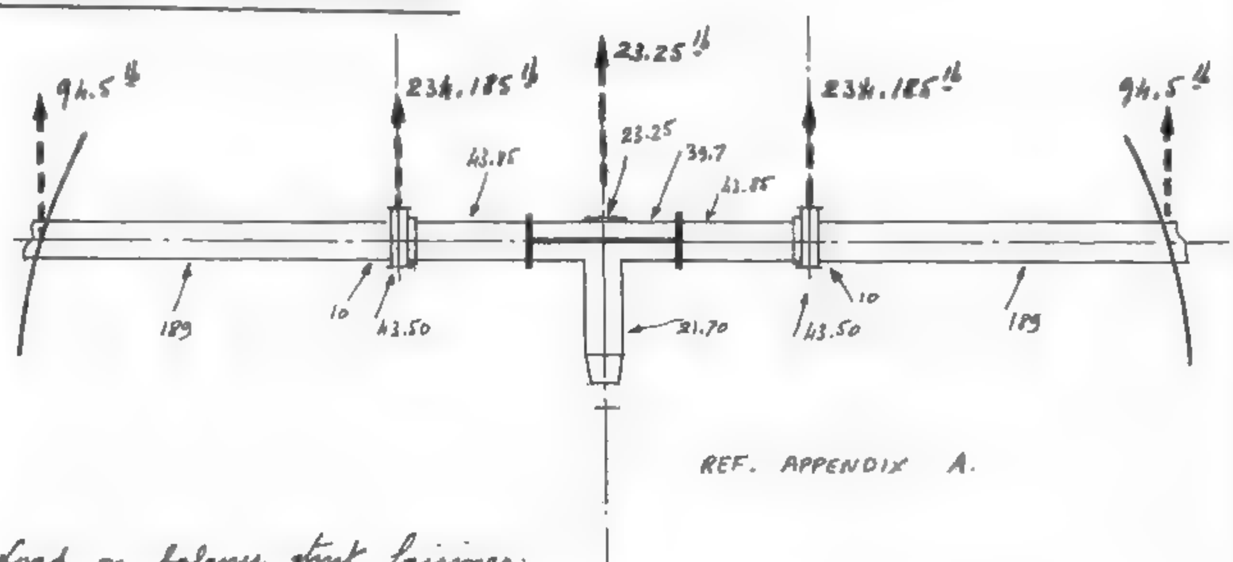
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL -

4.4 FAIRING LOADS

4.4.3 LOADS DUE TO STATIC WEIGHTS

FAIRINGS - TOTAL WEIGHT.



REF. APPENDIX A.

Load on balance strut fairings:

$$43.50 + 10 + \frac{189}{2} + 43.85 + \frac{23.25}{2} + \frac{39.7}{2} + \frac{21.70}{2} = 234.185 \text{ lb}$$

Load on tunnel wall attachment.

$$\frac{189}{2} = 94.5 \text{ lb}$$

TOTAL WEIGHT OF FAIRINGS.

$$(189 \times 2) + (10 \times 2) + (43.5 \times 2) + (43.85 \times 2) + (23.25 \times 2) + 39.7 + 21.70 =$$

$$378 + 20 + 87 + 87.60 + 46.50 + 39.7 + 21.70 = \underline{\underline{680.50 \text{ lb}}}$$

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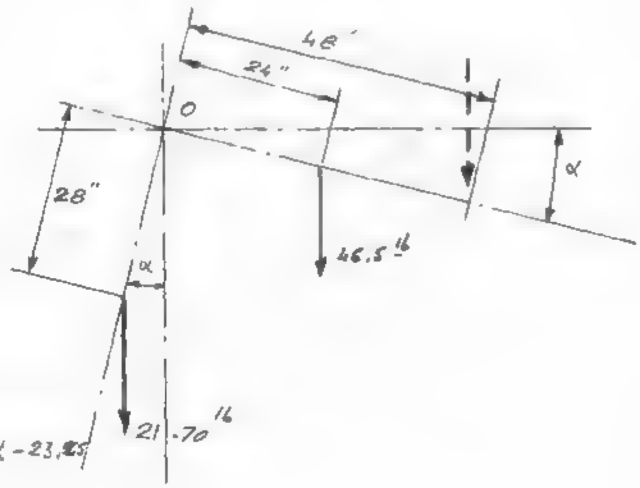
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

4-4 FAIRING LOADS

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

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



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

$$\frac{608 \sin\alpha - 1118 \cos\alpha}{48 \cos\alpha} = 12.65 \tan\alpha - 23.25$$

$\alpha = -10°$

Reaction at incidence strut

$12.65 \tan(-10°) - 23.25 =$

$= -2.23 - 23.25 = -25.48$ lb

Reactions at main struts

$-234.20 + \frac{2.23}{2} = -233.10$ lb

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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.

$\alpha = 20°$

Reaction at incidence strut

$12.65 \tan 20° - 23.25 =$

$= -23.25 + 4.6 = -18.65$ lb

Reactions at main struts

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

$\alpha = 45°$

Reaction at incidence strut.

$12.65 \tan 45° - 23.25 =$

$= -23.25 + 12.65 = -10.60$ lb

Reactions at main struts

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

SUMMARY OF STATIC LOADS ON STRUT FAIRINGS & TUNNEL WALLS.

$\alpha°$	MAIN STRUT FAIRING	INCIDENCE STRUT FAIRING	TUNNEL WALL
-10	233.10	25.5	94.5
0	234.20	23.2	94.5
20	236.50	18.6	94.5
45	240.5	10.2	94.5

ALL LOADS IN lb

+VE LOADS ARE PULL ON FAIRINGS OR DOWN LOADS ON TUNNEL WALL.

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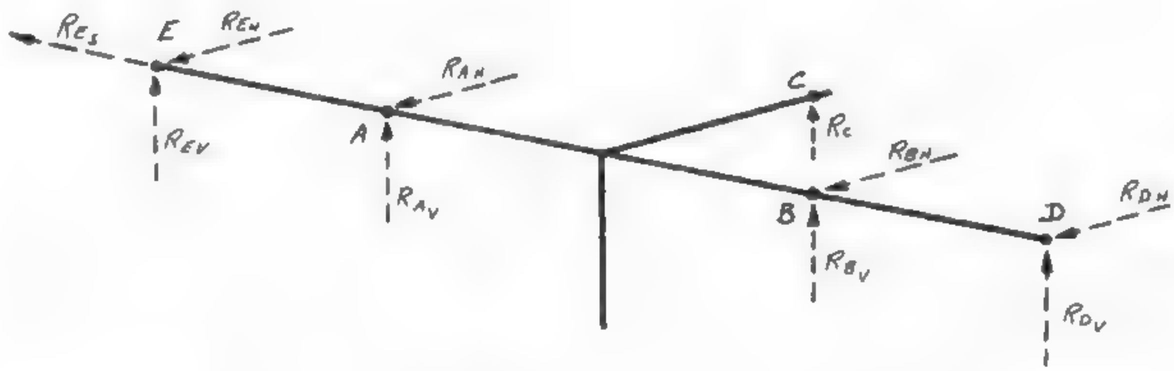
4.4 FAIRING LOADS

4-4-4 NET LOADS & REACTIONS -



REACTIONS \ α	−10°	0°	20°	45° lbs.
R_{AV}	238.3	239.4	241.7	243.6
R_{BV}	238.3	239.4	241.7	243.6
R_{AH}	173.6	173.6	173.6	102.7
R_{BH}	173.6	173.6	173.6	102.7
R_C	15.1	12.8	8.2	4.38
R_{DV}	94.5	94.5	94.5	94.5
R_{EV}	94.5	94.5	94.5	94.5
R_{DH}	78.2	78.2	78.2	46.9
R_{EH}	78.2	78.2	78.2	46.9
R_{ES}^* OPERATING	0	1211.0	0	0
R_{ES}^* PRESSURE	1372.0	1372.0	1372.0	1372.0

*. REF. - 4-3-5

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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 tubes, 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 in the wing attachment bolts (section 5-2-1)

The highest stresses will be those due to the pressure differential between the interior and outside of the model.

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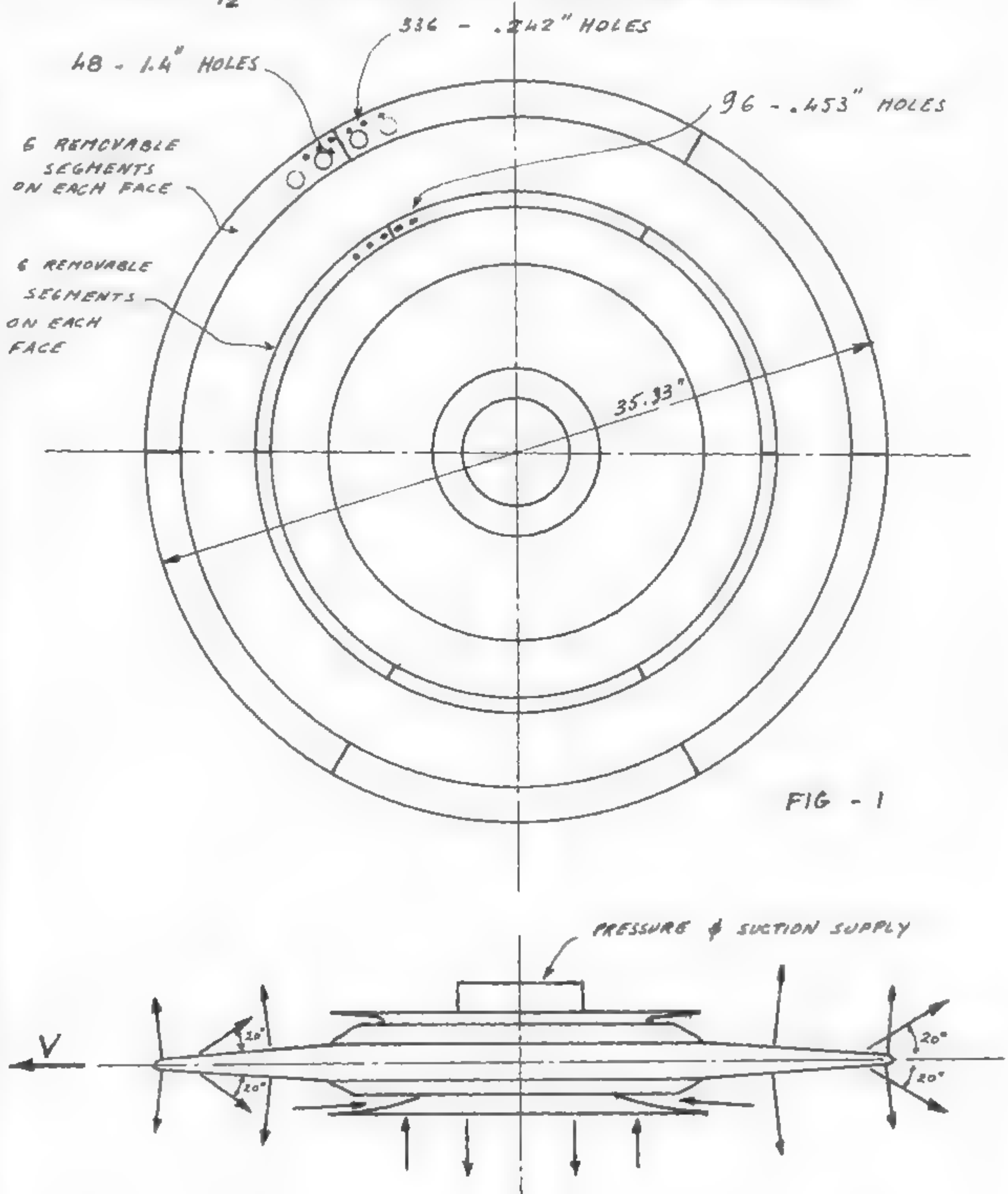
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 - FIG-8 - $\frac{1}{12}$ SCALE MODEL - SCHEMATIC DIAGRAM



TUNNEL SPEED : $V = 158.8 \frac{ft}{sec}$ $q = 30$ PSF.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-1-2 DIFFERENTIAL PRESSURE ON THE WING UPPER SURFACE.

MAX. internal pressure in the wing: 30.74 PSIA

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 L.E is $C_p = -10$.

Hence: the local pressure: $\Delta P = C_p q$

$$\Delta P_{AVE} = -5 \times 30 = -150 \text{ PSF} = -1.04 \text{ PSI}$$
$$\Delta P_{TIP} = -10 \times 30 = -300 \text{ PSF} = -2.08 \text{ PSI}$$

Hence total external pressure: $P_{AVE} = 14.7 - 1.04 = 13.66$ PSI
$P_{TIP} = 14.7 - 2.08 = 12.62$ PSI

Differential pressure taken by the wing structure:

$$\Delta P_{AVE} = 30.74 - 13.66 = 17.08 \text{ PSI}$$
$$\Delta P_{TIP} = 30.74 - 12.62 = 18.12 \text{ PSI}$$

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

With a load factor of 4, these pressures become

$$17.1 \times 4 = \boxed{68.4 \text{ PSI}}$$
$$18.2 \times 4 = \boxed{72.8 \text{ PSI}}$$

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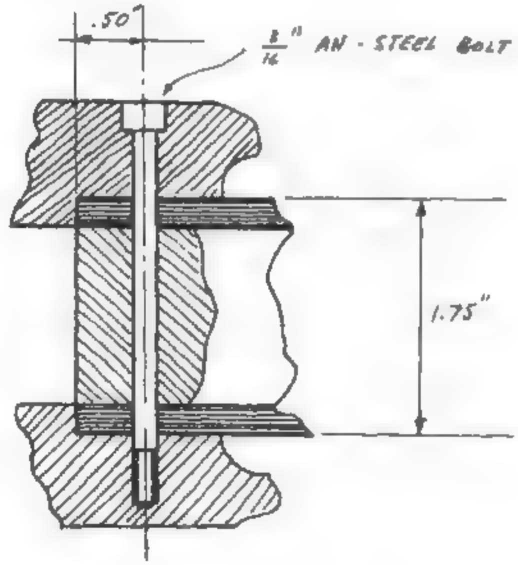
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

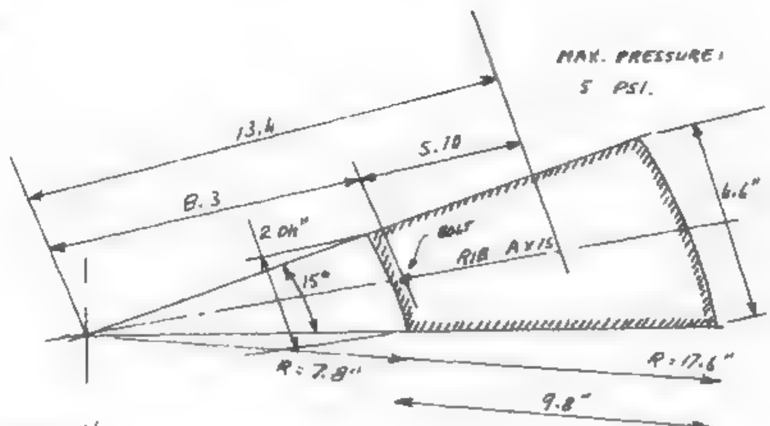
5-0 MODEL STRESS ANALYSIS

5-2-1 WING ATTACHMENT BOLTS



As a covering strength, 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 68.4 PSI on an area of 10 in²

Hence: tension in the bolt.
$68.4 \times 10 = 684.0$ lb



Area of the wing segment
$(2.04 + 4.6)\frac{9.8}{2} = 32.5$ in²

Moment about the bolt
$4 \times 32.5 \times 5 \times 5.1 = 3308$ in-lb

Shear on the bolt. $\frac{3308}{1.75} = 1890.0$ lb

Strength of the 3/16" bolt as per AN-C-5: Tension 2160 lb
shear 2070 lb

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

$$Y = 2160\sqrt{1 - \left(\frac{1890}{2070}\right)^3} = 2160 \times \sqrt{1 - .835} = 2160 \times .406 = 875 \text{ lb}$$

$$M.S. \quad \frac{875}{684.0} - 1 = \text{.128}$$

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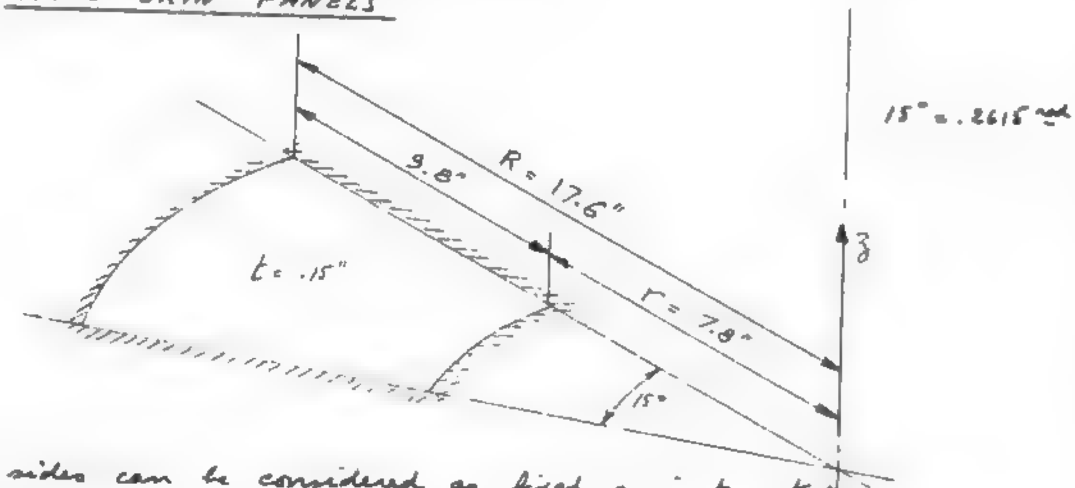
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-2-2 WING SKIN PANELS



Assume:

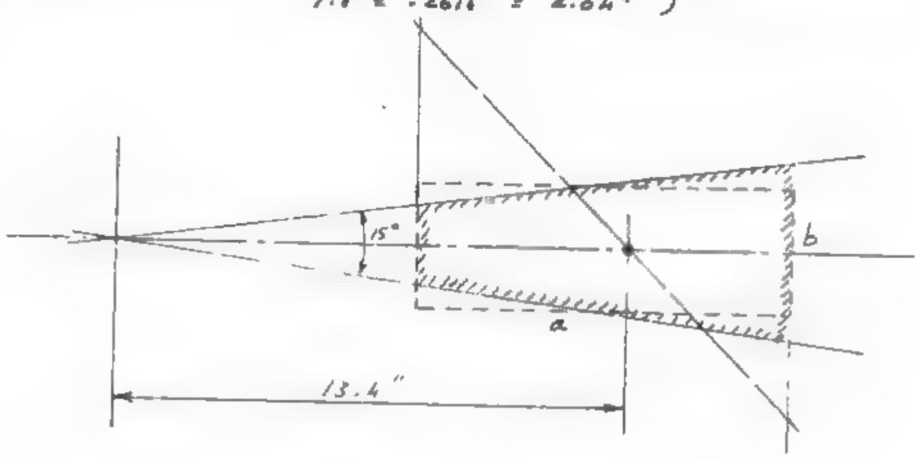
1 - all sides can be considered as fixed against rotation

2 - all sides can be assumed held against deflection in z direction.

Area of panel: $\pi \frac{15}{360}(17.6^2 - 7.8^2) = \frac{\pi}{24}(310 - 61) = 32.5 \text{ in}^2.$

Max pressure force on panel: $32.5 \times 17.10 = 556$ lb

Length of arcs: $17.6 \times .2615 = 4.6"$; $7.8 \times .2615 = 2.04"$ } mean length: 3.32"



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5-0 MODEL STRESS ANALYSIS

5-2-2 WING SKIN PANELS

Consider the rectangular plate shown in dotted line.
This plate is relatively thick and will take the load in bending rather than as a membrane.
we have: $b = 3.32''$ $a = 9.80''$ $\frac{b}{a} = .339$

Ref Resistance des materiaux appliquee à l'aviation by Paul Vallat.

Max. bending stress in the plate. $f_{b_M} = A\,p\left(\frac{b}{t}\right)^2$

Max. deflection at the center. $\delta_M = C\,\frac{p\,b}{E(1-\sigma^2)}\left(\frac{b}{t}\right)^3$

Coef. A from curve ② Diagram 32-1 — $A = .50$
Coef C " " ④ " " " — $C = .212$

Thus: $f_{b_M} = .50 \times 17.10\left(\frac{3.32}{.15}\right)^2 = 4190$ PSI @ 55000 PSI

$\delta_M = .212 \times \frac{17.10 \times 3.32}{30\,10^6(1.069)}\left(\frac{3.32}{.15}\right)^3 = .000209''$

Fully factored bending stress: $4 \times 4190 = 16780$ PSI

M.S. $\frac{55000}{16780} - 1 =$ 2.28

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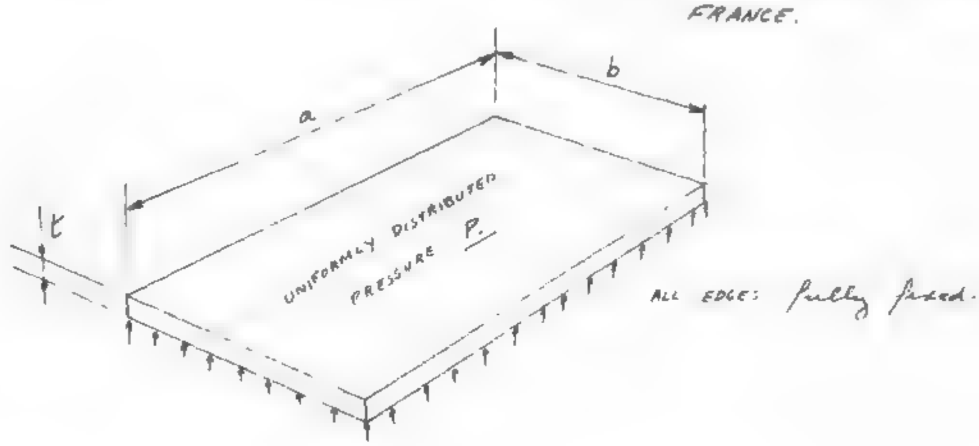
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

FLAT PLATES UNDER TRANSVERSE LOADING.

The following is translated from "RESISTANCE DES MATERIAUX APPLIQUÉE A L'AVIATION" BY PAUL VALLAT
1 ST. EDITION - 1944 - PUBLISHED BY: MENARD - EDITEURS
8 RUE DES REGANS - TOULOUSE
FRANCE.



* MAX. BENDING STRESS AT THE EDGES OF THE PLATE

$$f_{b_M} = A\,P\left(\frac{b}{t}\right)^2$$

MAX. DEFLECTION AT THE CENTER OF THE PLATE

$$\delta_M = C\,\frac{Pb}{E(1-\sigma^2)}\left(\frac{b}{t}\right)^3$$

WHERE

E = Young's modulus.
σ : Poisson's ratio
A : Coef obtained from curve next page
C : Coef obtained from curve next page
a, b & t = dimensions of the plate as shown above
P = applied uniformly distributed pressure

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

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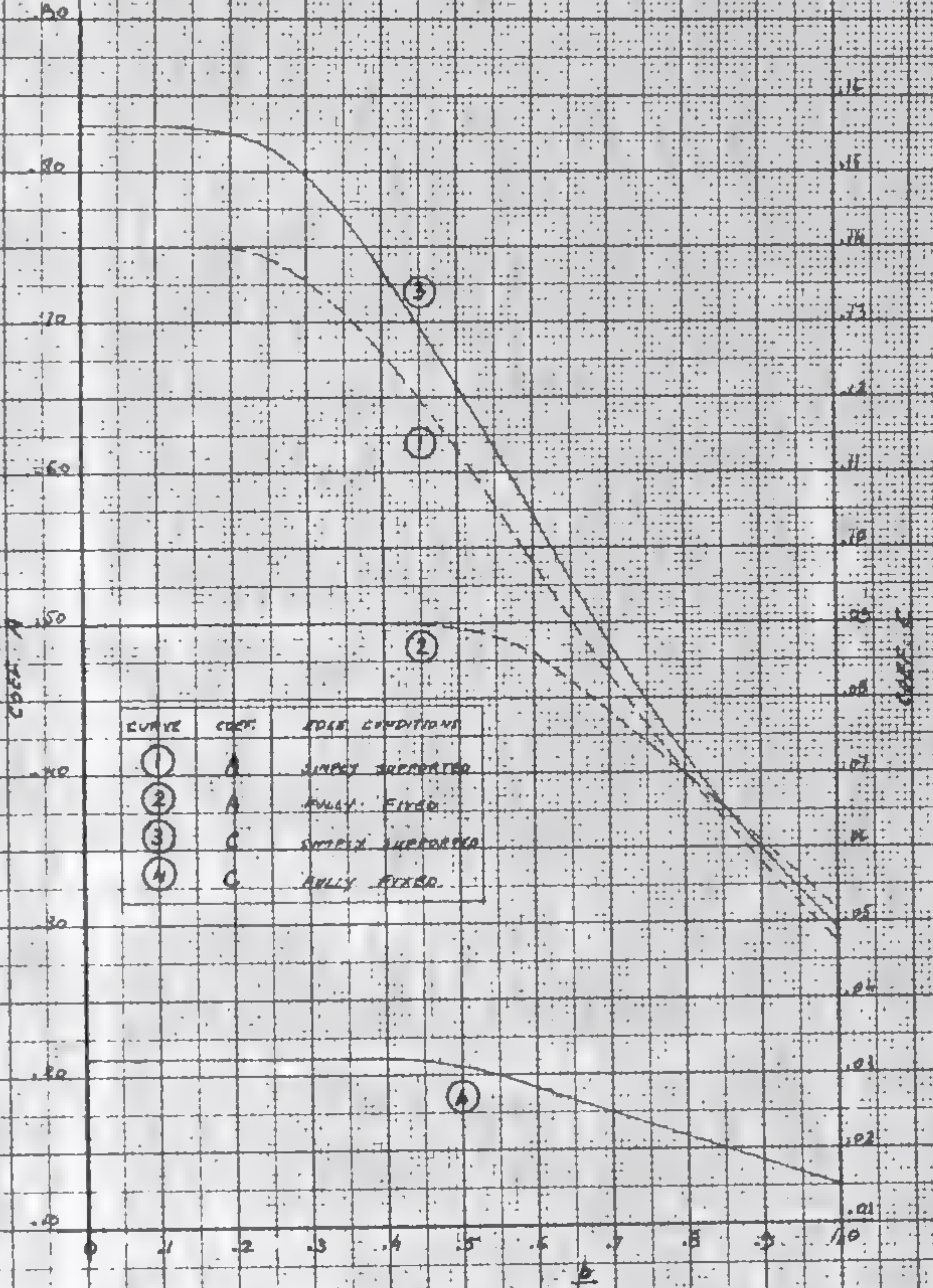
STRESS ANALYSIS OF 1/3 SCALE HOVERING & TRANSITION MODEL

REF "RESISTANCE DES MATERIAUX APPLIQUES A L'AVIATION"
BY P VALLAT



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STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-2-2 WING SKIN PANELS

ATTACHMENT SCREWS.

The skin is held on the ribs by 8 screws
AN-510 #4 or #5.

Screw strength in tension as per specifications
#5 396 lb
#4 : 313 lb

Load per screw with a max pressure force of 556 lb per panel at a pressure of 17.10 PSI (unfactored)

$\frac{556}{8} = 69.5$ lb unfactored

Fully factored load per screw 69.5 × 4 = 278 lb

Considering now a screw at the outer end of the rib and using the higher pressure 18.2 PSI
Fully factored load per screw

$278 \frac{18.2}{17.1} = 296$ lb (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 × 4 × 1.3 = 379 lb

∴ #5 screws are required

M.S. $\frac{396}{379} - 1 =$ .068*

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

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

5-0 MODEL STRESS ANALYSIS

5-2-3 WING NOZZLE REGION

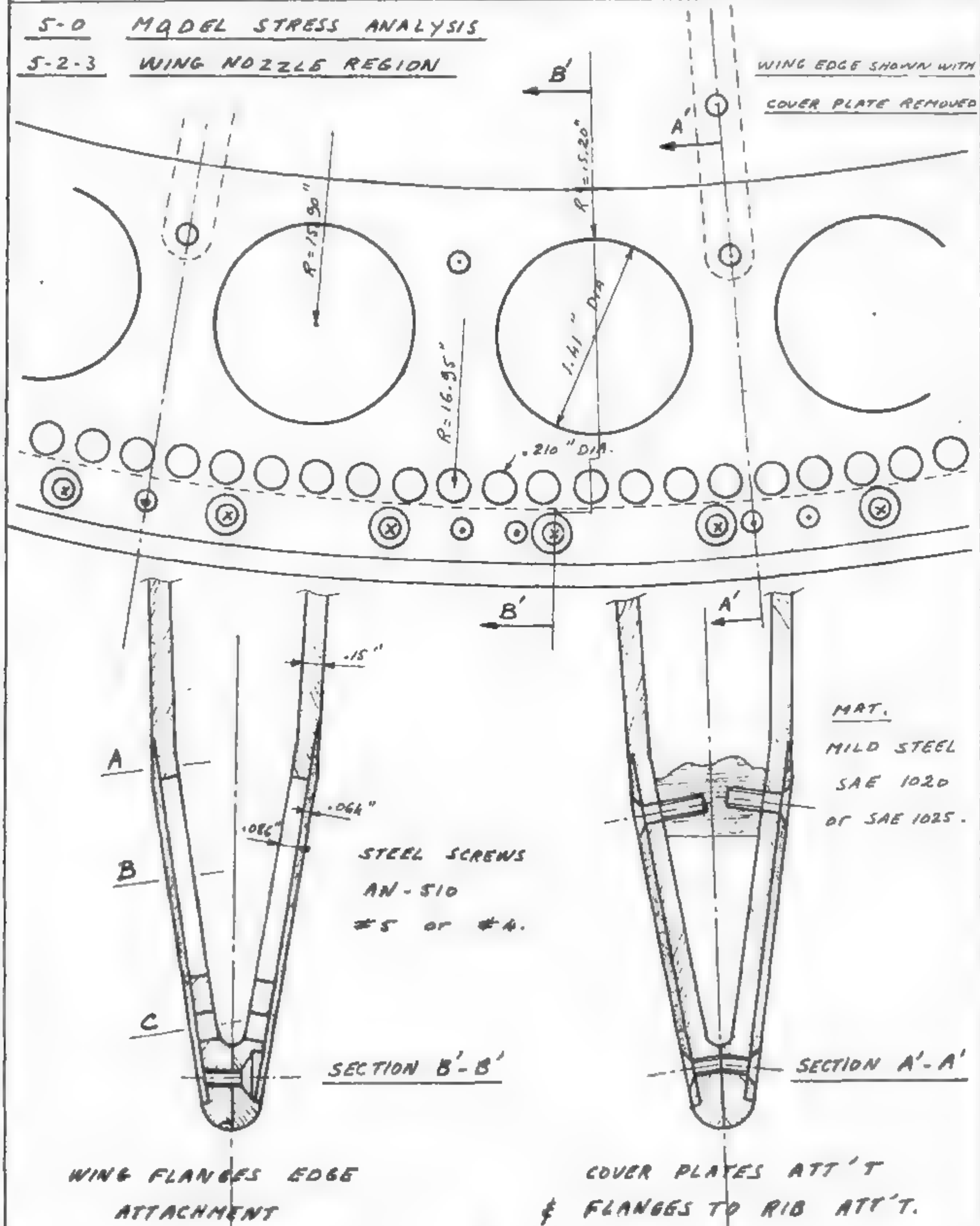

FIG-9- DETAILS OF OUTER EDGE

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STRESS ANALYSIS OF $\frac{1}{12}$ 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: $a \times b = 4.6" \times 2.0"$
then $\frac{b}{a} = .435$

This assumption can be made since it was found that the deflection at the center of the .15" 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 3 sections A, B & C indicated on the sketch, but will be factored up due 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 1.41" holes at section B

BENDING STRESS IN THE PLATE AS PER ASSUMPTIONS ① & ②

$$f_b = A p \left(\frac{b}{t}\right)^2 = .49 \times 18.20 \left(\frac{2.0}{.086}\right)^2 = 4830 \text{ PSI}$$

$A = .49$ (Curve ②)

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-2-3 WING NOZZLE REGION

STRESSING OF THE EDGE.

SECTION B.

Basic section in bending will be assumed to be a 15° arc of radius 15.90" i.e: 4.16" long. having a section modulus

$$\frac{4.16}{6}\ .086^2 = .00512\ \text{in}^3$$

The actual section is made of $(1.34" \times .086") + (1.34" \times .064")$ having a section modulus $\frac{1.34}{6}(.086^2 + .064^2) = .00257\ \text{in}^3$

Hence, the bending stress:

$$4830\ \frac{.00512}{.00257} = 9640\ \text{PSI} \quad @\ 55000$$

fully factored. $9640 \times 4 = 38600$ PSI M.S: $\frac{55000}{38600} - 1 =$ .425

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

$$\frac{4.43}{6}\ .086^2 = .00545\ \text{in}^3$$

The actual section has only 1.49" × .086" having a section modulus $\frac{1.49}{6}\ .086^2 = .001832\ \text{in}^3$

Hence, the bending stress:

$$4830\ \frac{.00545}{.001832} = 14400\ \text{PSI} \quad @\ 55000.$$

fully factored: $14400 \times 4 = 57600$ PSI

M.S: $\frac{55000}{57600} - 1 =$ -.04

ACTUAL MARGIN OF SAFETY ON APPLIED LOAD 3.95.

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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 lb for fully engaged threads.
#4 - 313 lb

This strength is based on threads engaged in a standard nut.
Min height of nut and nb of turns of thread
#5-44 : h = .102" - .114" n = 4.48
#4-48 : h = .087" - .098" n = 4.17

Strength per turn of thread
#5-44 : $\frac{396}{4.48}$ = 88.4 lb
#4-48 : $\frac{313}{4.17}$ = 75.0 lb

SCREWS ATTACHING WING FLANGES AT THE EDGE

- Length of thread engaged ≈ .15" > .102" hence full strength available
- Each screw can be considered as taking a maximum load equal to the pressure over 2 in² : 18.2 × 2 = 36.4 lb

if N° 4 screws are used: M.S : $\frac{313}{4 \times 36.4} - 1$ = 1.15
" " 5 " " " : M.S : $\frac{396}{4 \times 36.4} - 1$ = 1.72

SCREWS ATTACHING THE COVER PLATES.

- Length of thread engaged : .086" i.e.: nb of thread engaged:
#5 : 3.78 available strength : 88.4 × 3.78 = 334 lb
#4 : 4.13 " " : 75 × 4.13 = 310 lb
- Assuming again 2 in² pressure as a max load : 36.4 lb per screw.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-2-5 – WING .064" COVER PLATES ATTACHMENT SCREWS CONT'D.

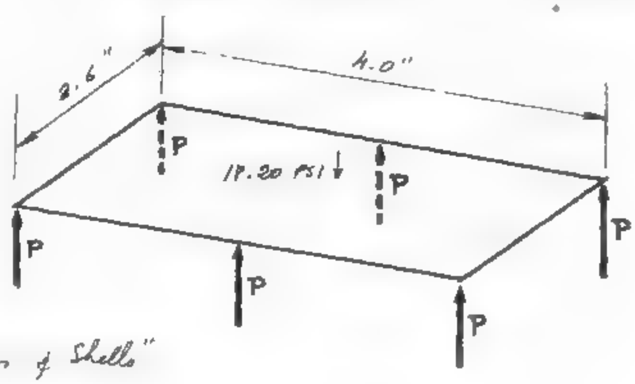
SCREWS ATTACHING THE COVER PLATES – CONT'D

If No. 4 screws are used: M.S. $\frac{310}{4 \times 36.4} - 1$ = ——— 1.1.

" " 5 " " " : M.S. $\frac{534}{4 \times 36.4} - 1$ = ——— 1.2

.064 COVER PLATE.

This plate will be covered for the case where it is used to blank the 2 sets of holes. Due to splices every other ribs; it must be considered as a plate under uniform loading supported at 6 points. The max pressure of 18.2 PSI will be considered over the plate



Using Timoshenko "Plates & Shells" page 243

Ratio $\frac{b}{a} = \frac{2.6}{2} = 1.3$ hence. $\alpha = .0423$

$\beta = .0210$

$\beta_1 = .0385$

Deflection at center of plate

$$w = \alpha \frac{q b^4}{E h^3} = .0423 \frac{18.2 \times 2.6^4}{30\ 10^6 \times .064^3} = .00446''$$

$$M_x = \beta q b^2 = .0210 \times 18.2 \times 2.6^2 = 2.585 \text{ in lb}$$

$$M_y = \beta_1 q b^2 = .0385 \times 18.2 \times 2.6^2 = 4.730 \text{ in lb}$$

$$\sqrt{M_x^2 + M_y^2} = \sqrt{2.585^2 + 4.73^2} = 5.32 \text{ in lb}$$

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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" × 1.00" of plate:

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

Max Bending stress in the plate: $\frac{5.32}{.000684} = 7800$ PSI @ 55000

fully factored: $7800 \times 4 = 31200$ PSI

M.S. $\frac{55000}{31200} - 1 =$ ——— .765

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

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 : $-.048$ and a load factor $n = 4$.

Hence, the failing pressure $4 \times 18.20 \times (1 - .048) = \underline{69.4 \text{ PSI}}$

Pressure at yield of the material : $69.4 \, \frac{36}{55} = \underline{45.3 \text{ PSI}}$

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

The minimum margin of safety on the cover plate is : .762

Hence the failing pressure: $4 \times 18.20 (1 + .762) = \underline{128 \text{ PSI}}$

Pressure at yield of the material : $128 \, \frac{36}{55} = \underline{83.7 \text{ PSI}}$

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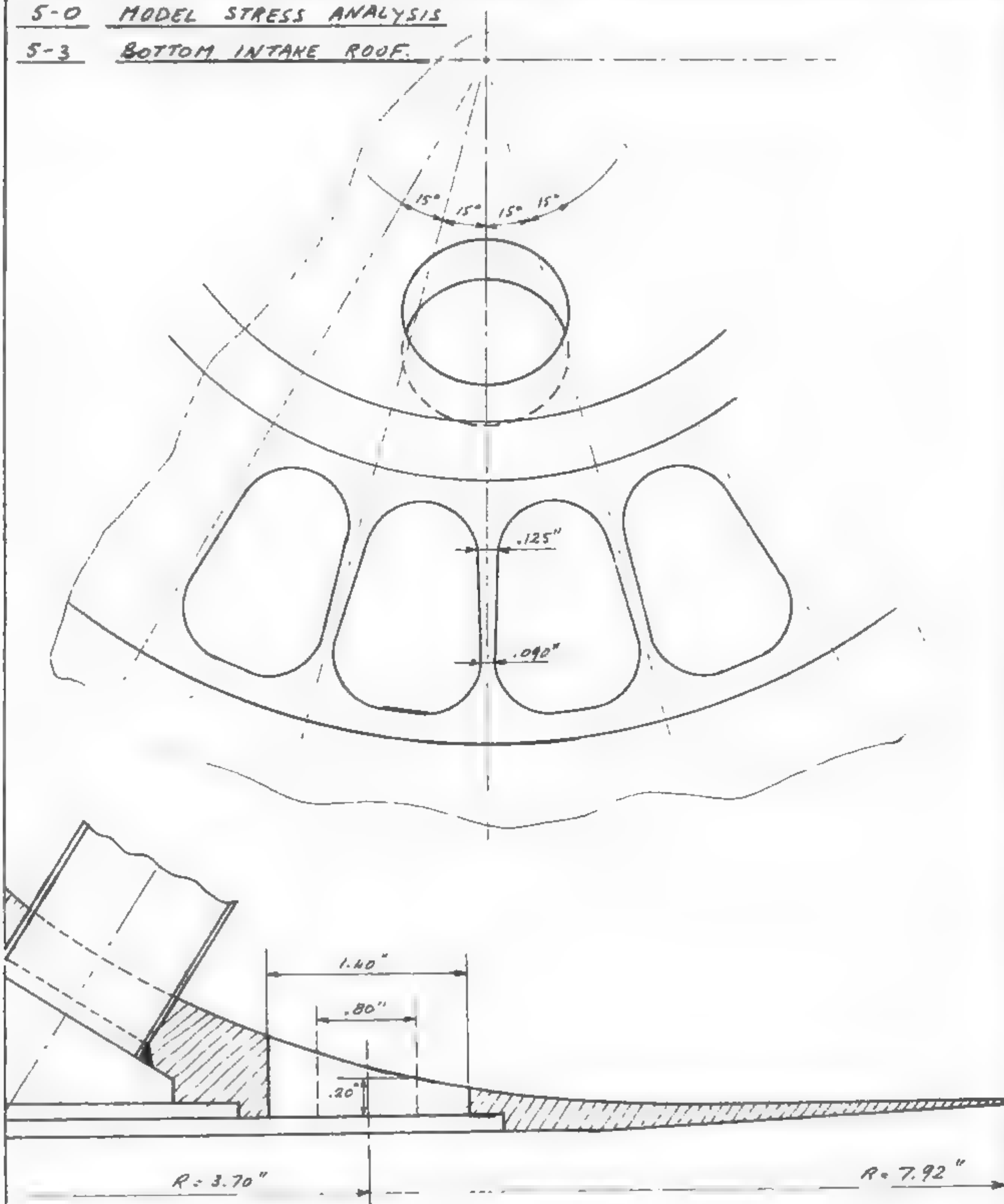
5-0 MODEL STRESS ANALYSIS

5-3 BOTTOM INTAKE ROOF.



MAX. DIFFERENTIAL PRESSURE : ESTIMATED : 1 PSI.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

5-0 MODEL STRESS ANALYSIS

5-3 BOTTOM INTAKE ROOF

5-3-1 INLET SPOKES.

Each spoke will be considered as taking the load applied on a 15° segment of annulus of radiis : 7.92" & 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:

$$\pi\,(7.92^2 - 3.7^2)\,\frac{15}{360} = 6.41\ \text{in}^2$$

Nett load per spoke : fully factored _ estimated differential pressure 1 PSI

$$6.41 \times 1 \times 4 = 25.65^{\text{lb}}$$

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

$$f_B = \frac{M}{Z} = \frac{\frac{PL}{2}}{\frac{bh^2}{6}} = 3\,\frac{PL}{bh^2} = 3\,\frac{25.65 \times .80}{.09 \times .20^2} = \frac{61.5}{.0036} = 17100 \text{ PSI}$$

$$M.S\quad \frac{55000}{17100} - 1 = \text{———} \; 2.22$$

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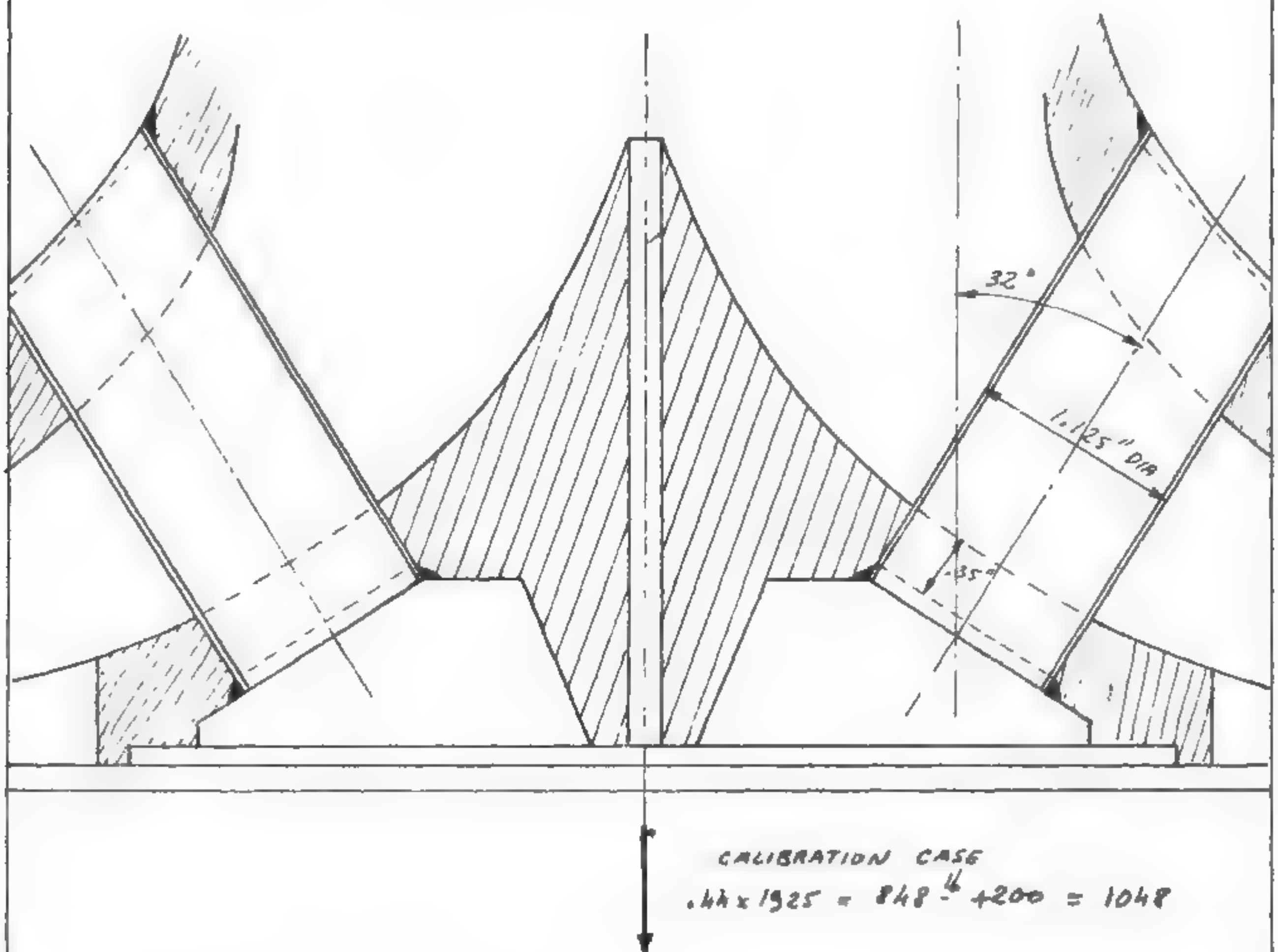
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

5-0 MODEL STRESS ANALYSIS

5-3 BOTTOM INTAKE ROOF

5-3-2 EXHAUST TUBES ATTACHMENT.



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 : $1048 \frac{4}{6} = 698$ lb

Area of solder in shear: $1.125 \times \pi \times .35 = 1.238$ in^2

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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.

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

Shear Stress on the solder: $\frac{824}{1.238} = 665$ PSI

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

Ref: AP-370 - CHAPT. 405-3 -18 ultimate shear strength of solder: 4000 PSI

M.S: $\frac{4000}{665} - 1 =$ 5.00

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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

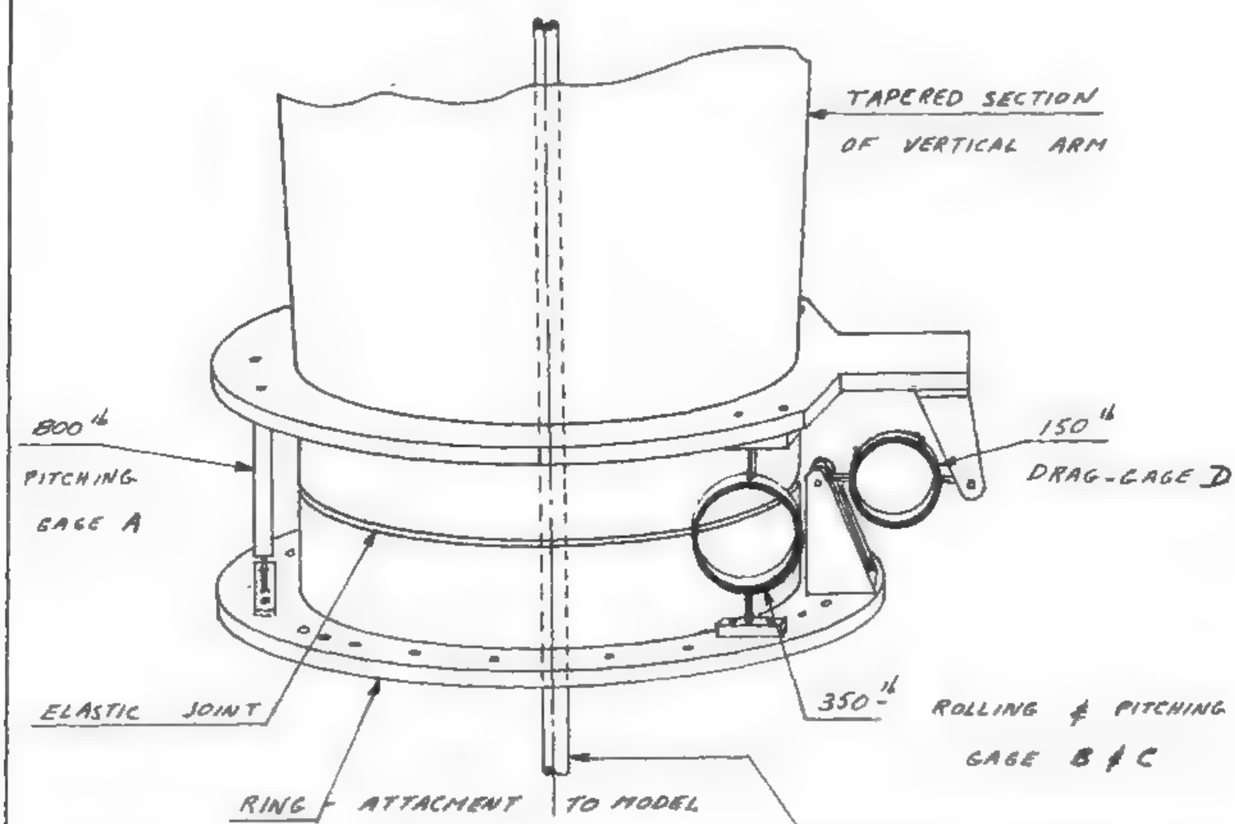

FIG-10 GAGE SECTION

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

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6·0 LOAD GAGE DESIGN

6-1 LOAD ANALYSIS

6-1-1 LOADING CONSIDERATIONS

DESCRIPTION OF GAGE SECTION - CONT'D

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

No gage has been provided for measurement of side load.

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 symmetry 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:

a/ Fore/aft load. Gage D will indicate a pull or a push. Gages A, B & C a pitching moment

b/ 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

6-0 LOAD GAGE DESIGN

6-1 LOAD ANALYSIS

6-1-1 LOADING CONSIDERATIONS -

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 guided 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.

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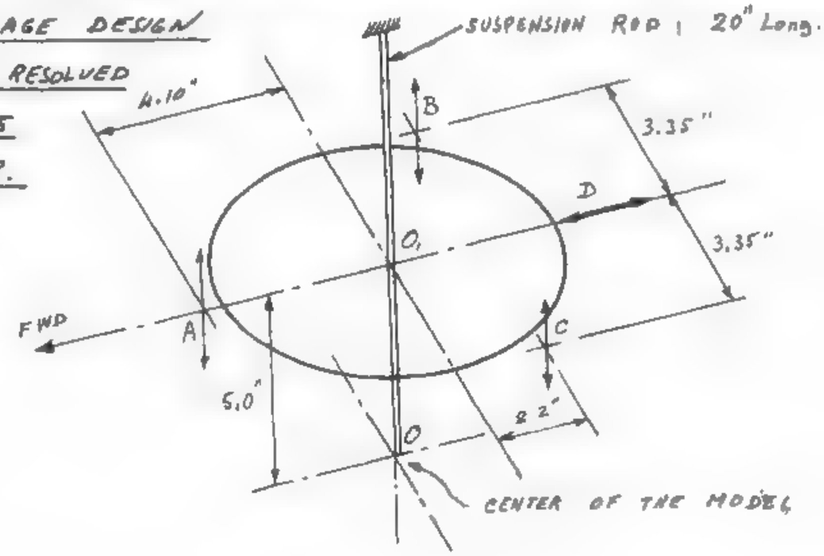
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL-

6-0 - LOAD GAGE DESIGN

6-1-2 - LOADS RESOLVED AT GAGE CENTER.



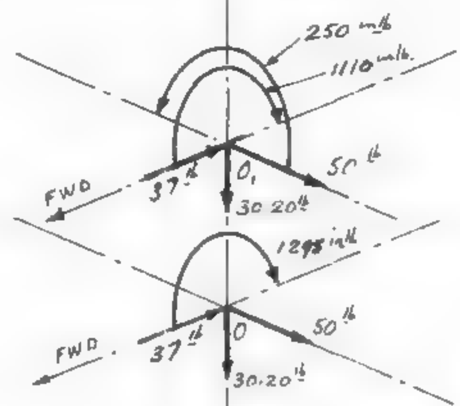
LOADS RESOLVED AT POINT O_1

A 50 lb side load is assumed acting at the center of the model

+ 20° CASE -

$M_L = 1295 - (37 \times 5.0) = 1110$ in lb

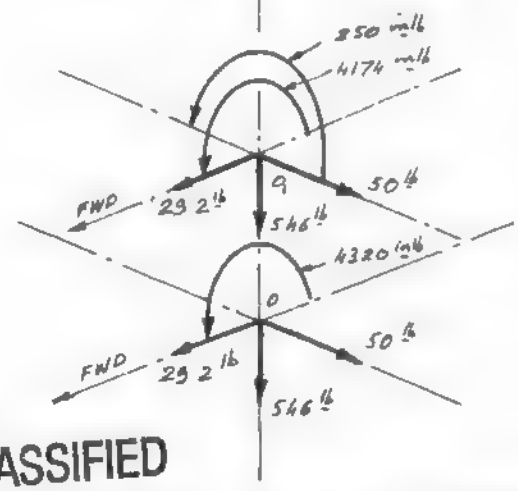
$M_T = 50 \times 5.0 = 250$ in lb



- 10° CASE

$M_L = 4320 - (29.2 \times 5.0) = 4174$ in lb

$M_T = 50 \times 5.0 = 250$ in lb



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

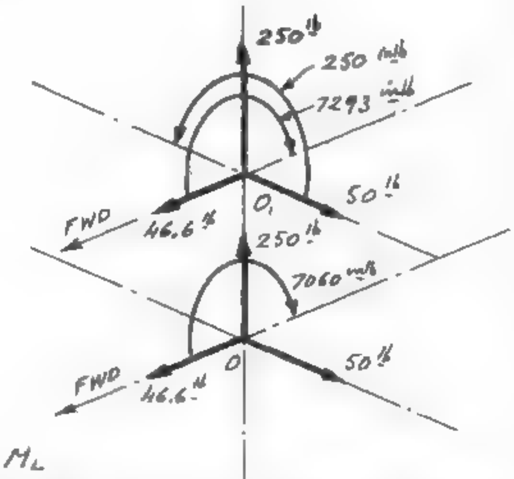
6-0 LOAD GAGE DESIGN

6-1-2 LOADS RESOLVED AT GAGE CENTER.

+45° CASE - TUNNEL AT $q = 30$ PSF

$M_L = 7060 + (46.6 \times 5.0) = 7293$ in-lb

$M_T = 50 \times 5.0 = 250$ in-lb



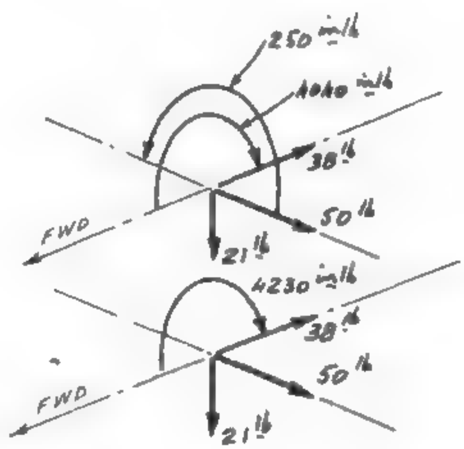
Value of q required to reduce the moment M_L to 4200 in-lb in order not to exceed the strength requirements of the range of $-10° < \alpha < 20°$.

$q_{45} = 30 \frac{4200}{7300} = 17.25.$ SAY 18 PSF

+45° CASE - TUNNEL AT $q = 18$ PSF.

$M_L = 4230 - (38 \times 5) = 4040$ in-lb

$M_T = 50 \times 5.0 = 250$ in-lb



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

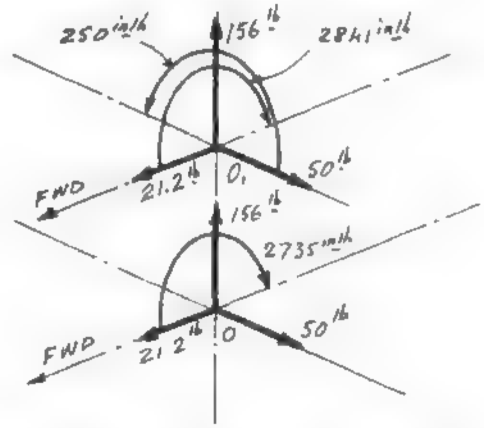
6-0 LOAD GAGE DESIGN

6-1-2 LOADS RESOLVED AT GAGE CENTER.

+35° CASE. $q = 30$ PSF

$M_L = 2735 + (21.2 \times 5) = 2841$ in-lb

$M_T = 50 \times 5.0 = 250$ in-lb



In this case, the moment is considerably smaller than 4200 in-lb hence the tunnel can be operated at $q = 30$ PSF

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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:

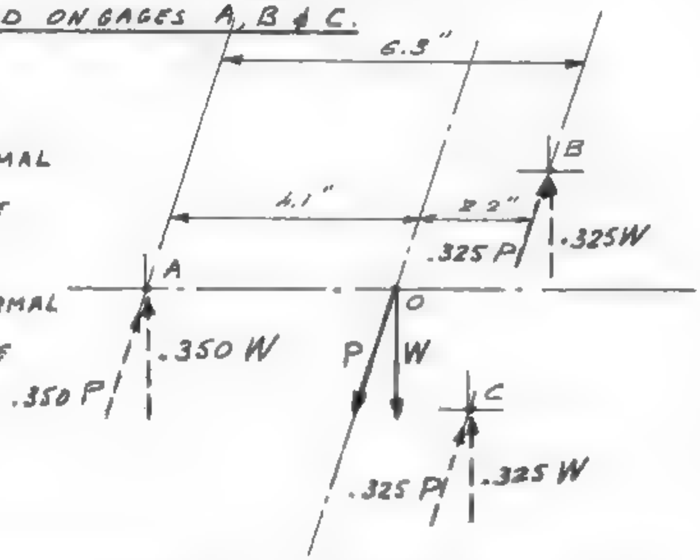
$W \frac{2.2}{6.3} = .350\,W$ NORMAL

$P \frac{2.2}{6.3} = .350\,P$ SIDE

LOAD ON GAGES B & C:

$W \frac{4.1}{6.3 \times 2} = .325\,W$ NORMAL

$P \frac{4.1}{6.3 \times 2} = .325\,P$ SIDE



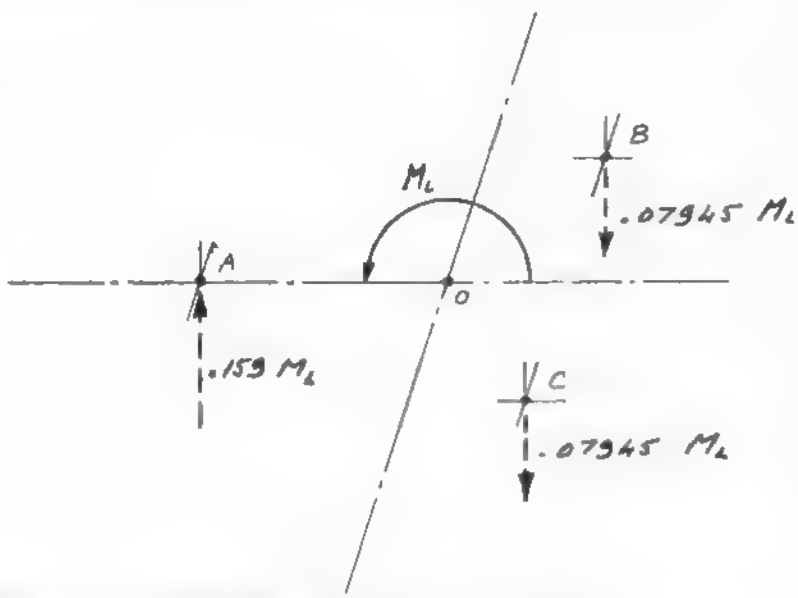
DISTRIBUTION OF A LONGITUDINAL MOMENT ON GAGES A, B & C.

LOAD ON GAGE A

$\frac{M_L}{6.3} = .159\ M_L$

LOAD ON GAGES B & C

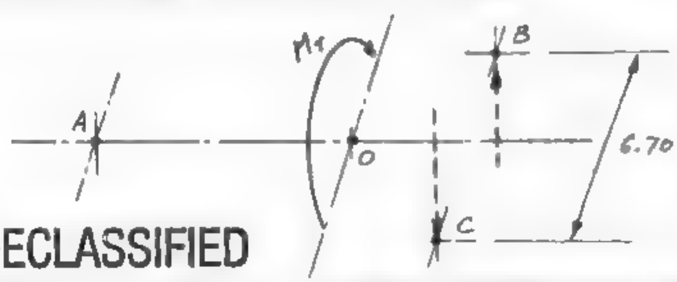
$\frac{-M_L}{2 \times 6.3} = -.07945\ M_L$



DISTRIBUTION OF A TRANSVERSAL MOMENT ON GAGES B & C

LOADS ON GAGES B & C

$\frac{M_T}{6.7} = \pm .1492\ M_T$



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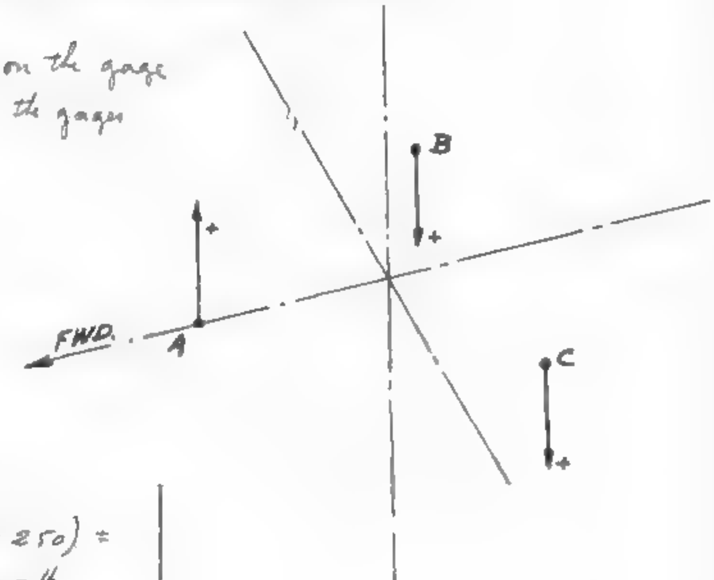
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6-1-3 LOAD DISTRIBUTION -

LOADS ON THE GAGES - EFFECT OF MOMENTS ONLY -

+ve load on gage A : compression on the gage
+ve " " " B or C : tension on the gages



-10° CASE -

GAGE :

A : $-.159 \times 4174 = \underline{-664\ lb}$

B : $(-.07945 \times 4174) + (.1492 \times 250) =$
$-332 + 37.3 = \underline{294.7\ lb}$

C : $(-.07945 \times 4174) - (.1492 \times 250) =$
$-332 - 37.3 = \underline{369.3\ lb}$

+20° CASE.

GAGE :

A : $-.159 \times 1110 = -\underline{176.5\ lb}$

B : $(.07945 \times 1110) + (.1492 \times 250) =$
$88.0 + 37.3 = \underline{125.3\ lb}$

C : $(.07945 \times 1110) - (.1492 \times 250) =$
$88.0 - 37.3 = \underline{50.7\ lb}$

+45° - 18 q - CASE.

GAGE :

A : $.159 \times 4040 = \underline{643\ lb}$

B : $(.07945 \times 4040) + (.1492 \times 250) =$
$321.5 + 37.3 = \underline{358.8\ lb}$

C : $(.07945 \times 4040) - (.1492 \times 250) =$
$321.5 - 37.3 = \underline{284.2\ lb}$

SUMMARY OF GAGE LOADS
EFFECT OF MOMENTS ONLY.

CASE :	-10°	+20°	+45°
Tunnel q	30	30	18
GAGE A	664 lb T	-176.5 lb C	643 lb C
GAGE B	-294.7 lb C	125.3 lb C	358.8 lb T
GAGE C	-369.3 lb C	50.7 lb T	284.2 lb T

REQUIRED GAGE RATING.

A : 800 lb
B : 350 lb
C : 350 lb

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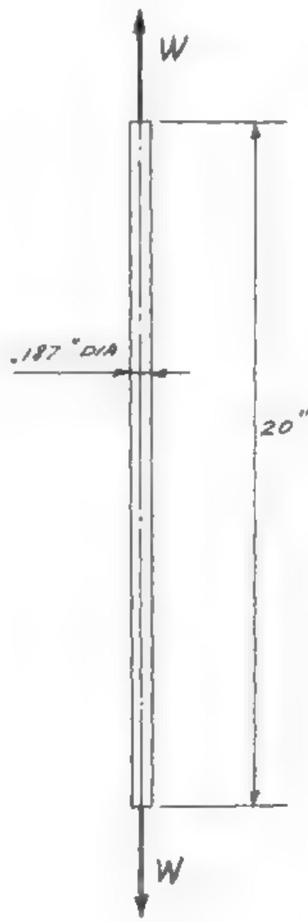
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-1-3 LOAD DISTRIBUTION

SUSPENSION ROD.



The rod is designed at an operating stress of 20000 PSI to take a max. load of 550 lb

Required diameter $\sqrt{\frac{4}{\pi}\frac{W}{f}} = D$

$$D = \sqrt{\frac{4}{\pi}\frac{550}{20000}} = \sqrt{.035} = .187''$$

Sectional area: $.187^2 \frac{\pi}{4} = .0275 \text{ in}^2$

ELONGATION. $\delta = \frac{WL}{AE}$

MAT: SAE - 4130 - CHR. MOLY - STEEL.
@ 125000 PSI UTS.

ELONGATION PER POUND LOAD

$$\delta = W \frac{20}{.0275 \times 30\ 10^6} = 2.42\ 10^{-5}\ W \text{ in/lb}$$

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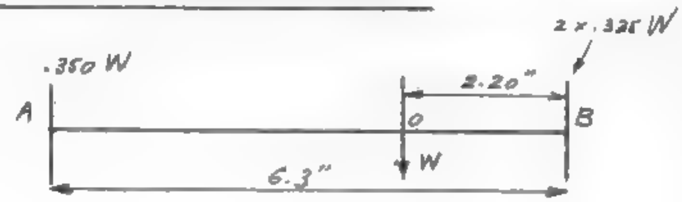
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6-1-3 LOAD DISTRIBUTION -

DISTRIBUTION OF LOAD BETWEEN GAGES AND CENTER ROD.



Deflection rate:

Gage A : $2.66 \; 10^{-5} \; \frac{in}{lb}$

Gage B : $7.42 \; 10^{-5} \; \frac{in}{lb}$

For a unit gage load

Deflection at A : $.35 \times 2.66 \; 10^{-5} = .93 \; 10^{-5}$ in

Deflection at B : $.325 \times 7.42 \; 10^{-5} = 2.415 \; 10^{-5}$ in

Then : deflection at O :

$$\left[2.415 - (2.415 - .93)\frac{2.2}{6.3}\right] 10^{-5} = 1.895 \; 10^{-5} \; \frac{in}{lb}$$

Deflection rate of the rod : $2.42 \; 10^{-5} \; \frac{in}{lb}$

Now, let W_1 & δ_1 be the load and deflection of the rod

and W_2 & δ_2 be the load and deflection of the gage system at point O

and ΔW the incremental load on the system

Then, we must have : $\Delta W = W_1 + W_2$ and $\delta_1 = \delta_2$

Let $\Delta W = 1$ and calculate a relation between W_1 & W_2

we have : $\delta_1 = 2.42 \; 10^{-5} W_1$

$\delta_2 = 1.895 \; 10^{-5} W_2$

$\therefore \quad 2.42 \; 10^{-5} W_1 = 1.895 \; 10^{-5} W_2$

$$W_2 = \frac{2.42}{1.895} W_1 = 1.278 \; W_1$$

Hence : $\Delta W = W_1 + 1.278 \; W_1 = 2.278 \; W_1 = 1$

then $W_1 = \frac{1}{2.278} = .44$: The rod takes 44% of W

the gages 56% of W.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-1-3 LOAD DISTRIBUTION -

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

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

Hence: in terms of the incremental load ΔW.

load on gage A: $.56 \times .35 = .196 = 19.6\%$
Load on gage B or C: $.56 \times .325 = .182 = 18.2\%$

Hence: The load distribution is:

ROD	GAGE A	GAGE B	GAGE C
44 %	19.6 %	18.2 %	18.2 %

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-1-3 LOAD DISTRIBUTION

LOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 lb.

SUCTION ON

−10° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP. 197	−3 lb	−1.32 ↑	−.588 ↑	−.546 ↑	−.546 ↑
PRESSURE	286 lb	126 ↓	56 ↓	52 ↓	52 ↓
AIRLOAD	63.13 lb	27.8 ↓	12.4 ↓	11.5 ↓	11.5 ↓
MOMENTS		0	664 ↓	−295 ↑	−369 ↑
		352.48 ↓	731.8 ↓	232.1 ↑	306.1 ↑

+20° CASE - q = 30 PSF.

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP. 188	−12	−5.28 ↑	−2.35 ↑	−2.185 ↑	−2.185 ↑
PRESSURE	286	126 ↓	56 ↓	52 ↓	52 ↓
AIRLOAD	−443.8	−195.2 ↑	−87.0 ↑	−80.8 ↑	−80.8 ↑
MOMENTS		0	222.5 ↑	148.55 ↓	74 ↓
		145.52 ↓	−255.85 ↑	117.565 ↓	43.015 ↓

NOTE. Airload + pressure load + normal component of model weight = net normal load given page 40.
Load given above under normal component is the change in normal load due to model weight with angle of attack

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STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MONEY

6-1-3 LOAD DISTRIBUTION -

LOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 lb.

SUCTION ON

+45° CASE - q = 18 PSF

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP. 141	-59 lb	- 26 ↑	- 11.56 ↑	- 10.72 ↑	- 10.72 ↑
PRESSURE	286 lb	126 ↓	56 ↓	52 ↓	52 ↓
AIRLOAD	-406 lb	- 178.9 ↑	- 79.5 ↑	- 73.8 ↑	- 73.8 ↑
MOMENTS		0	- 643 ↑	358 ↓	284 ↓
		121.1 ↓	678.06 ↑	326.48 ↓	251.48 ↓

SUCTION OFF.

-10° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP 197	- 3 lb	- 1.32 ↑	-.588 ↑	-.546 ↑	-.546 ↑
PRESSURE *	320	141 ↓	62.6 ↓	58.2 ↓	58.2 ↓
AIR LOAD	63.13	27.8 ↓	12.4 ↓	11.5 ↓	11.5 ↓
MOMENTS			664 ↓	295 ↑	369 ↑
		367.48 ↓	718.412 ↓	- 225.85 ↑	- 299.85 ↑

* SEE PAGE 20

SEE NOTE PAGE 94

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

6-1-3 LOAD DISTRIBUTION

LOAD ON THE GAGES WITH THE ROD ADJUSTED TO TAKE 200 lb

SUCTION OFF -

+20° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP. 188	-12 lb	-5.28 ↑	-2.35 ↑	-2.185 ↑	-2.185 ↑
PRESSURE *	320 lb	141 ↓	62.6 ↓	58.2 ↓	58.2 ↓
AIRLOAD	-443.8 lb	-195.2 ↑	-87.0 ↑	-80.8 ↑	-80.8 ↑
MOMENTS		0	222.5 ↑	148.55 ↓	74 ↓
		140.52 ↓	-249.25 ↑	223.765 ↓	49.215 ↓

+45° CASE - q = 18 PSF

LOAD		ROD	A	B	C
		44%	19.6%	18.2%	18.2%
MODEL WEIGHT	200 lb	200 ↓	0	0	0
NORMAL COMP 141	-59 lb	-26 ↑	-11.55 ↑	-10.72 ↑	-10.72 ↑
PRESSURE *	320 lb	141 ↓	62.6 ↓	58.2 ↓	58.2 ↓
AIRLOAD	-406 lb	-178.5 ↑	-79.5 ↑	-73.8 ↑	-73.8 ↑
MOMENTS		0	-643 ↑	359 ↓	284 ↓
		136.5 ↓	-671.45 ↑	332.68 ↓	257.68 ↓

* SEE PAGE 20

SEE NOTE PAGE 94

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-1-3 - LOAD DISTRIBUTION -

LOAD ON THE GAGES WITH THE ROD DISCONNECTED.

SUCTION ON.

-10° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		0 %	35 %	32.5 %	32.5 %
WEIGHT COMP.	197	0	69 ↓	64 ↓	64 ↓
PRESSURE *	286	0	100 ↓	93 ↓	93 ↓
AIRLOAD	63.13	0	22.1 ↓	20.5 ↓	20.5 ↓
MOMENTS		0	664 ↓	- 295 ↑	- 369 ↑
		0	855.1 ↓	- 117.5 ↑	- 191.5 ↑

+ 20° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		0 %	35 %	32.5 %	32.5 %
WEIGHT COMP.	188 lb.	0	65.8 ↓	61.1 ↓	61.1 ↓
PRESSURE *	286	0	100 ↓	93 ↓	93 ↓
AIRLOAD	-4.38	0	- 155.4 ↑	- 144.2 ↑	- 144.2 ↑
MOMENTS		0	- 222.5 ↑	148.55 ↓	74 ↓
		0	- 212.1 ↑	158.4 ↓	83.9 ↓

* . SEE PAGE 20

SEE NOTE PAGE 94

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STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

6-1-3 LOAD DISTRIBUTION

LOAD ON THE GAGES WITH THE ROD DISCONNECTED.

SUCTION ON

+45° CASE - q = 18 PSF

LOAD		ROD	A	B	C
		0 %	35 %	32.5 %	32.5 %
WEIGHT COMP.	141	0	49.4 ↓	45.8 ↓	45.8 ↓
PRESSURE *	286	0	100 ↓	93 ↓	93 ↓
AIRLOAD	-406	0	-142 ↑	-132 ↑	-132 ↑
MOMENTS		0	-643 ↑	359 ↓	284 ↓
			-635.6 ↑	365.8 ↓	290.8 ↓

SUCTION OFF.

-10° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		0 %	35 %	32.5 %	32.5 %
WEIGHT COMP.	197	0	69 ↓	64 ↓	64 ↓
PRESSURE *	320	0	112 ↓	104 ↓	104 ↓
AIRLOAD	63.13	0	22.1 ↓	20.5 ↓	20.5 ↓
MOMENTS		0	664 ↓	-295 ↑	-369 ↑
		0	867.1 ↓	-106.5 ↑	-180.5 ↑

* SEE PAGE 20

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6-1.3 LOAD DISTRIBUTION

LOAD ON THE GAGES WITH THE ROD DISCONNECTED.

SUCTION OFF-

+ 20° CASE - q = 30 PSF

LOAD		ROD	A	B	C
		0%	35 %	32.5 %	32.5 %
WEIGHT COMP.	188	0	65.8 ↓	61.1 ↓	61.1 ↓
PRESSURE *	320	0	112 ↓	104 ↓	104 ↓
AIRLOAD	-443.8	0	-155.4 ↑	-144.2 ↑	-144.2 ↑
MOMENTS		0	-222.5 ↑	148.5 ↓	74 ↓
		0	-200.1 ↑	169.4 ↓	94.9 ↓

+ 45° CASE - q = 18 PSF

LOAD		ROD	A	B	C
		0%	35 %	32.5 %	32.5 %
WEIGHT COMP.	141	0	49.4 ↓	45.8 ↓	45.8 ↓
PRESSURE *	320	0	112 ↓	104 ↓	104 ↓
AIRLOAD	-406	0	142 ↑	132 ↑	132 ↑
MOMENTS		0	643 ↑	359 ↓	284 ↓
		0	-623.6 ↑	376.8 ↓	301.8 ↓

* SEE PAGE 20

SEE NOTE PAGE 94

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6-1-3 LOAD DISTRIBUTION

SUMMARY OF LOADS ON GAGES & ROD.

	CASE	q PSF	SUCTION ON - OFF	ROD PRELOAD	ROD lb	A lb	B lb	C lb
(1)	-10	30	ON	200	352.48 ↓	731.8 ↓	-232.1 ↑	-306.1 ↑
	+20	30	ON	200	145.52 ↓	-255.85 ↑	117.56 ↓	43.02 ↓
	+45	18	ON	200	121.10 ↓	-678.06 ↑	326.48 ↓	251.48 ↓
(2)	-10	30	OFF	200	367.48 ↓	718.41 ↓	-225.85 ↑	-299.85 ↑
	+20	30	OFF	200	140.52 ↓	-249.25 ↑	223.77 ↓	49.22 ↓
	+45	18	OFF	200	136.5 ↓	-671.45 ↑	332.68 ↓	257.68 ↓
(3)	-10	30	ON	DISCONNECT. 0	0	855.1 ↓	-117.5 ↑	-191.5 ↑
	+20	30	ON	0	0	-212.1 ↑	158.4 ↓	83.9 ↓
	+45	18	ON	0	0	-635.6 ↑	365.8 ↓	290.8 ↓
(4)	-10	30	OFF	0	0	867.1 ↓	-106.5 ↑	-180.5 ↑
	+20	30	OFF	0	0	-200.1 ↑	169.4 ↓	94.9 ↑
	+45	18	OFF	0	0	-623.6 ↑	376.8 ↓	301.8 ↓
	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.
Cases (2) & (4) are tunnel starting cases.

3 - Loads on gages B & C are interchangeable depending on the direction of the side load.

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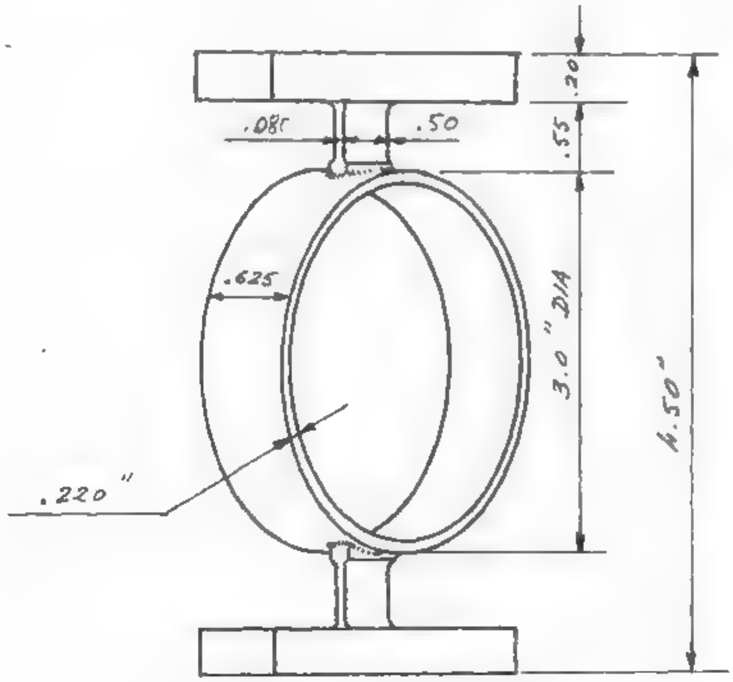
6-2 GAGE DESIGN

6-2-1 GAGE A - 800 lb



This gage is designed according to report AVRO/SPG/TR-87 for an operating max stress of 40000 PSI at the strain gage section

Required thickness.

$$t = \sqrt{.07425\ K^2 + .545 \times 3K} - .2725\ K$$

where $K = \frac{W}{40000 b} = \frac{800}{40000 \times .625} = .032$

$$\therefore t = \sqrt{.07425 \times .032^2 + 1.635 \times .032} - .2725 \times .032$$

$$t = \sqrt{.000076 + .0523} - .008725 = \sqrt{.052376} - .008725$$

$$= .2287 - .0087 = .220''$$

MATERIAL :

AN-QQ-S-689 COND "F"

F_{TU} : 125000 PSI - F_{TY} : 100000 PSI - F_{SU} : 75000 PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

6-2 GAGE DESIGN

6-2-1 -

GAGE A - cont'd.

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

a) Max. bending in the ring at the flexure: $.3183\ W R_m$ in lb

b) Max bending in the ring at the strain gages: $.1817\ W R_m$ in lb

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: $\frac{.625 \times .22^2}{6} = .00504$ in³

Sectional area of the ring: $.625 \times .22 = .1375$ in²

Bending moments:

at a/ : $.3183 \times 800 \times \frac{3 - .22}{2} = 354$ in lb

at b/ : $.1817 \times 800 \times \frac{3 - .22}{2} = 202$ in lb

Stresses at point a/

Bending: $\frac{354}{.00504} = 70200$ PSI

Shear : $\frac{800}{2 \times .1375} = 2910$ PSI

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

Stresses at point b/

Bending : $\frac{202}{.00504} = 40000$ PSI

Tension : $\frac{800}{2 \times .1375} = 2910$ PSI

Total stress : $40000 + 2910 = 42910$ PSI unfactored.

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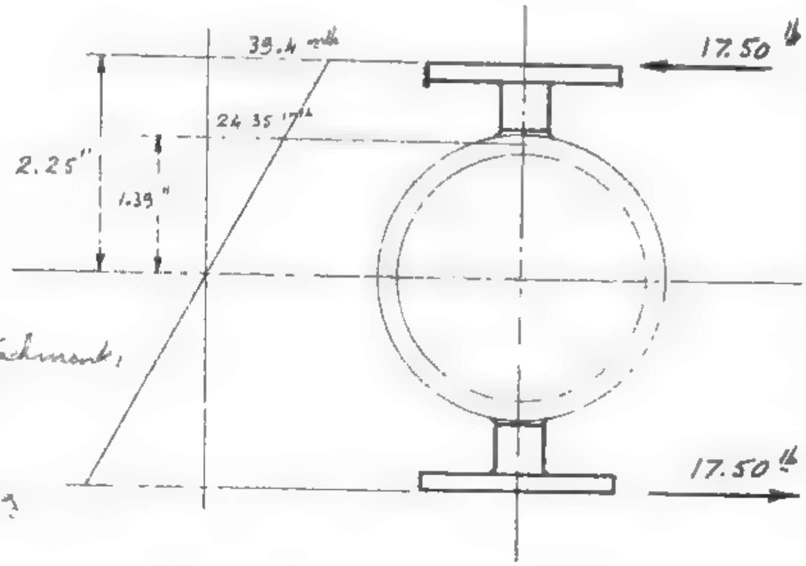
6-2 GAGE DESIGN

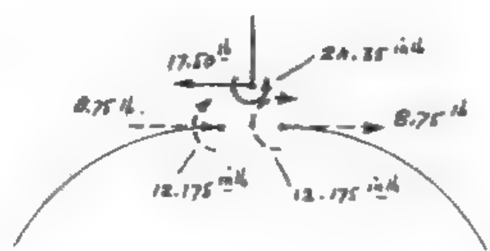
6-2-1-
GAGE A - cont'd.



Bending moment at attachment,
$17.5 \times 2.25 = 39.4$ in lb

Bending moment in ring attachment.
$17.5 \times 1.39 = 24.35$ in lb

Ring section modulus : .00504 in^3
Ring sectional area : .1375 in^2



Bending stress in ring
$$\frac{12.175}{.00504} = 2420 \text{ PSI}$$

Normal stress : $\frac{8.75}{.1375} = 63.7$ lb

Max. total normal stress : $2420 + 63.7 = 2483.7$ PSI say 2,500 PSI

Total stress in the ring at this point
$70320 + 2500 = \underline{72820 \text{ psi}}$ unfactored

$$\text{LIM. M.S.} \quad \frac{100000}{72820} - 1 = \text{———————} \; {}^{*}.37$$

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

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6 - 2 GAGE DESIGN

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

FLEXURES -

From report AVRO/SPG/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 in²
Flexure length . .55"

The side load on the ring induces a bending moment :

$$17.5 \times 2.05 = 35.9 \ \text{in lb}$$

Section modulus :

$$\frac{.08}{6} .50^2 = .00333 \ \text{in}^3$$

Bending stress :

$$\frac{35.9}{.00333} = 10800 \ \text{PSI}$$

Total max normal stress : 20 000 + 10800 = 30800 PSI unfactored

Stability in compression as per JOHNSON'S FORMULA

Least moment of inertia : $\frac{.5 \times .08^3}{12} = .0000 2135 \ \text{in}^4$

Radius of gyration $\rho = \sqrt{\frac{.0000 2135}{.040}} = \sqrt{.000533} = .0231"$

Slenderness ratio . $\lambda = \frac{.55}{.0231} = 23.8$

Buckling stress : Johnson's formula : $f_c = f_u - \frac{1}{4E}\left(\frac{f_u \lambda}{\pi}\right)^2$

$$f_c = 125000 - \frac{1}{4 \times 3 \ 10^7}\left(\frac{125000 \times 23.8}{\pi}\right)^2 = 125000 - \frac{89.5 \ 10^{10}}{12 \ 10^7}$$

$$= 125000 - 7450 = 117550 \ \text{PSI}$$

unfactored : MARGIN OF SAFETY : $\frac{117550}{30800} - 1 =$ 2.82

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

6 - 2 GAGE DESIGN

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

ATTACHMENT BOLTS.

Attachment is by means of: 2 - $\frac{1}{4}$" AN STEEL BOLTS - at each end
steel @ 125000 PSI - Tensile strength of one bolt Ref AN-C-5 4080 lb

Available strength . 4080 × 2 = 8160 lb

Applied load: max. load with factor of 4:
800 × 4 = 3200 lb

$$M.S. \quad \frac{8160}{3200} - 1 = \text{———} \; 1.5.$$

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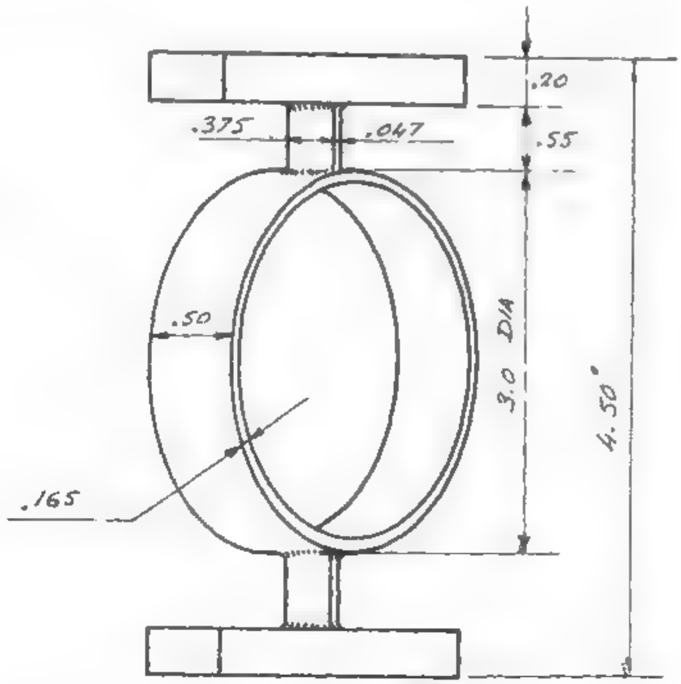
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-2. GAGE DESIGN

6-2-2. GAGES B & C

RATED LOAD : 350 lb



This gage is designed according to report AVRO/SPG/TR-81 for an operating max stress of 40000 PSI at the strain gage section:

Required thickness

$$t = \sqrt{.07425\ K^2 + .545 \times 3\,K} - .2725\ K$$

$$\text{where} \quad K = \frac{W}{40000\ b} = \frac{350}{40000 \times .50} = .0175$$

$$\therefore t = \sqrt{.07425 \times .0175^2 + 1.635 \times .0175} - .2725 \times .0175$$

$$t = \sqrt{.00002275 + .0286} - .004768 = \sqrt{.02862275} - .004768$$

$$= .1693 - .004768 = .16453$$

take .1650"

MATERIAL :

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

F_{TU} . 125000 PSI - F... - F_{SU} : 75000 PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-2 GAGE DESIGN

6-2-2

GAGE B & C - cont'd.

With reference to "Formulas for Stress and Strains" by Roark

a) Max bending in the ring at the flexure. $.3183\ W\ R_m$ in-lb

b) Max. bending in the ring at the strain gages: $.1817\ W\ R_m$ in-lb

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: $\frac{.50 \times .165^2}{6} = .00227$ in³

Sectional area of the ring: $.50 \times .165 = .0825$ in²

Bending moments:

at a) : $.3183 \times 350 \times \frac{3-.165}{2} = 158$ in-lb.

$.1817 \times 350 \times \frac{3-.165}{2} = 90.2$ in-lb

Stresses at point a)

Bending: $\frac{158}{.00227} = 69600$ PSI

Shear : $\frac{350}{2 \times .0825} = 2125$ PSI

Principal Stress $\frac{69600}{2} + \sqrt{\left(\frac{69600}{2}\right)^2 + 2125^2} = 70000$ PSI unfactored

Stresses at point b)

Bending : $\frac{90.2}{.00227} = 39750$ PSI

Tension : $\frac{350}{2 \times .0825} = 2125$

Total Stress : $39750 + 2125 = 41875$ PSI unfactored.

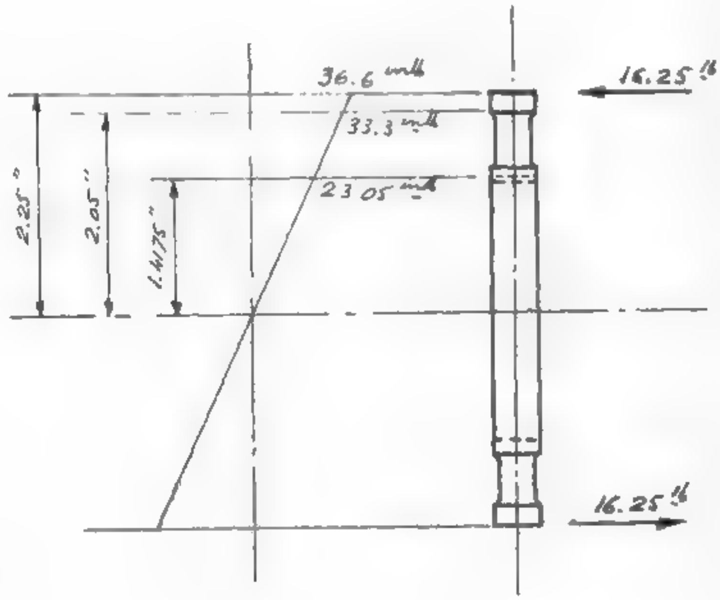
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-2 GAGE DESIGN

6-2-2 GAGES B & C.

Side load on the gages.

$50 \times .325 = 16.25^{lb}$

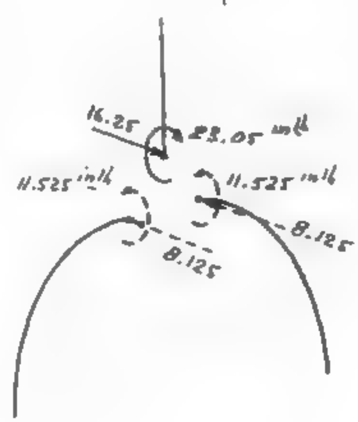


Torsional section modulus of the ring section

$K = \beta \times .165^2 \times .50$

$\beta = .270$ for $\frac{.165}{.50} = .330$

$K = .27 \times .165^2 \times .50 = .00367 \text{ in}^3$



Max Torsional shear stress $= \frac{T}{K}$

$\frac{11.525}{.00367} = 4230$ PSI

Direct shear stress on the section

$\frac{8.125}{.0825} = 98.5$ PSI

Total Shear Stress on the section:

$4230 + 98.5 + 2125 = 6458.5$ PSI

Principal stress $\frac{69600}{2} + \sqrt{\left(\frac{69600}{2}\right)^2 + 6458.5^2} = 70200$ PSI unfactored.

LIM M.S. $\frac{100000}{70200} - 1 =$ .42 *

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

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-2 GAGE DESIGN

6-2-2
GAGES B & C

FLEXURES:

From report AVRO/SPG/TR 87, for a flexure operating at 20000 PSI under 550 lb with width b = .375" ; thickness h = .047"

Sectional area: $.375 \times .047 = .0176$ in²

Flexure length: .55"

The side load on the ring induces a bending moment:

$16.25 \times 2.05 = 33.3$ in lb

Section modulus:

$\frac{.047}{6} \times .375^2 = .0011$ in³

Bending stress:

$$\frac{33.3}{.0011} = 30200 \text{ PSI}$$

Total max stress: $20000 + 30200 = 50200$ PSI

Stability in compression as per JOHNSON'S FORMULA

Least moment of inertia: $\frac{.375 \times .047^3}{12} = 3.25 \; 10^{-6}$ in⁴

Radius of gyration: $\rho = \sqrt{\frac{3.25 \; 10^{-6}}{1.76 \; 10^{-2}}} = \sqrt{1.85 \; 10^{-4}} = .0136''$

Slenderness ratio: $\lambda = \frac{.55}{.0136} = 40.4$

Buckling stress Johnson Formula $f_c = f_u - \frac{1}{4E}\left(\frac{f_u \lambda}{\pi}\right)^2$

$$f_c = 125000 - \frac{1}{4 \times 3\;10^7}\left(\frac{125000 \times 40.4}{\pi}\right)^2 = 125000 - \frac{25.8 \; 10^{11}}{12 \; 10^7} = 125000 - 21500$$
$$= 103500 \text{ PSI}$$

unfactored MARGIN OF SAFETY: $\frac{103500}{50200} - 1 = 1.06$

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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 @ 125000 PSI - Tensile strength of one bolt : Ref. AN-C-5. 4080 lb

Available strength 4080 × 2 = 8160 lb

Applied load : max. load with factor of 4
350 × 4 = 1400 lb

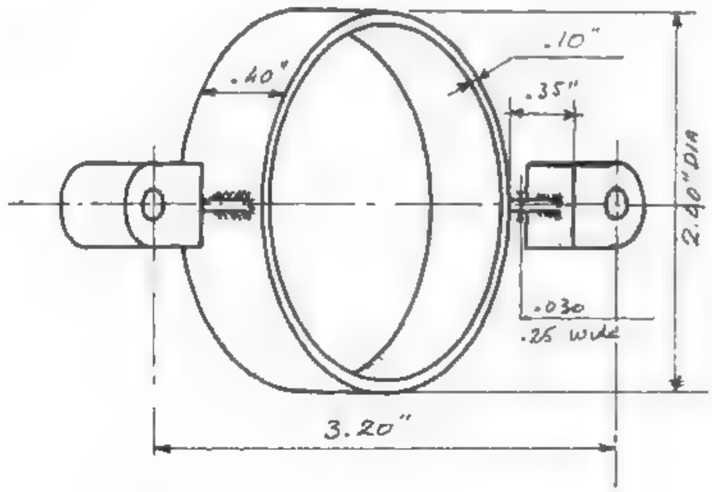
$$M.S. \ \frac{8160}{1400} - 1 = 4.8$$

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

6-2 GAGE DESIGN

6-2-3
GAGE D

RATED LOAD 150 lb



This gage is designed according to report AVRO/SPG/TR-87 for an operating max. stress of 40000 PSI at the strain gage section.

Required thickness.

$$t = \sqrt{.07425\ K^2 + .545 \times 2K} - .2725\ K$$

where $K = \frac{W}{40000b} = \frac{150}{40000 \times .40} = .00938$

$$\therefore t = \sqrt{.07425 \times .00938^2 + .545 \times 2 \times .00938} - .2725 \times .00938$$

$$t = \sqrt{.00000652 + .01025} - .002555 = \sqrt{.01025652} - .002555$$

$$.10127 - .00255 = .09872''$$

Say. .10"

MATERIAL:

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

F_{TU} : 125000 PSI - F_{TY} . 100 000 PSI - F_{SU} 75000 PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

6-2 - GAGE DESIGN

6-2-3

GAGE D - cont'd.

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

a) Max bending in the ring at the flexure: .3183 $W R_m$ in lb

b) Max. bending in the ring at the strain gages: .1817 $W R_m$ in lb

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 $\frac{.40 \times .10^2}{6} = .000667$ in^3

Sectional area of the ring = .40 x .10 = .040 in^2

Bending moments:

at a/ : $.3183 \times 150 \times \frac{2-.10}{2} = 46.6$ in lb

at b/ : $.1817 \times 150 \times \frac{2-.10}{2} = 26.6$ in lb

Stresses at point a)

Bending : $\frac{46.6}{.000667} = 70000$ PSI

Shear : $\frac{150}{2 \times .040} = 1875$ PSI

Principal Stress: $\frac{70000}{2} + \sqrt{\left(\frac{70000}{2}\right)^2 + 1875^2} = 70100$ PSI unfactored.

unfactored: LIM. M.S. $\frac{100000}{70100} - 1 =$ —— .43

Stresses at point b/

Bending : $\frac{26.6}{.000667} = 40000$ PSI

Tension : $\frac{150}{2 \times .040} = 1875$ PSI

Total Stress : 40000 + 1875 = 41875 PSI unfactored

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

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 lb with width l = .25" : thickness K = .030"
Flexure length .35"
Sectional area .25 × .03 = .0075 in²

Stability in compression as per JOHNSON'S FORMULA

Least moment of inertia $\frac{.25 \times .03^3}{12} = .5625\ 10^{-6}$ in⁴

Radius of gyration $\rho = \sqrt{\frac{.5625\ 10^{-6}}{.75\ 10^{-2}}} = .866\ 10^{-2} = .00866''$

Slenderness ratio $\lambda = \frac{.35}{.00866} = 40.5$

Buckling stress. Johnson's formula $f_c = f_a - \frac{1}{4E}\left(\frac{f_a \lambda}{\pi}\right)^2$

$$f_c = 125000 - \frac{1}{4 \times 3\ 10^7}\left(\frac{125000 \times 40.5}{\pi}\right)^2$$

$$= 125000 - \frac{1}{12\ 10^7}\left(25.95\ 10^{11}\right) = 125000 - 21650$$

$$= 103350 \text{ PSI}$$

MARGIN OF SAFETY $\frac{103350}{20000} - 1 =$ ———— 4.17

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

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

6-2 GAGE DESIGN

6-2-3
GAGE D - CONT'D.

Attachment by means of 1 - $\frac{1}{4}$" AN STEEL BOLT at each end
Steel @ 125000 PSI — Bolts in double shear
Shear strength - Ref AN-C-5 - single shear: 3680 lb

Strength of bolt: 3680 × 2 = 7360 lb

Applied load: max. load with factor of 4:
150 × 4 = 600 lb.

M S $\frac{7360}{600} - 1 =$ ——————————> 1c

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

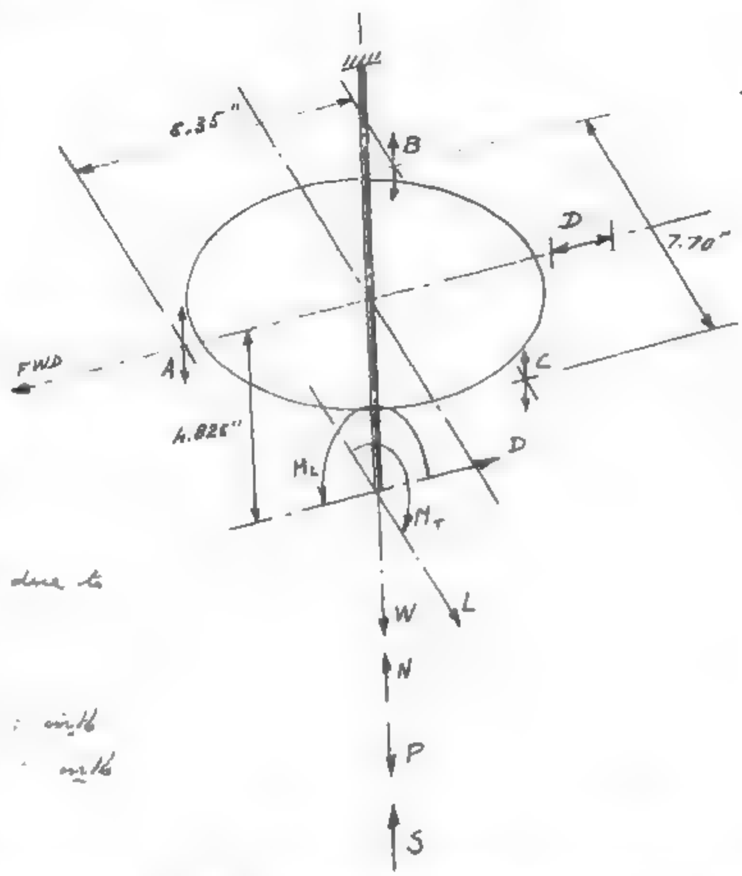
6.0 LOAD GAGE DESIGN

6.3 GAGE EQUATIONS - LOAD ON GAGES.

GAGE	A	B	C	D	
WEIGHT	.196 W(1-cos α)	.182 W(1-cos α)	.182 W(1-cos α)	W sin α	
PRESSURE	4.47 P_p	4.09 P_p	4.09 P_p	0	
SUCTION	-2.87 P_s	-2.625 P_s	-2.625 P_s	0	
NORMAL LOAD	-.196 N	-.182 N	-.182 N	0	
DRAG LOAD	.760 (D+W sin α)	-.380 (D+W sin α)	-.380 (D+W sin α)	D	
SIDE LOAD	0	.626 L	-.626 L	0	
PITCHING M_T	.1575 M_L	-.07875 M_L	-.07875 M_L	0	
ROLLING M_T	0	-.130 M_T	+.130 M_T	0	

POSITIVE GAGE LOAD IS TENSION

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



WHERE

W = model weight : lb

P_p = pressure in outer pipe : psig

P_s = pressure in inner pipe : psig

N = Normal load on model due to airload . lb

D = Net chordwise force on model due to thrust and airload . lb

L = Side force on model . lb

M_L = Pitching moment on model : in lb

M_T = Rolling moment on model : in lb

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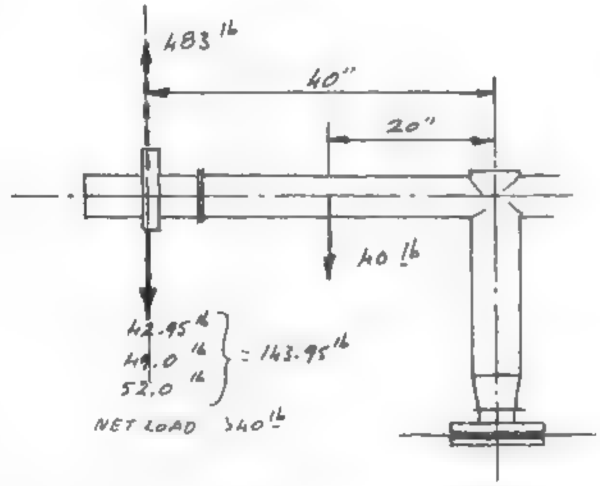
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7.0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 HORIZONTAL TUBE

7-1-1 TUBE IN BENDING.



SECTION PROPERTIES OF THE TUBE.

Size: 7" × 3/16" - ID = 6.625"

Sectional area:

$A = \frac{\pi}{4}(7^2 - 6.625^2) = 3.94 \text{ in}^2$

Moment of inertia:

$I = \frac{\pi}{64}(7^4 - 6.625^4) = 23.3 \text{ in}^4$

Section modulus

$Z = \frac{\pi}{32}\left(\frac{7^4 - 6.625^4}{7}\right) = 6.65 \text{ in}^3$

The max support reactions under both static and aerodynamic loading occurs with the incidence of the model at 45°, then

45° CASE.

REF. SECTION 4-3-3 - & APPENDIX A

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 airload

Vertically. $333.1 \times 40 = 13330$ in lb

REF. 4-3-5

Horizontally: $126.1 \times 40 = 5050$ in lb

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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

45° CASE - CONT'D.

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

Then: max. bend. stresses in the tube

$f_b = \frac{M}{Z} \quad 4\frac{12800}{6.65} = 7660$ PSI

M.S. $\frac{55000}{7660} - 1 =$ ———— 6.16

−10° CASE.

This case is to be considered as bending moments from static load add to bending moment from airload. (330 − 144) = 186 = R_A.

Static load:

$M = (186 \times 40) - (.40 \times 20) = 7440 - 800 = 6640$ in-lb.

Airload:

Vertical: $109.31 \times 40 = 4370$ in-lb

Horizontal: $13.59 \times 40 = 544$ in-lb

Total Bending moment.

$M_T = \sqrt{(6640 + 4370)^2 + 544^2} = 11024$ in-lb

Max bending stress:

$fb = 4\frac{11024}{6.65} = 6640$ PSI

M.S. = $\frac{55000}{6640} - 1 =$ ———— 7.30

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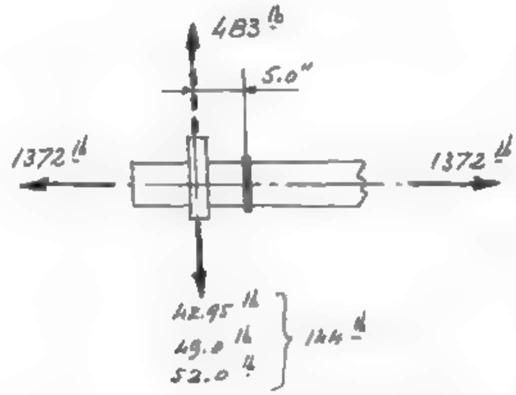
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1 HORIZONTAL TUBE

7-1-2 - FLANGES ON 7.00" TUBE.

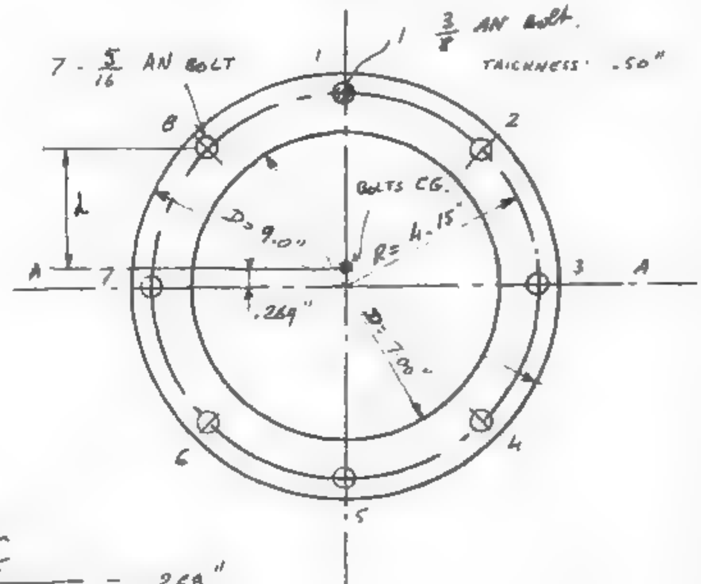


Bending Moment:
$340 \times 5 = 1700$ in-lb unfactored

Shear force:
$484 - 144 = 340$ lb unfactored.

Bolt strength in tension
Ref. AN-C-5
AN-6 : 3/8" DIA : 10100 lb
AN-5 : 5/16" DIA : 6500 lb

Bolt strength in shear
AN-6 : 3/8" DIA. : 8280 lb
AN-5 : 5/16" DIA. : 5750 lb



Centroid of bolt cluster in tension

$$(10100 - 6500)\frac{4.15}{10100 + (7 \times 6500)} = .269''$$

Distribution of tensions due to bending in the bolt cluster

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

With S = the strength of any bolt. F = force on the bolts;
d = distance of bolt to centroid.

$$F_{j_M} = M \frac{d_j S_j}{\Sigma d^2 S}$$

Direct tension: $F_{j_T} = T \frac{S_j}{\Sigma S}$

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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.

BOLT.	1	2	3	4	5	6	7	8
S	10,100	6,500	6,500	6,500	6,500	6,500	6,500	6,500
d	3.881	2.661	-.269	-3.199	-4.419	-3.199	-.269	2.661
d^2	15.1	7.1	.0725	10.12	19.55	10.12	.0725	7.1
Sd	39.2	17.3	-1.75	-20.8	-28.7	-20.8	-1.75	17.3
Sd^2	152.5	46.2	.471	65.8	127.0	65.8	.471	46.2
$Sd/\Sigma Sd^2$	.0778	.0344	-.00347	-.0413	-.0570	-.0413	-.00347	.0344
$\frac{S}{\Sigma S}$	.182	.117	.117	.117	.117	.117	.117	.117
F_{jM} lb	161.0	71.0	-7.2	-85.5	-118.0	-85.5	-7.2	71.0
F_{jT} lb	250.0	160.5	160.5	160.5	160.5	160.5	160.5	160.5
$F_{j\,TOTAL}$ lb	411.0	231.5	153.3	85.0	42.5	85.0	153.3	231.5

unfactored loads.

$\Sigma Sd^2 = 504.442.$ $\Sigma S = 55.6$

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

Bolts in Shear:

Total Shear strength available $8280 + (7 \times 5750) = 8280 + 40250$
$= 48530$ lb

Shear on AN-6 Bolt: $339 \frac{8280}{48530} = 57$ lb unfactored

Shear on AN-5 Bolt: $339 \frac{5750}{48530} = 40.1$ lb unfactored.

Allowable tension on bolts:

Ref. AN-C-5

$$Y = b\sqrt{1-\left(\frac{x}{a}\right)^3} = 10100\sqrt{1-\left(\frac{57}{8280}\right)^3} = 10100 \times \sqrt{1-(.00688)^3}$$

effect of shear is negligible

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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:

AN-6 : M.S : $\frac{10100}{4 \times 411} - 1 =$ —— 5.14

AN-5 : M.S : $\frac{6500}{4 \times 231.5} - 1 =$ —— 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.

AN-6 - MS $\frac{10100}{4 \times 411} - 1 =$ ———— 5.14

AN-5 : MS $\frac{6500}{4 \times 231.5} - 1 =$ ———— 6.03

WELD.

Assume the load of AN-6 bolt taken by 2" of $\frac{1}{4}$" weld

Weld area: $2 \times .25 = .50 \text{ in}^2$

Allowable UTS of weld metal : 51000 PSI (Ref. AN-C-5)

" USS " " " : 32000 PSI (" ")

Weld Stress: $\frac{411}{.5} = 822$ PSI unfactored.

MS $\frac{32000}{4 \times 822} - 1 =$ ———— 8.71

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-3 - MAIN SUPPORT BEARINGS.

MAIN STRUTS BEARINGS.

SKF. BALL BEARING - No. 6238-M.

Ref. SKF CATALOG No. 551 - STATIC STRENGTH : RADIAL: 53000 lb
DYNAMIC " : " . 44000 lb

Max applied load. $\sqrt{333.1^2 + 126.1^2} = 356$ lb - Ref. 4.3.

$$M.S \quad \frac{53000}{4 \times 356} - 1 = \text{———} > 10$$

Static load on bearings : tunnel stopped. 352 lb - Ref. B.3.

BEARING HOUSING.

MOUNTING BOLTS

9 BOLTS : $\frac{1}{2}$" DIA INTERNAL WRENCHING

NAS BOLTS in tension : 23500 lb per bolt

Total strength available 23500 × 9 = 211500 lb

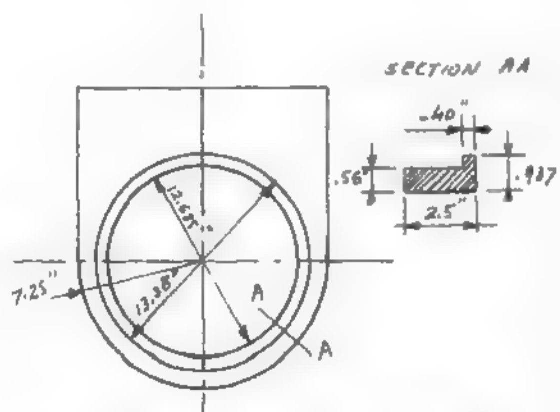
$$M.S: \quad \frac{211500}{4 \times 356} - 1 = \text{———} > 10$$

LUG :

MATERIAL: SAE 1020 STEEL.

Stressing as per Melcon & Hoblit method :

Tension & bearing.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-3 MAIN SUPPORT BEARINGS.

LUG - CONT'D.

Tension.

Ratio : $\frac{Width}{I\,D} = \frac{7.25 \times 2}{13.38} = 1.083$

Coef: $K_t = .99$ from graph n° 12

Tensile stress in the ring. $f_t = \frac{P}{K_t A} = \frac{356 \times 4}{.99 \times 2.5 \times .56} = 1260$ PSI

Bearing :

Ratio : $\frac{\text{edge distance}}{I.D}$. In this case ; concentric lug :

$\therefore$ Ratio $\frac{\text{edge distance}}{I.D.} = \frac{Width}{2\ I.D.} = \frac{1.083}{2} = .5415$

Coef $K_{br} = .10$ from graph n° 13

Bearing stress on the ring : $f_{br} = \frac{P}{K_{br} A} = \frac{356 \times 4}{.10 \times 2.5 \times .56} = 10200$ PSI

Characteristics of material

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

UTS : 55000 PSI UBS : 90000 PSI

YTS : 36000 PSI

MARGINS OF SAFETY

TENSION : $\frac{55000}{1260} - 1 =$ ————— >10

BEARING $\frac{90000}{10200} - 1 =$ ————— 7.8

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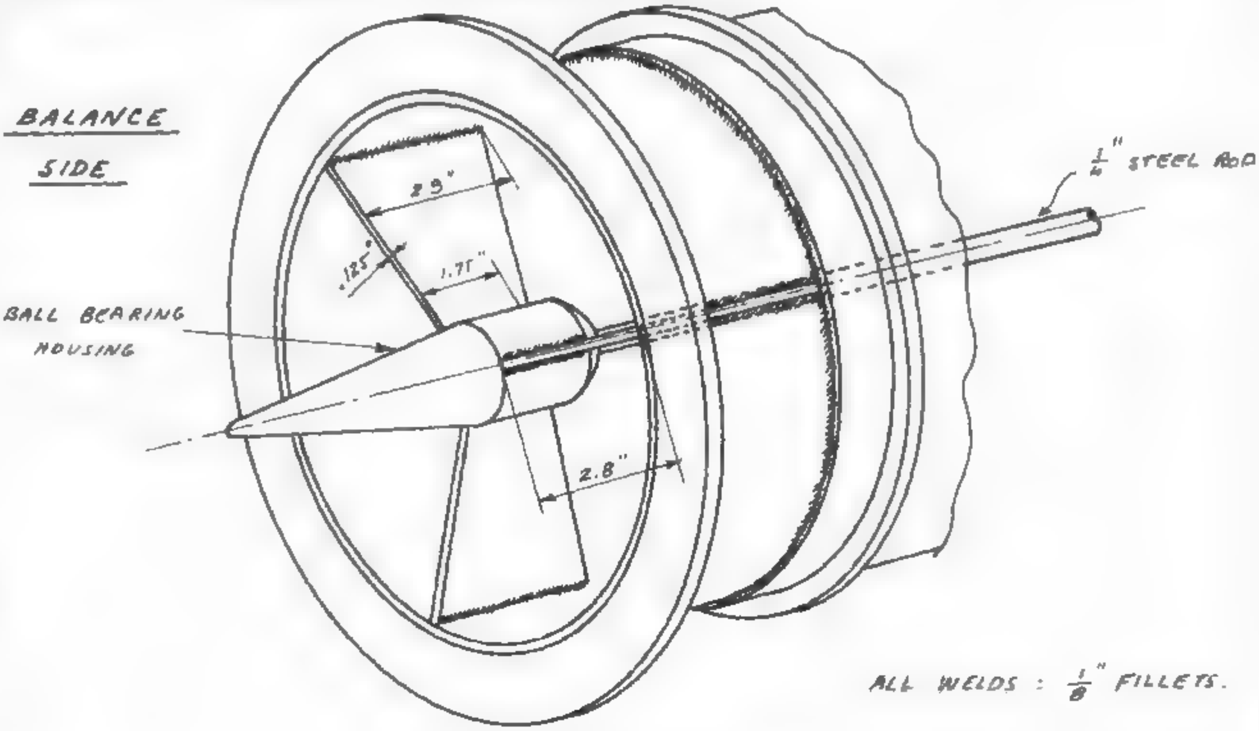
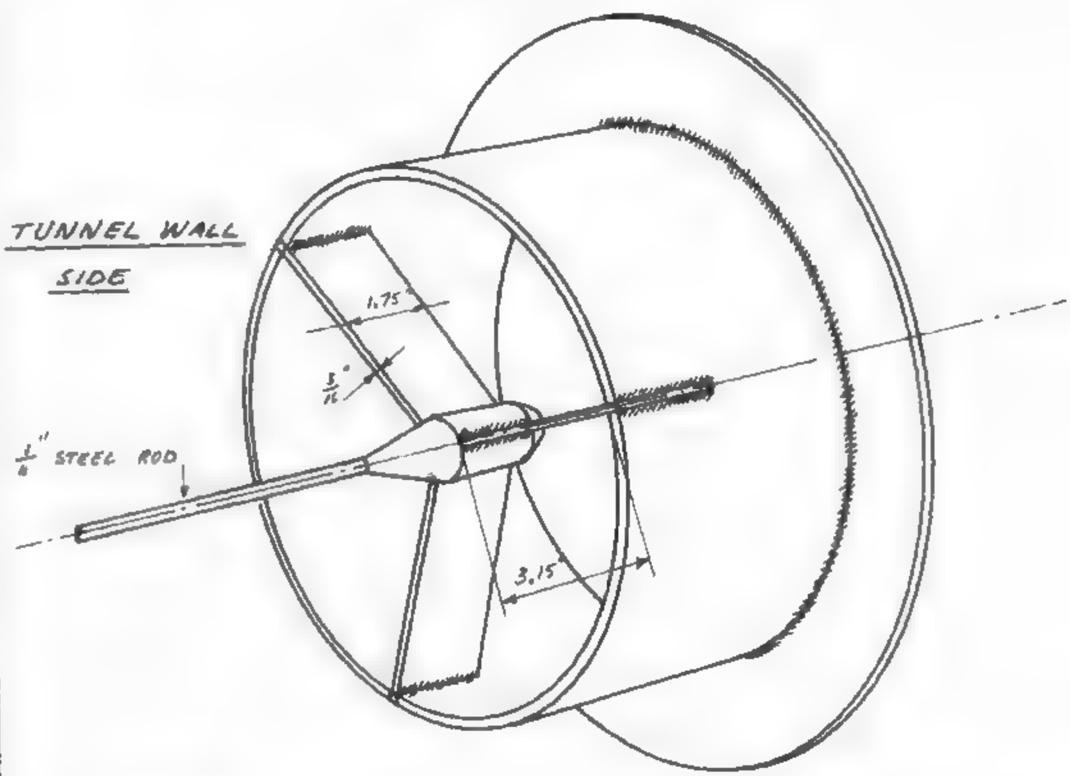
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4 - PRESSURE HOLDING LINK.



ALL WELDS : 1/8" FILLETS.



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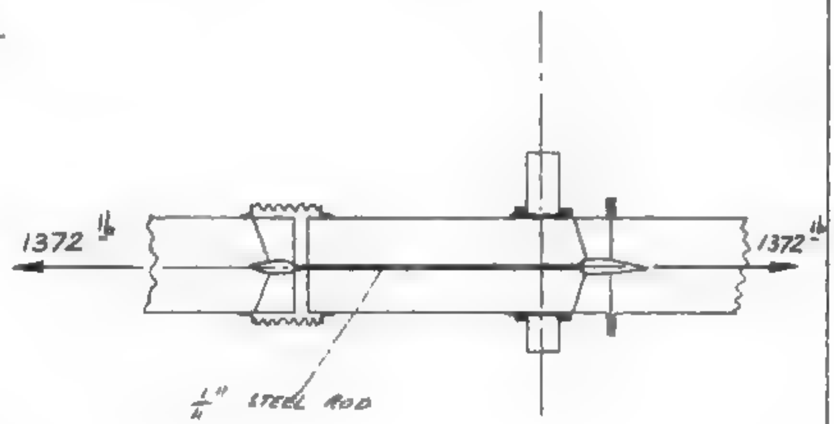
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

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. REF. 4-3 5

FULLY FACTORED LOAD: 1372 × 4 = 5490 lb

Sectional area - $.233^2 \frac{\pi}{4} = .0427 \text{ in}^2$

Tensile stress: $\frac{5490}{.0427} = 128800$ PSI

1 - The rod is made of SAE 4130 steel @ 125000 PSI

M.S. $\frac{125000}{128000} - 1 =$ ——— -.03

ACTUAL M.S. ——— 3.97

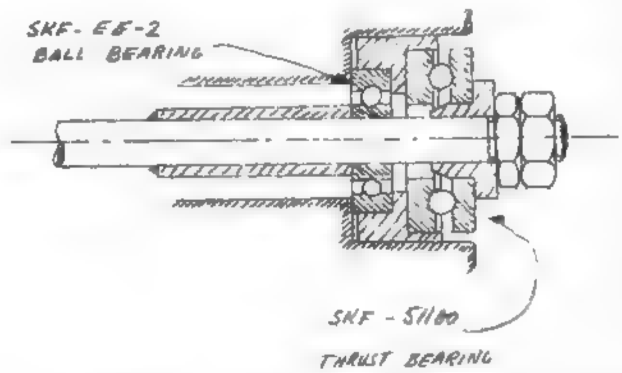
Rod elongation under load: $\frac{1372 \times 24.4}{.0427 \times 30\ 10^6} = .0262"$

BALL BEARINGS CAPACITY

Ref SKF- CATALOG N° 551

EE-2 - Static 216 lb radial
Dynamic: 430 lb radial

51100 - Static 2500 lb axial
Dynamic 1730 lb axial.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-1-4

PRESSURE HOLDING LINK. CONT'D.

SKF - BALL BEARINGS:

According to SKF catalogue N° 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 #: 51100 : the failing load is approx: 2500 × 8 = 20000 lb

$$M.S. \quad \frac{20000}{1372} - 1 = \text{———} \quad 13.5$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.

7-1-4 PRESSURE HOLDING LINK.

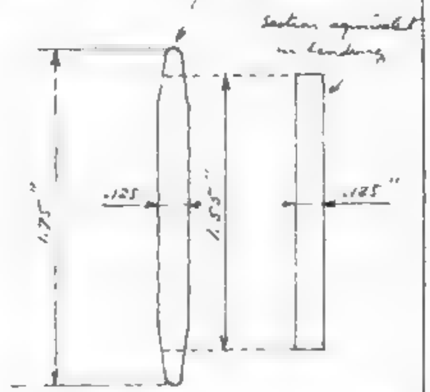
END BRACKETS -

BALANCE SIDE.

Each vane takes $\frac{1}{3}$ of the load.
Each vane is fully fixed on the bearing housing and can also be considered as fully fixed on the tube side since it is welded to two rings

Hence load in the vane $1372 \times \frac{4}{3} = 1830$ lb fully factored.

Max bending moment $1830 \; \frac{2.8}{2} = 2560$ in.lb



Section modulus of vane at small end

$\frac{1.55^2 \times .125}{6} = .050$ in³

Bending Stress: $\frac{2560}{.050} = 51200$ PSI

M.S $\frac{55000}{51200} - 1 =$ .07

WELD FILLETS:

2 fillets, .125" × 1.75" taking 2560 in.lb bending
+ 1830 lb direct shear

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

Weld area: $2 \times .125 \times 1.75 = .437$ in²

direct Shear stress: $\frac{1830}{.437} = 4180$ PSI

Section modulus of weld in shear: $2 \; \frac{1.75^2 \times .125}{6} = .1272$ in³

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STRESS ANALYSIS OF $\frac{1}{12}$ 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

$$\text{max.} \quad \frac{2560}{.1272} = 20150 \text{ PSI}$$

Max shear stress in the weld: $\sqrt{20150^2 + 4180^2} = 20600$ PSI

$$\text{M.S.} \quad \frac{32000}{20600} - 1 = \text{———————} .55$$

TUNNEL WALL SIDE -

Each vane takes $\frac{1}{3}$ of the load

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

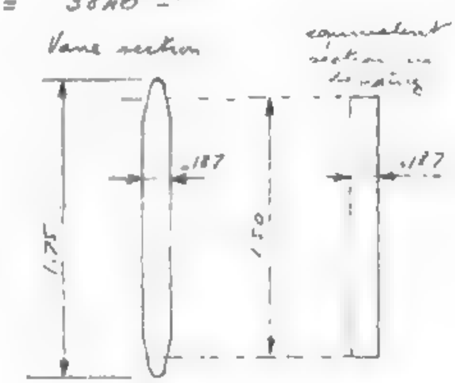
Hence: load on each vane: $1372 \frac{4}{3} = 1830^{lb}$ full. fact

Max Bending Moment

$$1830 \times \frac{2}{3} \times 3.15 = 3840^{in\,lb}$$

Section modulus of the vane:

$$\frac{1.5^2 \times .187}{6} = .0701 \ in^3$$



Max. bending stress

$$\frac{3840}{.0701} = 54800 \text{ PSI}$$

$$\text{M.S.} \quad \frac{55000}{54800} - 1 = \text{———————} .005$$

STRESS ANALYSIS OF $\frac{1}{12}$ 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. .125 × 1.75" taking 3840 in-lb bending + 1830 lb direct shear

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

Weld area: $2 \times .125 \times 1.75 = .437 \text{ in}^2$

Direct shear stress $\frac{1830}{.437} = 4180$ PSI

Section modulus of weld in shear. $2 \frac{1.75^2 \times .125}{6} = .1272 \text{ in}^3$

Shear stress due to bending in the weld:

max: $\frac{3840}{.1272} = 30200$ PSI

Max shear stress in the weld: $\sqrt{30200^2 + 4180^2} = 30500$ PSI

M.S. $\frac{32000}{30500} - 1 = .05$

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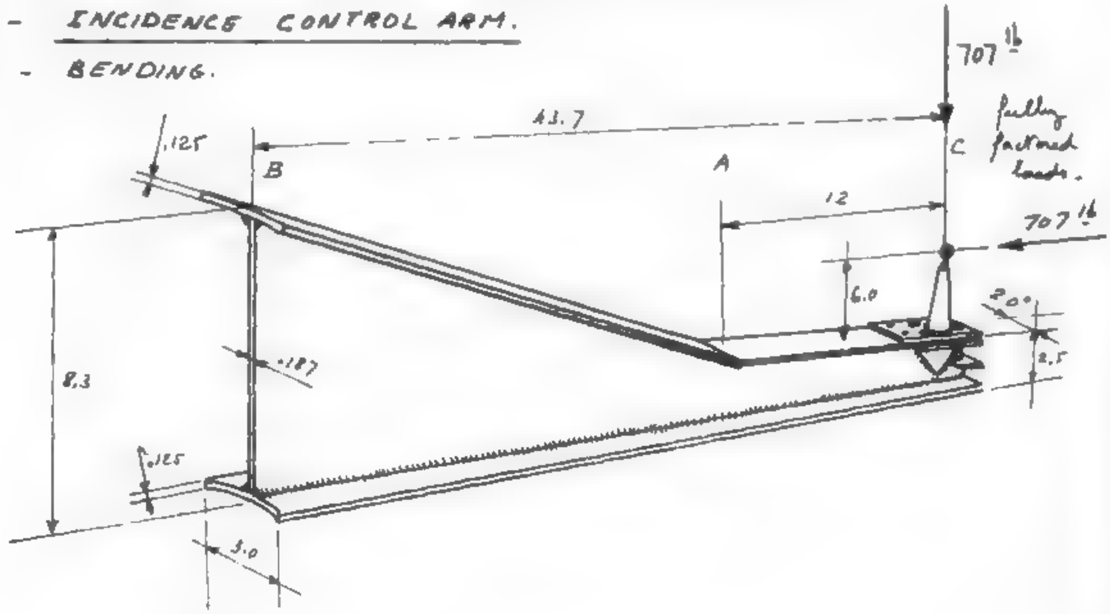
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL-

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2- - INCIDENCE CONTROL ARM.

7-2-1 - BENDING.



Max load on this member is 250 lb when $\alpha = 45°$ and tunnel stopped

Hence: load normal to the arm and fully factored:

$$\frac{250 \times 4}{\sqrt{2}} = 707^{lb}$$

Compression in the arm. $\frac{250 \times 4}{\sqrt{2}} = 707^{lb}$

Bending Moments

$M_C: 707 \times (6 + 2.5 - 1.25) = 707 \times 7.25 = 5120$ in lb

$M_A: 707 \times (6 + 2.5 - 1.25) - (707 \times 12) = 5120 - 8490 = -3360$ in lb

$M_B = 707\,(6 + 2.5 - 4.15) - (707 \times 43.7) = 3075 - 30900 = -27825$ in lb

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL -

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2-1 INCIDENCE CONTROL ARM. - BENDING

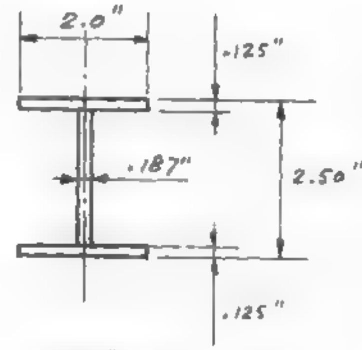
SECTION A & C

Sectional area: $2.5 \times 2 - 2.25 \times 1.813 =$

$5 - 4.08 = .92 \text{ in}^2$

Section modulus $\frac{2.5^2 \times 2 - 2.25^2 \times 1.813}{6} =$

$= \frac{13 - 9.22}{6} = .63 \text{ in}^3$



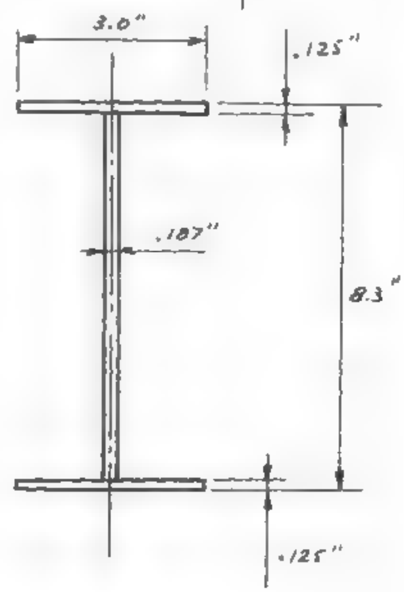
SECTION B

Sectional area: $8.3 \times 3 - 8.05 \times 2.813 =$

$24.9 - 23.4 = 1.5 \text{ in}^2$

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 $\frac{5120}{.63} = 8140$ PSI

Section B: $\frac{27825}{4} = 6960$ PSI

Compression stress

Section C: $\frac{707}{.92} = 768$ PSI

Section B $\frac{707}{1.5} = 472$ PSI

Total max stresses

Section C: $8140 + 768 = 8908$ PSI

Section B: $6960 + 472 = 7432$ PSI

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 - STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2- - INCIDENCE CONTROL ARM.

7-2-1 - BENDING

MARGIN OF SAFETY -

Section C $\frac{55000}{8908} - 1 =$ ———————— 5.18

Section B : $\frac{55000}{7432} - 1 =$ ———————— 7.40

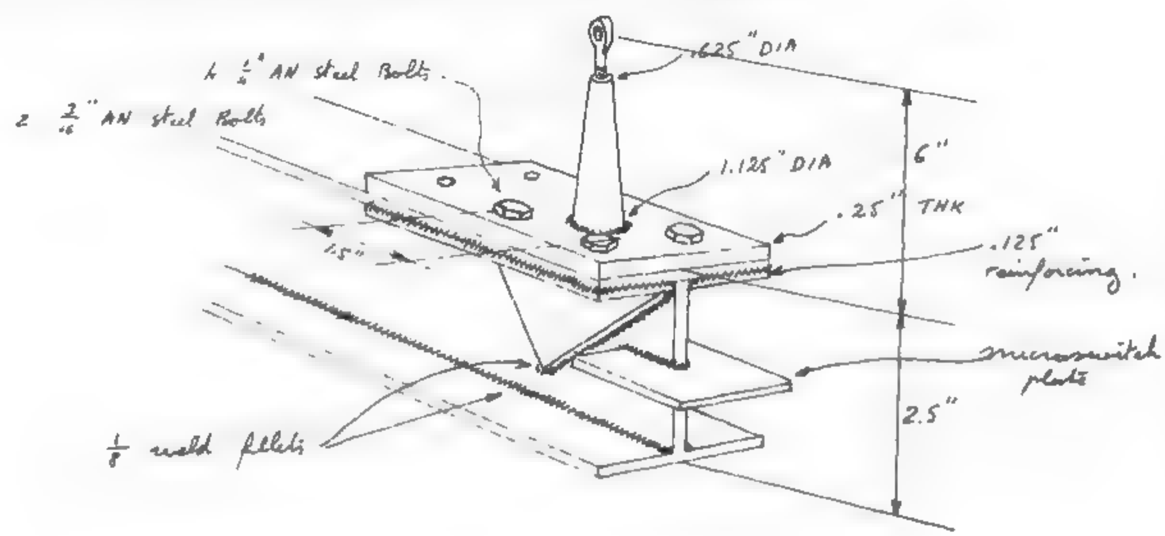
WELD FILLETS - AT SECTION B

The stresses are the same as those calculated at section B.
The strength of the weld metal is 51000

M.S: $\frac{51000}{7432} - 1 =$ ———————— 5.87

7-2-2

ATTACHMENT LINK TO BALANCE STRUT.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2 INCIDENCE CONTROL ARM.

7-2-2

ATTACHMENT LINK - CONT'D

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

Bending moment · $707 \times 6 = 4242$ in-lb

Section modulus : $\frac{\pi}{32} D^3 = .0984 \times 1.125^3 = .0984 \times 1.424 = .14$ in³

Sectional area : $\frac{\pi}{4} D^2 = \frac{\pi}{4} \times 1.125^2 = 1.0$ in²

Bending stress : $\frac{4242}{.14} = 30300$ PSI

Compression stress : $\frac{707}{1.0} = 707$ PSI

Total max. comp. stress : $30300 + 707 = 31007$ PSI

$$M.S \quad \frac{55000}{31007} - 1 = \text{———} .77$$

WELD FILLETS -

2 FILLETS $\frac{1}{8}$" wide

Consider the fillets as rings having $\frac{1}{8}$" width and a mean dia. of 1.125"
$\therefore D = 1.25"$ $d = 1.00"$

Sectional area : $\frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}(1.25^2 - 1^2) = \frac{\pi}{4} \times .56 = .440$ in²

Section modulus $\frac{\pi}{32}\left(\frac{D^4 - d^4}{D}\right) = .0984\left(\frac{1.25^4 - 1^4}{1.25}\right) = .0984 \times \frac{2.44}{1.25} = .092$ in³

Hence, for both sections

$$A = .44 \times 2 = .88 \text{ in}^2$$
$$Z = .092 \times 2 = .184 \text{ in}^3$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS – MODEL SUPPORT STRUCTURE

7-2 INCIDENCE CONTROL ARM.

7-2-2

ATTACHMENT LINK – CONT'D.

WELD FILLETS – CONT'D.

Bending stress in the fillet $\frac{4242}{.184} = 23100$ PSI

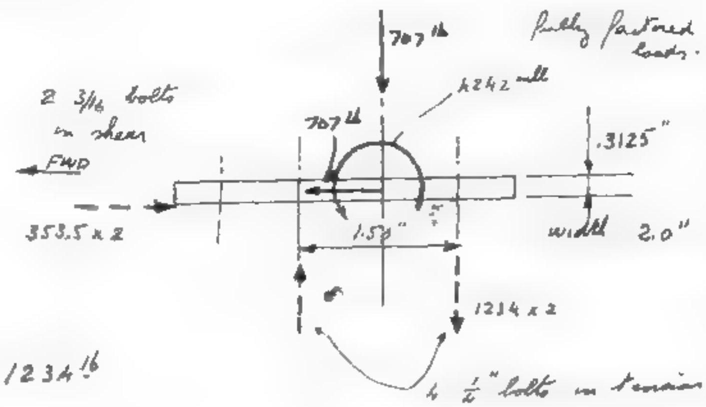
Compression stress in the fillet $\frac{707}{.88} = 804$ PSI

Total max comp. stress $23100 + 804 = 23904$ PSI

M.S. $\frac{51000}{23904} - 1 =$ ———— 1.13

7-2-3

BASE PLATE.



Shear per 3/16 bolt:
$\frac{707}{2} = 353.5$ lb

Tension on aft bolts
$= \frac{4242}{2 \times 1.5} - \frac{707}{4} = 1410 - 176 = 1234$ lb

Strength of AN 3 steel bolts in shear 2070 lb (AN-C 5)

M.S. $\frac{2070}{353.5} - 1 =$ ———— 4.85

Strength of AN-4 steel bolts in tension 4080 lb (AN-C-5)

M.S. $\frac{4080}{1234} - 1 =$ ———— 2.3

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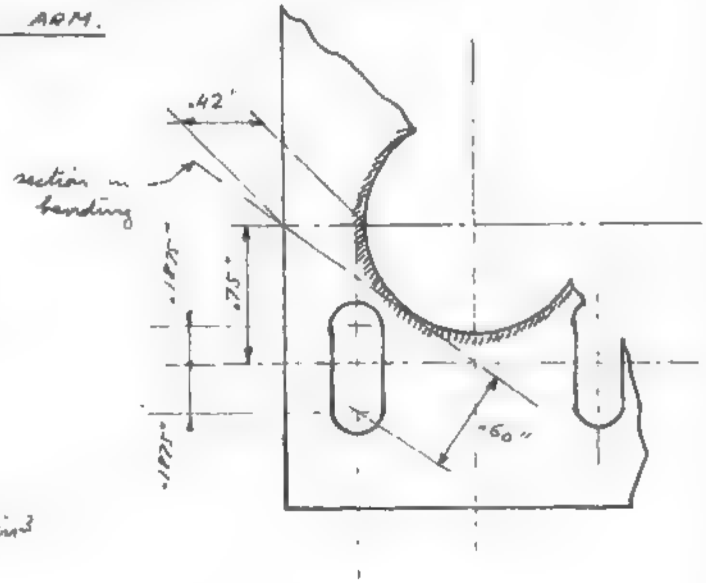
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

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 1.20" thickness .3125"

Section modulus:

$$\frac{.3125^2 \times 1.2}{6} = .0195 \text{ in}^3$$

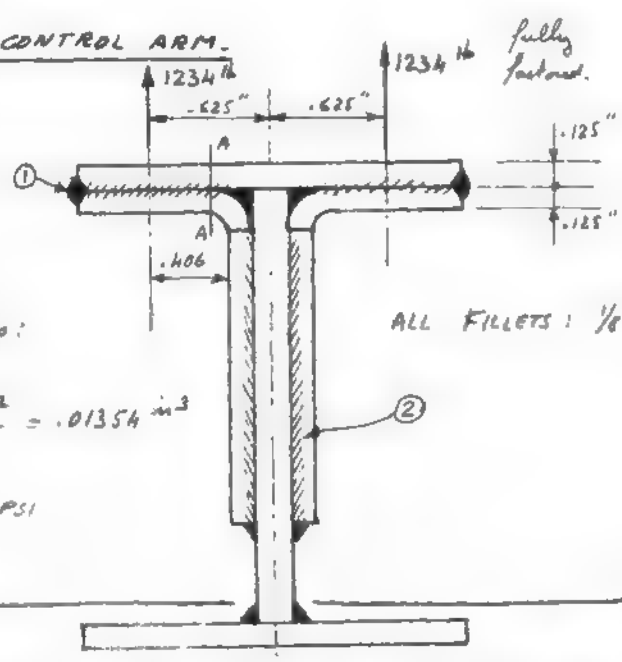
Bending moment: $1234 \times .6 = 740$ in lb. fully factored

Max bending stress: $\frac{740}{.0195} = 38000$ PSI

M.S. $\frac{55000}{38000} - 1 =$ .44

7-2-4

LOCAL REINFORCMENT OF THE CONTROL ARM.



Bending moment at section AA.
$1234 \times .406 = 501$ in lb

Consider a section in bending 1.30" long. made of 2 .125" plates:

Section modulus: $1.30 \times \frac{.25^2}{6} = .01354 \text{ in}^3$

Bending stress: $\frac{501}{.01354} = 37000$ PSI

M.S. $\frac{55000}{37000} - 1 =$ .48

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-2- INCIDENCE CONTROL ARM.

7-2-4

LOCAL REINFORCMENTS - CONT'D.

SHEAR STRESS IN FILLET Nº ①

Area of fillet in shear: $.125 \times 2.00 = .25 \text{ in}^2$

Shear on this section: $1.5 \frac{W}{h} = 1.5 \frac{1234}{.25} = 7410$ lb fully fact.

Shear stress in the weld.

$$\frac{7410}{.25} = 29600 \text{ PSI}$$

$$M.S. \quad \frac{32000}{29600} - 1 = \text{———} .083$$

NOTE The length of weld has been taken as 1.30" along the length + .70" across the back

SHEAR STRESS IN FILLET Nº ②

It is assumed that ½ of the load is introduced in the 3/16" web by the upper ⅛" 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: $3.0 \times .125 = .375 \text{ in}^2$

fully factored load $\frac{1234}{2} = 617$ lb

Shear stress in the weld: $\frac{617}{.375} = 16500 \text{ PSI}$

$$M.S. \quad \frac{31000}{16500} - 1 = \text{———} .88$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

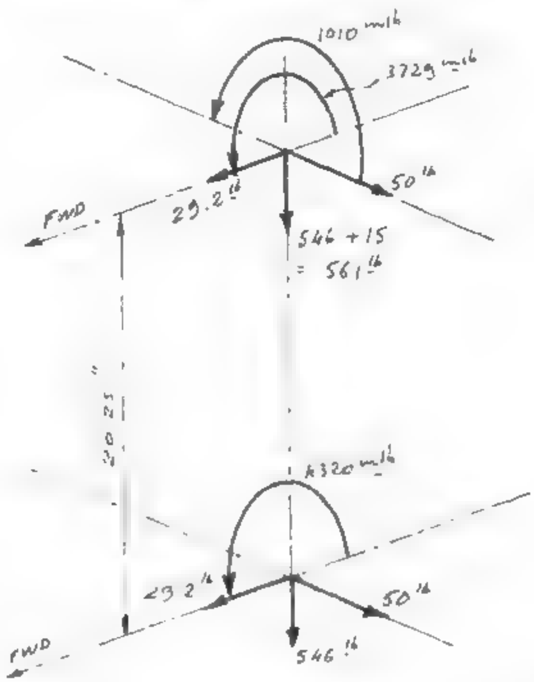
7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3- TAPERED SECTION OF VERTICAL ARM.

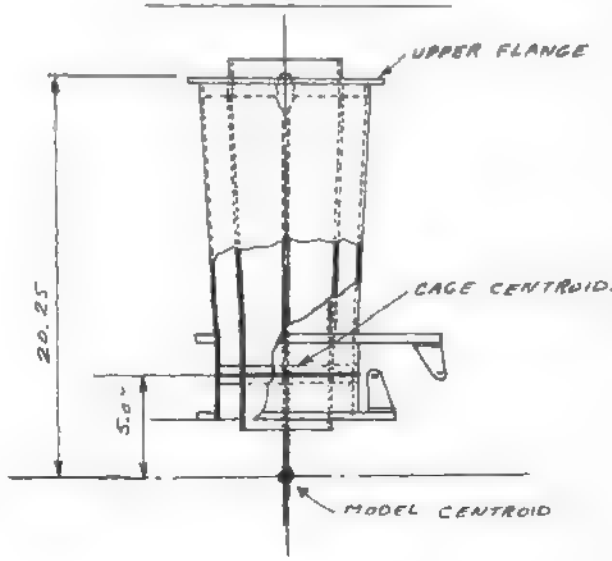
7-3-1 UPPER FLANGE.

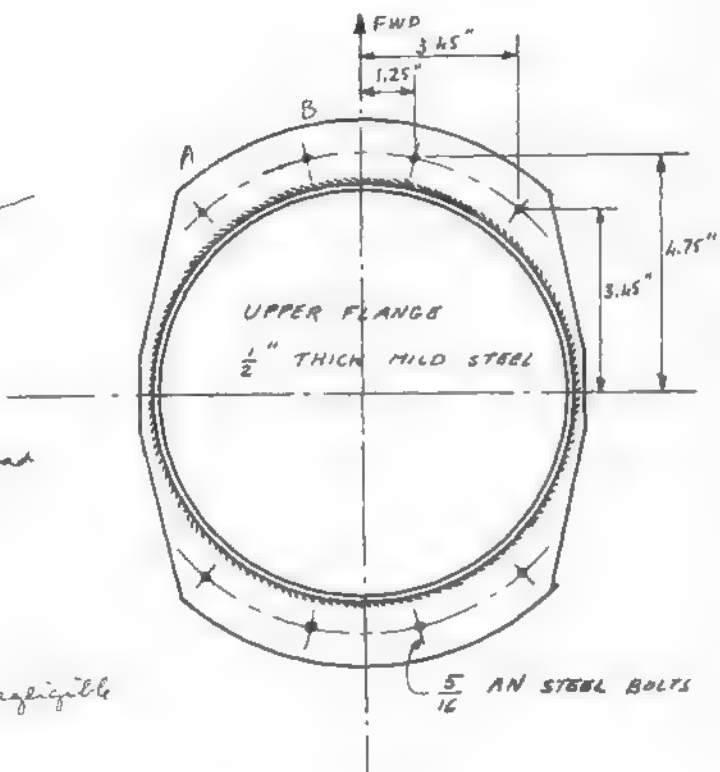
Considering the same cases as for the gauge (Section 6) and resolving at the upper flange.

−10° Case is the stressing case



REMOVABLE SECTION





Load per bolt due to Vertical load

$\frac{561}{8} = 70.2^{lb}$ tension

Total shear on the bolts.

$\sqrt{29.2^2 + 50^2} = 57^{lb}$

Shear per bolt $\frac{57}{8} = 7.25^{lb}$ negligible

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7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE.

7-3-

TAPERED SECTION OF VERTICAL ARM - CONT'D.

7-3-1 UPPER FLANGE

Loads on the bolts due to moments.
The bolts are stressed as clusters under tension & compression

Longitudinal moment

Load on bolt B. $\frac{M \times 4.75}{4 \times (4.75^2 + 3.45^2)} = 1.188 \frac{M}{34.5} = .0344\ M$
$= .0344 \times 4320 = 148.5^{lb}$

Load on bolt A: $\frac{M \times 3.45}{4 (4.75^2 + 3.45^2)} = .0250\ M$
$= .025 \times 4320 = 108^{lb}$

Transversal moment

Load on bolt A: $\frac{M \times 3.45}{4(3.45^2 + 1.25^2)} = .862 \frac{M}{13.46} = .064\ M$
$= .064 \times 1010 = 63.4^{lb}$

Load on bolt B: $\frac{M \times 1.25}{4(3.45^2 + 1.25^2)} = .0232\ M$
$= .0232 \times 1010 = 23.4^{lb}$

Total max. load is on bolt: A = 108 + 63.4 = 171.4^{lb} tension
B = 148.5 + 23.4 = 171.9^{lb} tension

say 172^{lb} + 70.2^{lb} from direct load on previous page

Total unfactored load on one $\frac{5}{16}$ AN bolt. 172 + 70.2 = 242.2^{lb}

With factor of 4: 242.2 × 4 = 968.8^{lb}

Strength of bolt in tension. Ref AN-C-5: 6500^{lb}

$M.S. = \frac{6500}{968.8} - 1 = $ ———————— 5.7

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

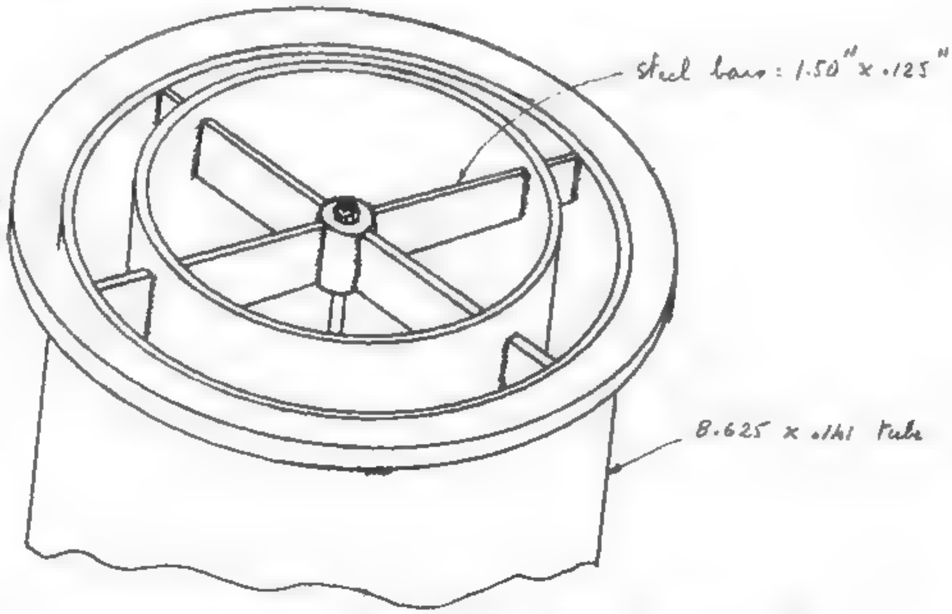
7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3- TAPERED SECTION OF VERTICAL ARM.

7-3-2

CRUCIFORM BRACKET.

MODEL SUSPENSION ROD ATTACHMENT.



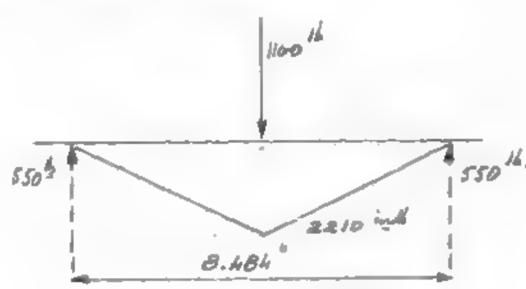
This bracket is stressed to have the same strength than the rod in tension

Strength of the rod: taking strength of equivalent $\frac{3}{16}$ AN Bolt @ 125000 PSI - 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:

$$\frac{1.5^2 \times .125}{6} = .0468 \text{ in}^3$$

Bending stress:

$$\frac{2210}{.0468} = 47250 \text{ PSI}$$

$$M.S. \quad \frac{55000}{47250} - 1 = +.160$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3- TAPERED SECTION OF VERTICAL ARM

7-3-2 CRUCIFORM BRACKET.

WELD FILLETS ON HUB.

2 $\frac{1}{8}$" fillets : .125 x 1.5" taking 2210 in-lb bending
+ 550 lb direct shear

Weld section area: $2 \times .125 \times 1.5 = .375$ in²

Direct shear stress. $\frac{550}{.375} = 1470$ PSI

Section modulus of weld in shear.

$2 \times \frac{1.5^2 \times .125}{6} = .0937$ in³

Shear stress due to bending: $\frac{2210}{.0937} = 26600$ PSI

Total max shear stress: $\sqrt{26600^2 + 1470^2} = 26650$ PSI

M.S $\frac{32000}{26650} - 1 =$ .20

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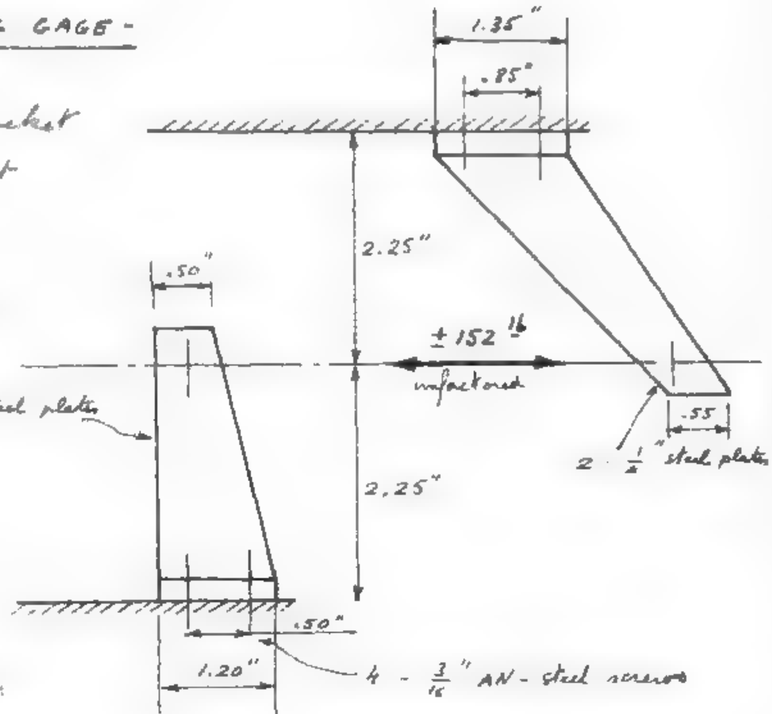
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

7-0 STRESS ANALYSIS - MODEL SUPPORT STRUCTURE

7-3- TAPERED SECTION OF VERTICAL ARM-

7-3-3 BRACKETS ATTACHING DRAG GAGE-



Stressing of the lower bracket will cover the upper bracket

Bending Moment at root
$152 \times 2.25 = 342$ in-lb (LIM.)

Section in bending: 2 - $\frac{1}{4}$" steel plates
2 sections: 1.20" × .25"

$Z = \frac{2}{6}(1.20^2 \times .25) = .12$ in^3

Bending stress, fully factored:
$4 \; \frac{342}{.12} = 11400$ PSI (ULT.)

M.S.: $\frac{55000}{11400} - 1 =$ ——— 3.82

Load on attachment screws
$\frac{1}{2} \; 342 \; \frac{4}{.5} = 1370$ lb ULT.

strength of $\frac{3}{16}$" AN screws in tension: Ref. AN-C-5: 2160 lb

M.S.: $\frac{2160}{1370} - 1 =$ ——— .57

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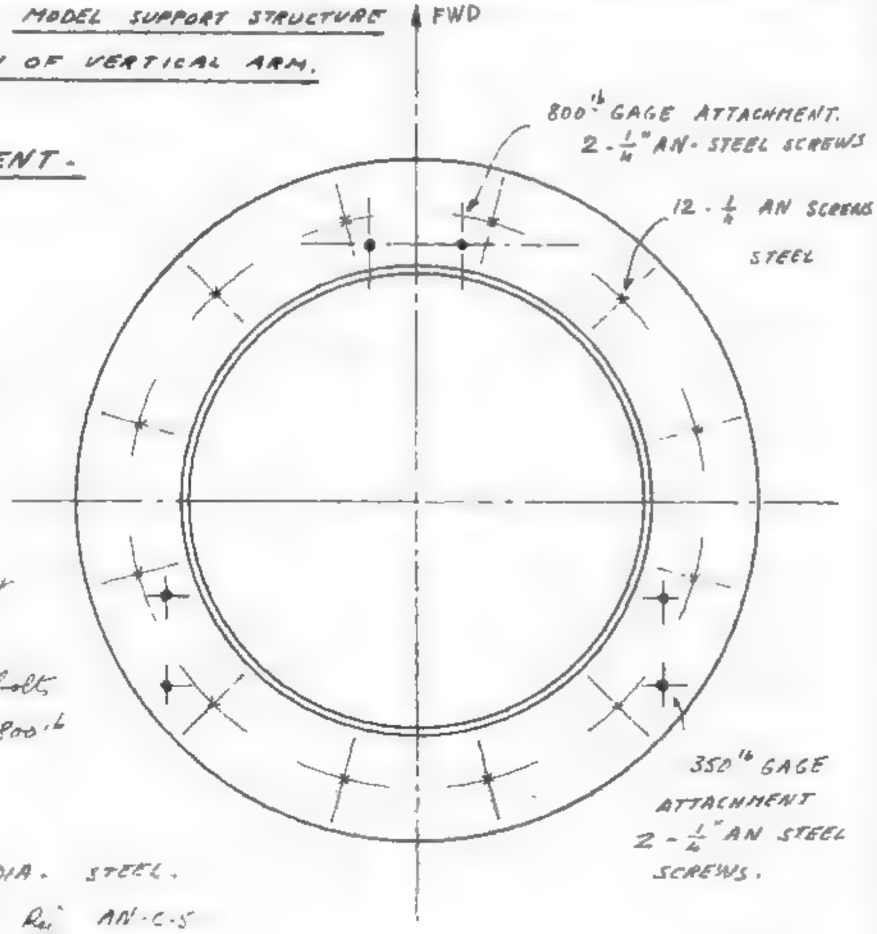
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

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 gage attachment

Thus, the attachment can be covered by considering the two bolts taking the load of the 800 lb gage.

2 AN - SCREWS - 1/4" DIA. STEEL.
MAX Tensile Strength Ref AN-C-5
4080 x 2 = 8160 lb

Factored load: 800 x 4 = 3200 lb

$$M.S. \quad \frac{8160}{3200} - 1 = \text{———} \; 1.55$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

B-0 STRESS ANALYSIS - FAIRING

B-1

HORIZONTAL TUBE.

B-1-1 BENDING.

Section properties of the tube:

Size: 10" x .141" ID = 9.718"

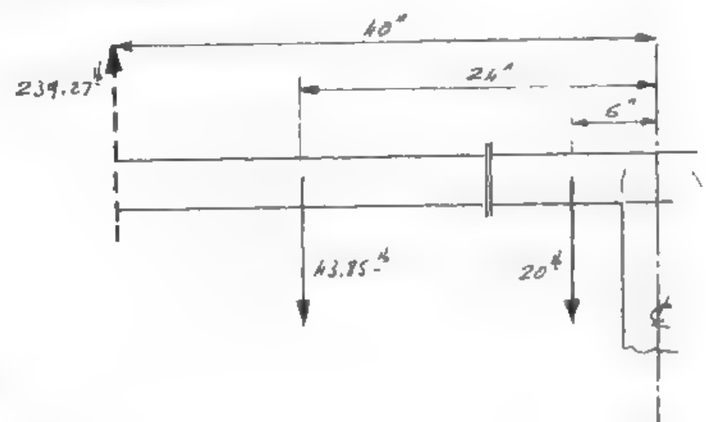
Sectional area: $A = \frac{\pi}{4}\left(10^2 - 9.718^2\right) = 3.53 \text{ in}^2$

Moment of inertia: $I = \frac{\pi}{64}\left(10^4 - 9.718^4\right) = 54 \text{ in}^4$

Section modulus: $Z = \frac{\pi}{32} \frac{10^4 - 9.718^4}{10} = 10.8 \text{ in}^3$

Stresses under static load + airloads:

Bending moment under static loads:



Bending moment at ℄

$M = (239.27 \times 40) - (43.85 \times 24) - (20 \times 6) =$
$9560 - 1052 - 120 = 8388 \text{ in lb}$

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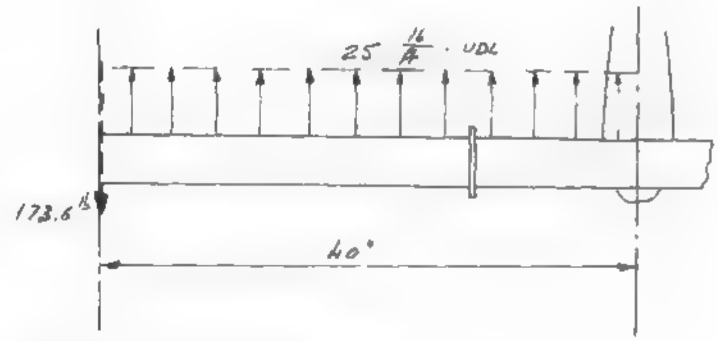
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

B.0 STRESS ANALYSIS - FAIRING.

B-1 HORIZONTAL TUBE

B-1-1 BENDING.

Bending moment under airload



Bending moment

$$M = 173.6 \times 40 - 25 \frac{40^2}{2 \times 12} = 6940 - 1666 = 5274 \text{ in.lb}$$

Total Bending moment on the section.

$$M_T = \sqrt{8388^2 + 5274^2} = 9870 \text{ in.lb} \quad (\text{LIM})$$

Bending stress : max.

$$4 \frac{9870}{10.8} = 3660 \text{ PSI} \quad (\text{ULT})$$

$$\text{M.S} \quad \frac{55000}{3660} - 1 = \quad > 10$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

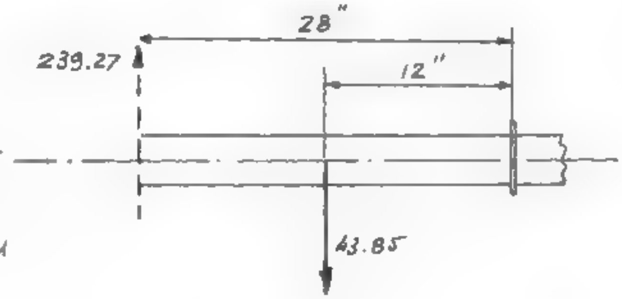
8-0 STRESS ANALYSIS - FAIRING

8-1 HORIZONTAL TUBE

8-1-2

FLANGES ON 10" TUBE.

FLANGE LOADING.



STATIC LOADS : VERTICAL

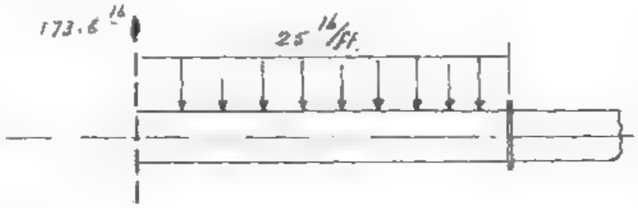
Bending moment at flange section:

$(239.27 \times 28) - (43.85 \times 12) =$

$6700 - 527 = 6173$ in lb unfactored

Shear force:

$239.27 - 43.85 = 195.42$ lb unfactored



AIR LOADS HORIZONTAL

Bending moment at flange section

$(173.6 \times 28) - 25 \dfrac{28^2}{12 \times 2} =$

$4860 - 815 = 4045$ in lb unfactored

Shear force.

$173.6 - 25 \dfrac{28}{12} = 173.6 - 58.3 = 115.3$ lb unfactored.

TOTAL BENDING MOMENT:

$\sqrt{6173^2 + 4045^2} = 7380$ in lb unfactored.

Total Shear force

$\sqrt{195.42^2 + 115.3^2} = 226$ lb unfactored

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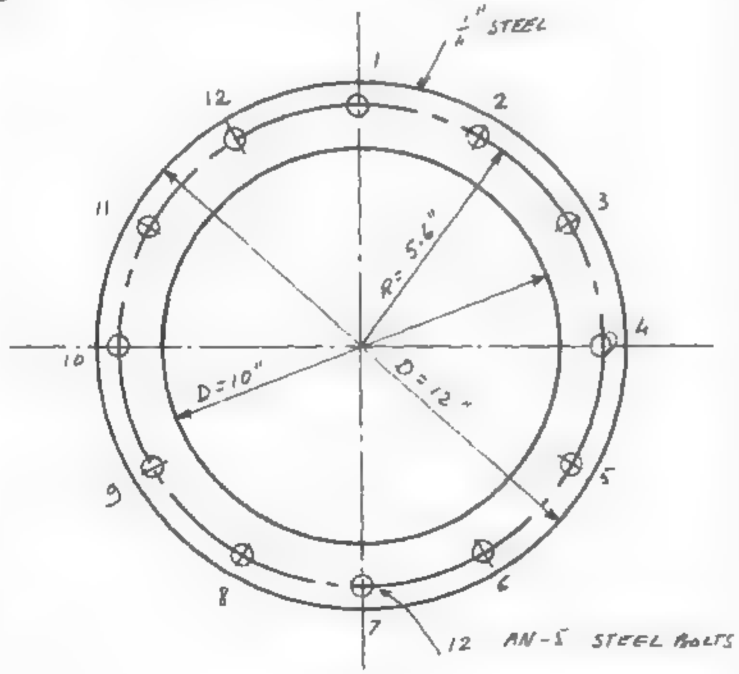
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

8-0 STRESS ANALYSIS - FAIRING

B-1 HORIZONTAL TUBE

B-1-2.

FLANGES ON 10" TUBE -



Bolt strength in tension
Ref AN-C-5.
AN-5 - $\frac{5}{16}$" DIA. : 6500 lb

Bolt strength in Shear
AN-5 - $\frac{5}{16}$" DIA : 5750 lb

Distribution of tensions due to bending in the bolt cluster

$$F_j = M \frac{d_j}{\Sigma d^2}$$

Considering only the bolt having greatest tension

$$\Sigma d^2 = 5.6^2 \left[2 + 4 \sin^2 60^\circ + 4 \sin^2 30^\circ\right]$$

$$\therefore \quad F = \frac{M}{5.6\left[2 + 4\sin^2 60^\circ + 4 \sin^2 30^\circ\right]} \quad \text{for } d_j = 5.6. \qquad F = .0298\ M$$

$$\therefore F = 7380 \times .0298 = 220 \text{ lb} \quad \text{unfactored}$$

Shear per bolt: $\frac{226}{12} = 18.85$ lb unfactored.

Such low shear does not practically reduce the tensile strength

$$\therefore \qquad M.S \qquad \frac{6500}{4 \times 220} - 1 = \text{———————} 6.4$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

B-0 STRESS ANALYSIS - FAIRING

B-1 HORIZONTAL TUBE

B-1-2

FLANGES ON 10" TUBE.

WELDS.

Assume max load on bolt to be taken by 2" of $\frac{1}{4}$" weld.

Weld area: $2 \times .25 = .50 \text{ in}^2$

Allowable U.S.S. of weld metal 32000 PSI (Ref. AN-C-5)

Weld stress: $\frac{220}{.50} = 440$ PSI unfactored

$$M.S \quad \frac{32000}{4 \times 440} - 1 = \text{———} > 10$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

8-0 STRESS ANALYSIS - FAIRING.

8.2 VERTICAL FAIRING

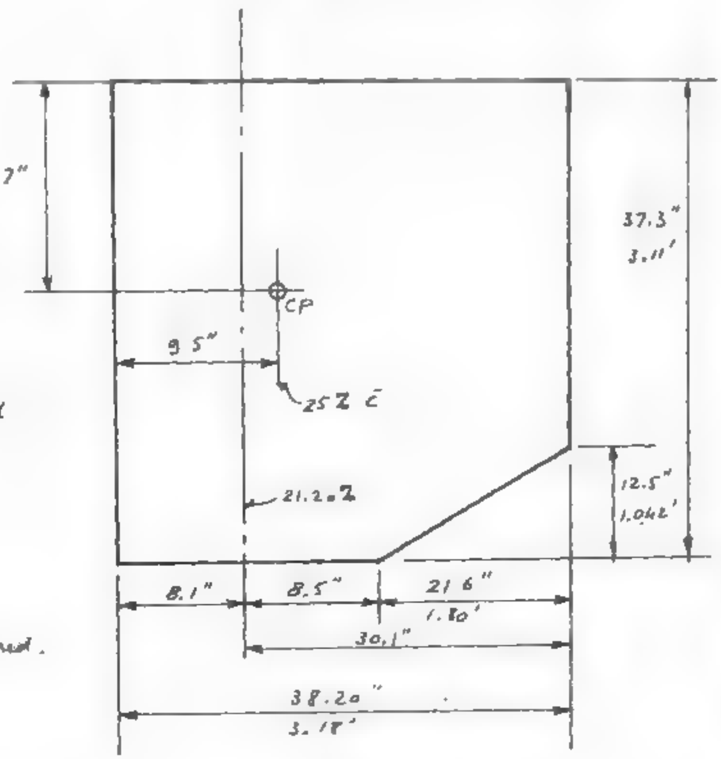
8-2-1 - LOADING.

MAT. AL.ALLOY. .064".

AREA:

$\left(3.11 \times 3.18\right) - \left(\frac{1.80 \times 1.042}{2}\right) =$

$9.88 - .94 = 8.94\ ft^2$



Side load on fairing.

C_L @ 5° ≃ .50

Total load at 30 q.

$.50 \times 8.94 \times 30 = 134^{lb}$ unfactored

Aft load on fairing:

C_D @ 5° ≃ .30

Total load at 30 q:

$.30 \times 8.94 \times 30 = 80.5^{lb}$ unfactored.

Fully factored loads: (n = 4)

Side load: $134 \times 4 = 536^{lb}$

Drag load: $80.5 \times 4 = 322^{lb}$

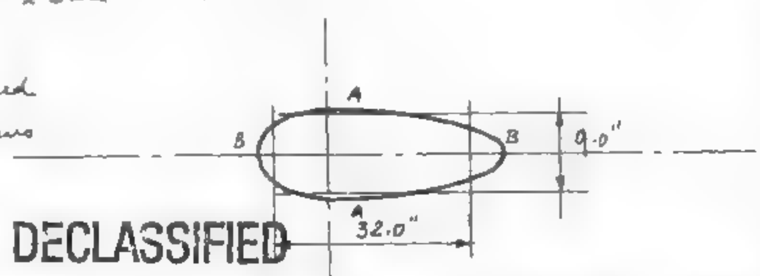
Assuming CP at 25% chord and ½ span

Moments at root

SIDE MOMENT: $18.7 \times 536 = 10000$ in.lb

AFT MOMENT: $18.7 \times 322 = 6020$ in.lb

These moments are considered as taken by groups of screws as shown on sketch.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

B-0 STRESS ANALYSIS - FAIRING.

B-2 VERTICAL FAIRING.

B-2-2 - VERTICAL FAIRING ATTACHMENT.

Loads on groups of rivets.

RIVETS AA: $\frac{10000}{9} = 1120^{lb}$

RIVETS BB: $\frac{6020}{32} = 201^{lb}$

Bearing strength of -AD $\frac{5}{32}$" rivets on .064" 3S-½H al alloy

In the absence of exact data regarding the max. allowable bearing stress on 3S-½H, this stress is taken as being twice the UTS by comparison with other similar soft al. all.

UTS. = 20 000 PSI (Ref. Engineering Manual)

∴ UBS = 2 × 20000 = 40 000 PSI.

Bearing strength on .064 (AN-C-5) for $\frac{e}{D} = 2.0$

$$1020 \ \frac{40000}{100000} = 408^{lb}$$

The 1120^{lb} load is to be taken by rivets at 2.00" pitch and a length of: 12" will be interested to take this load. Hence 6 rivets having a total strength of: $6 \times 408 = 2448^{lb}$

$$M.S \quad \frac{2448}{1120} - 1 = 1.19$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

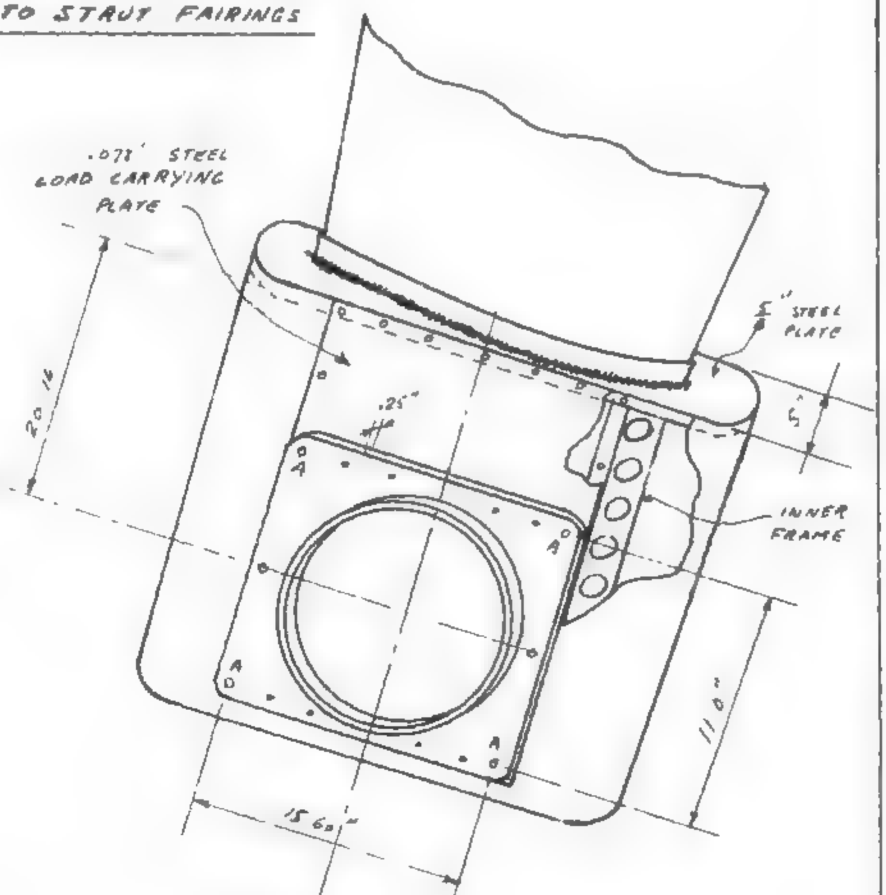
8-0 STRESS ANALYSIS - FAIRING

8-3 ATTACHMENT TO STRUT FAIRINGS

8-3-1 LOADING.

NOTE Bolts "A" join flanges on both sides and are blocked tight on a tube spacer

Flanges offset to load carrying plate:
inner flange .95"
outer flange 1.50"



APPLIED LOADS:

On the inner side where loading is max

- 240 lb Vertically down.
- 174 lb Horizontally aft.
- 80.5 lb Side load due to Vertical fairing

} unfactored

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 stressing, only load on the inner side will be considered

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STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

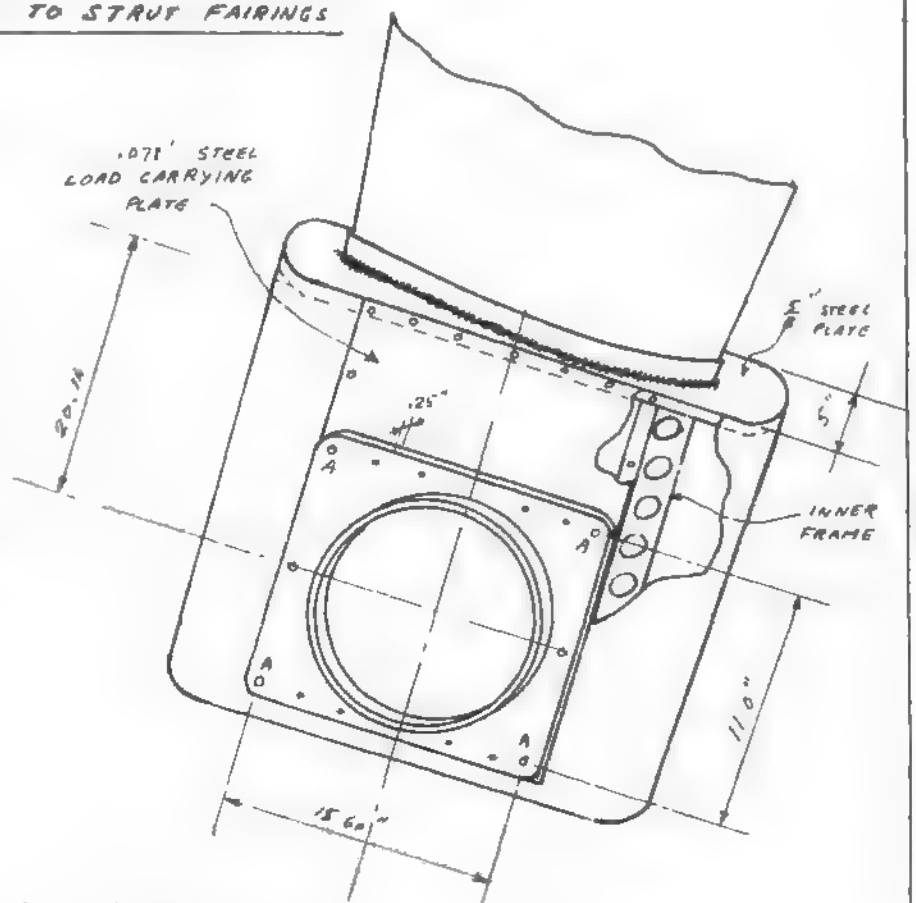
8-0 STRESS ANALYSIS - FAIRING

8-3 ATTACHMENT TO STRUT FAIRINGS

8-3-1 LOADING.

NOTE: Bolts "A" join flanges on both sides and are blocked tight on a tube spacer

Flanges offset to load carrying plate:
inner flange .95"
outer flange 1.50"



APPLIED LOADS:

On the inner side where loading is max

240 lb Vertically down.
174 lb Horizontally aft.
80.5 lb Side load due to Vertical fairing
} unfactored.

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 stressing, only load on the inner side will be considered.

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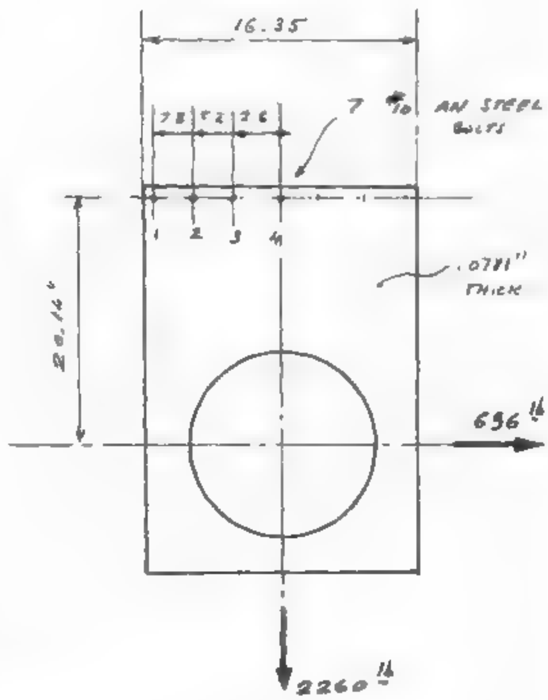
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

8-0 STRESS ANALYSIS - FAIRING

8-3 ATTACHMENT TO STRUT FAIRING

8-3-2

LOAD CARRYING STEEL PLATE -



Max. Vertical load

$$960 + 322\ \frac{20.14}{5} = 960 + 1300 = 2260^{lb}$$

Load per bolt due to 2260 lb

$$\frac{2260}{7} = 323^{lb}$$

Load per bolt due to side load.

$$\frac{696}{7} = 99.4^{lb}$$

Load on bolts due to moment of side load:

Moment: $696 \times 20.14 = 14000$ in lb

Load on bolt 1

$$14000\ \frac{7.8}{(7.8^2 + 5.2^2 + 2.6^2)2} = 14000\ \frac{7.8}{189.6} = 73.9 \times 7.8 = 577^{lb} \text{ Vertical}$$

Load on bolt 2 : $73.9 \times 5.2 = 384^{lb}$ Vertical

Load on bolt 3 . $73.9 \times 2.6 = 192^{lb}$ Vertical

Total load on bolt 1 : $\sqrt{(323 + 577)^2 + 99.4^2} = 905^{lb}$

Strength of bolt in shear Ref AN-C-5 2126 lb

$$M.S\ \ \frac{2126}{905} - 1 = \text{———} \ 1.34$$

Steel plate: Strength of a 1" strip under tension at UTS 55000 PSI

$1" \times .0781 \times 55000 = 4300^{lb}$

Assuming a 1" strip carries the load to bolt 1.

$$M.S\ \ \frac{4300}{905} - 1 = \text{———} \ 3.75$$

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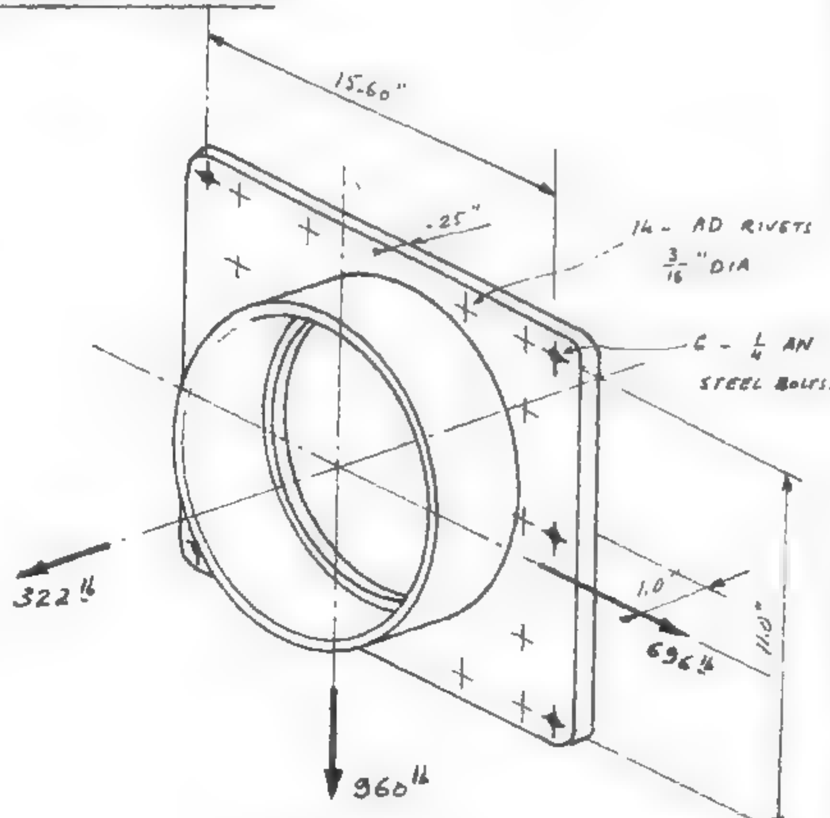
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

B-0 STRESS ANALYSIS - FAIRING

B-3 ATTACHMENT TO STRUT FAIRINGS

B-3-3.

BEARING FLANGES



Fully factored loads.

Load per bolt due to 322 lb Tension:

$\frac{322}{6} = 53.7$ lb

Tension on upper bolts due to moment of Vertical load.

$960 \frac{1}{11.0} \times \frac{1}{2} = 43.6$ lb

Tension on side bolts due to moment of Horizontal load

$696 \frac{1}{15.6} \frac{1}{3} = 14.9$ lb

Max tension on one bolt: $53.7 + 43.6 + 14.9 = 112.2$ lb

Total shear strength of the assembly. (Bearing not critical!) Ref AN-C-5

$(6 \times 3680) + (14 \times 862) = 22100 + 12050 = 34150$ lb

Shear per bolt: $V \frac{3680}{34150} = .108\ V$

Total Shear force: $\sqrt{960^2 + 696^2} = 1182$ lb

Shear per bolt: $1182 \times .108 = 128$ lb

Strength of $\frac{1}{4}$ AN steel bolt. (AN-C-5) Tension 4080 lb

Shear 3680

M.S. ——————— >10

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STRESS ANALYSIS OF $\frac{1}{12}$ 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: .25" × 8"

Section modulus. $.25^2 \frac{8}{6}$ = .0832 in³

Bending stress: $\frac{112.2 \times 4.0}{.0832}$ = 5400 PSI

M.S. $\frac{55000}{5400} - 1$ = 9.2

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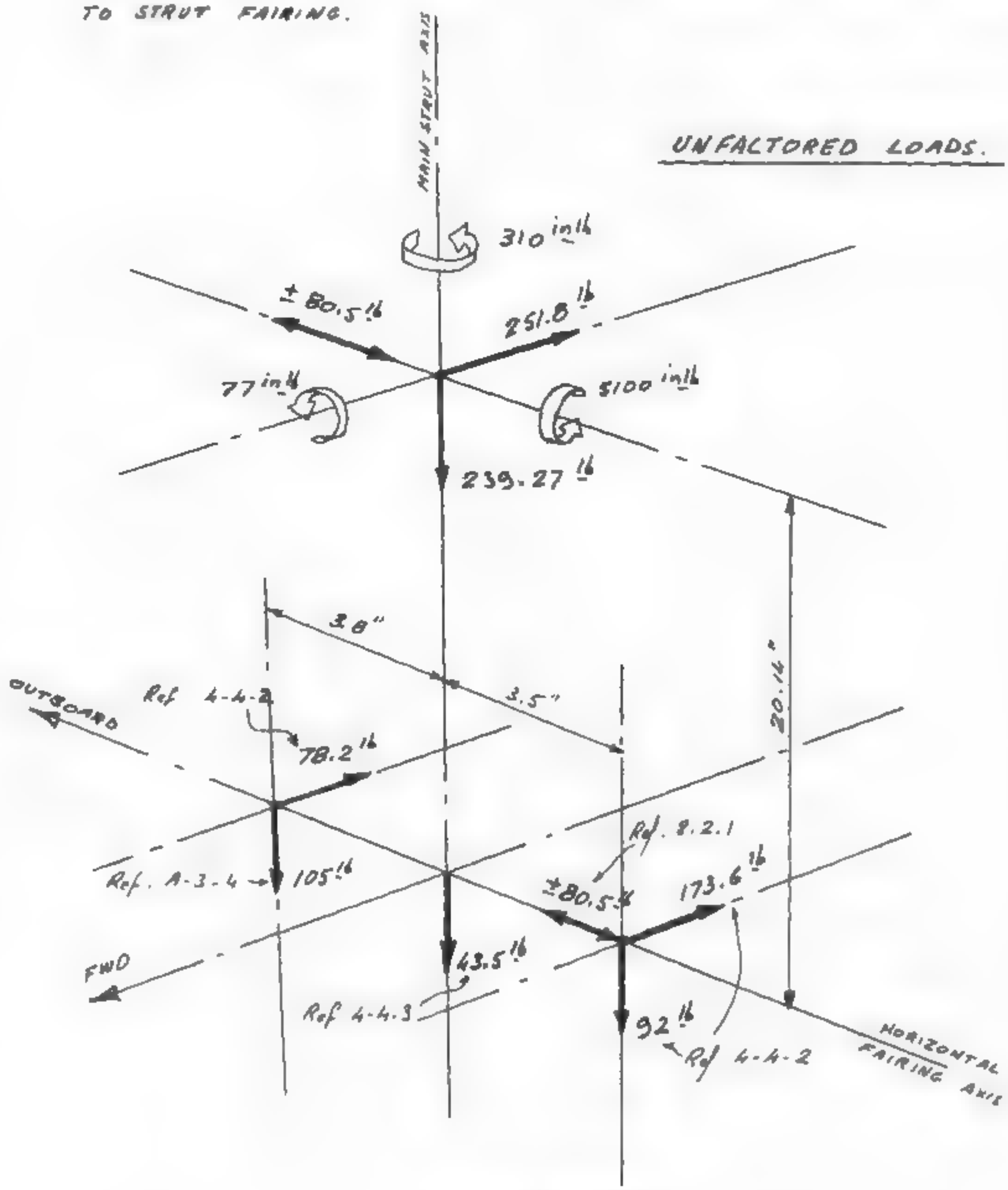
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL.

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 FLANGE ITEM 420 SK 30290 - FAIRING ASS'Y ATTACHMENT TO STRUT FAIRING.



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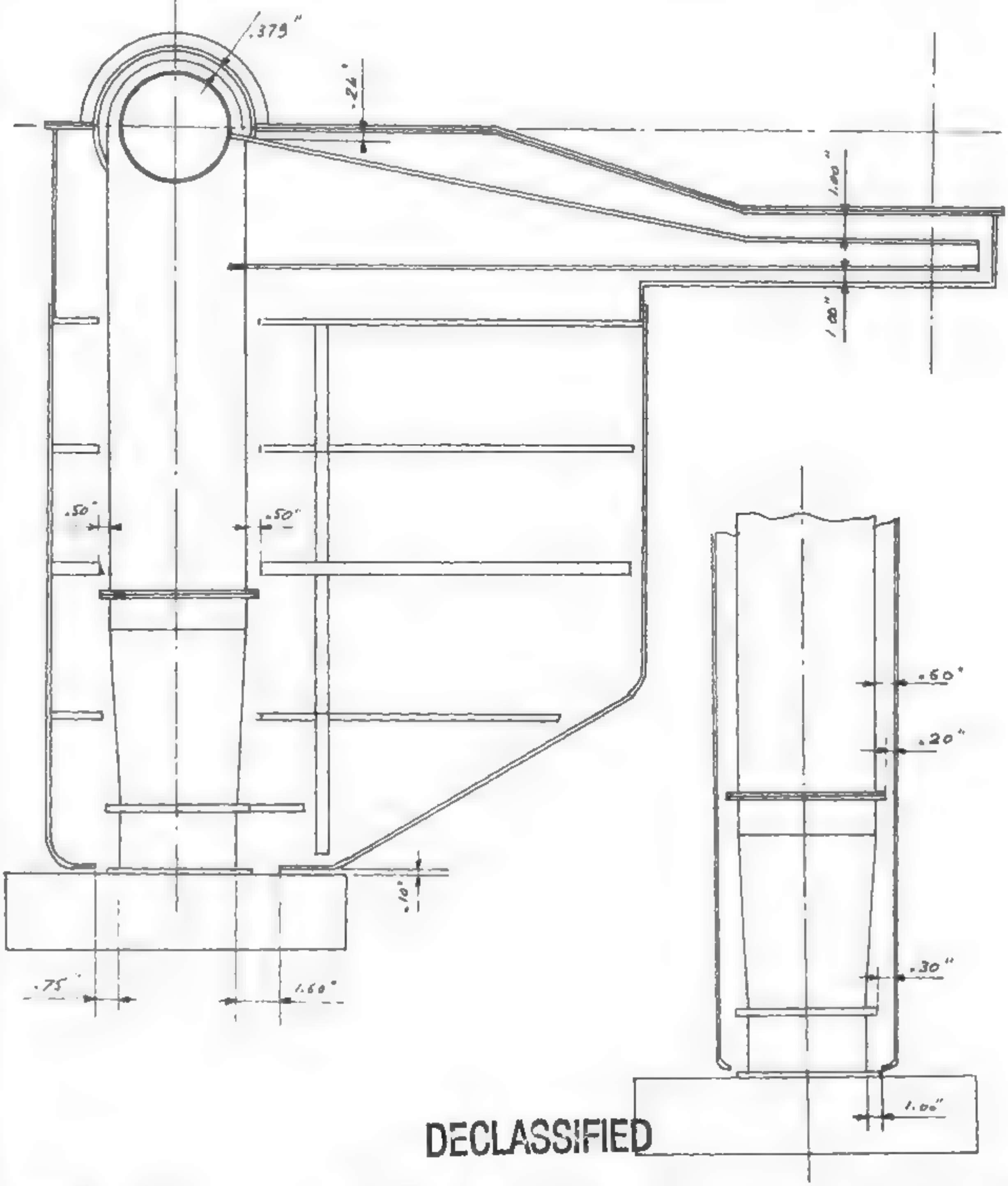
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

9-0 DEFLECTIONS.

9-1

NOMINAL MINIMUM CLEARANCES - FIG - 11



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

9-0 DEFLECTIONS

9-2 GAGE SECTION DEFLECTION.

The gages are designed as per report · AVRO/SPG/TR-87.

GAGE A - 800 lb

OUTER DIA. 3.00" WIDTH $b = .625"$

Operating Stress: 40 000 PSI

thickness: $t = .220$ $\frac{D}{t} = 13.63$

GAGE B & C - 350 lb

OUTER DIA. 3.00" WIDTH $b = .500"$

Operating Stress: 40 000 PSI

thickness: $t = .165$ $\frac{D}{t} = 18.20$

GAGE DEFLECTION AND ROTATION OF MODEL.

GAGE A: $\delta_{800} = .0213"$ $\therefore \delta_1 = \frac{.0213}{800} = 2.66 \; 10^{-5} \frac{in}{lb}$

GAGE B & C: $\delta_{350} = .0260"$ $\therefore \delta_1 = \frac{.0260}{350} = 7.42 \; 10^{-5} \frac{in}{lb}$

ROTATION OF MODEL UNDER 100 lb APPLIED AT CENTER.

Load on gage A: $100 \times .350 = 35$ lb

Load on gage B or C: $100 \times .325 = 32.5$ lb

Gage A deflection: $2.66 \times 35 \; 10^{-5} = .000932"$

Gage B deflection: $7.42 \times 32.5 \; 10^{-5} = .00241"$

Deflection angle of the model: $\frac{.00241 - .000932}{6.3} = .000235$ rad.

Rotation of the model in degrees: $57.3 \times .000235 = .0134°$ per 100 lb

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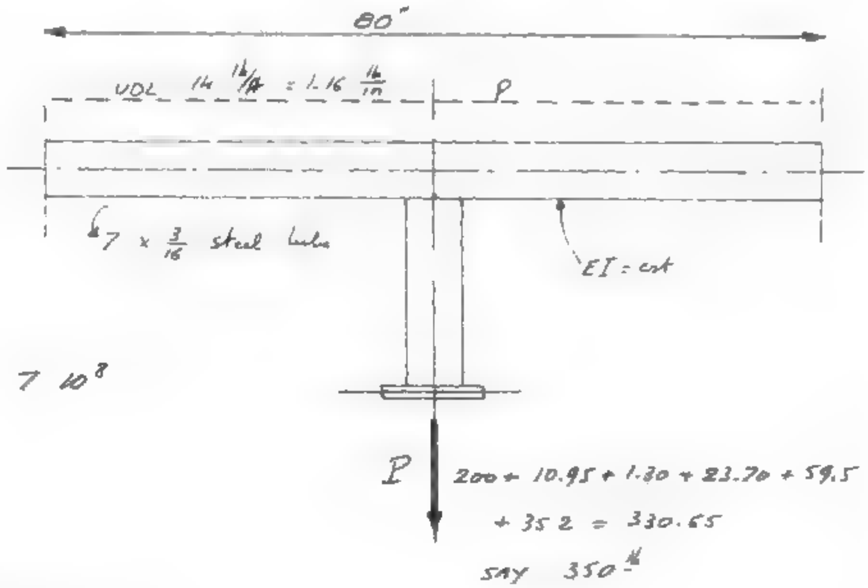
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

9-0 DEFLECTIONS

9-3 DEFLECTION OF MODEL SUPPORT STRUCTURE

9-3-1

DEFLECTION OF MODEL MOUNT UNDER STATIC LOAD. 1 - VERTICAL.



$E = 30\ 10^6$ PSI

$I = 23.35\ in^4$

$EI = 30\ 10^6 \times 23.35 = 7\ 10^8$

DEFLECTION UNDER UDL. p.

$$\delta_1 = \frac{5}{384}\, p\, \frac{\ell^4}{EI} = \frac{.01302 \times 80^4}{7\ 10^8}\, p = .00768\ p = 7.68\ 10^{-3}\ p$$

DEFLECTION UNDER CONCENTRATED LOAD P

$$\delta_2 = \frac{P\ell^3}{48\,EI} = P\,\frac{80^3}{48 \times 7\ 10^8} = 1.525\ 10^{-5}\ P$$

TOTAL DEFLECTION: $\delta = \delta_1 + \delta_2 = \underline{7.68\ 10^{-2}\ p + 1.525\ 10^{-5}\ P}$

$$\delta = 7.68\ 10^{-2} \times 1.16 + 1.525\ 10^{-5} \times 350 = .0089 + .00534 =$$

$$= .01424''$$

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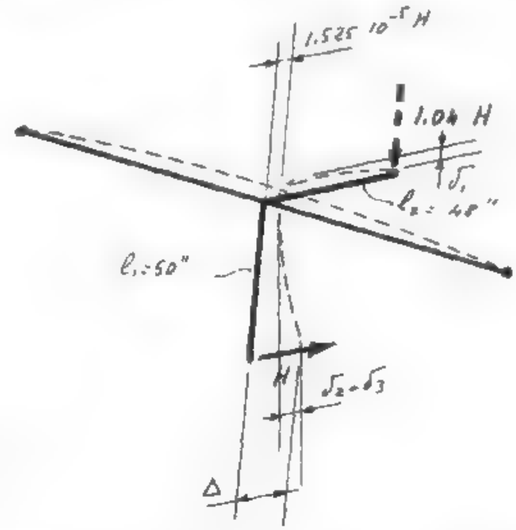
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

9-0 DEFLECTIONS

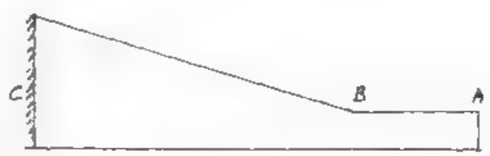
9-3 DEFLECTION OF MODEL SUPPORT STRUCTURE

9-3-2

DEFLECTION OF MODEL MOUNT UNDER A DRAG LOAD AT MODEL CENTER. HORIZONTAL.



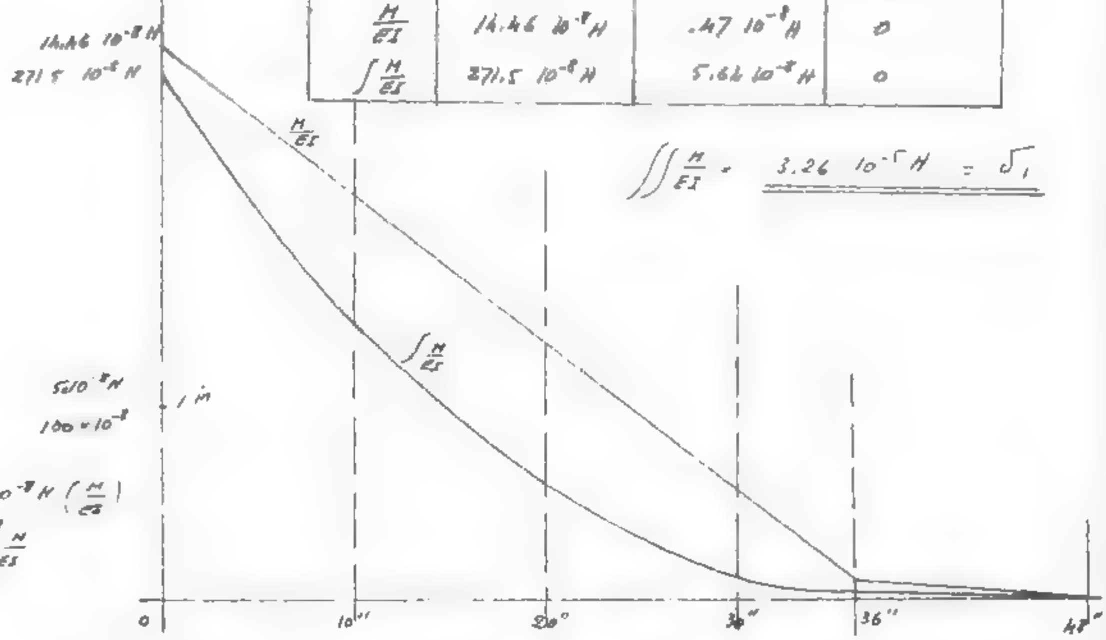
The incidence control arm has a variable moment of inertia along its length



Deflection calculated by integrating twice $\frac{M}{EI}$ along the length of the beam

	C	B	A
l	48	12	0
M	49.9 H	12.48 H	0
I	11.5 in⁴	.884 in⁴	.884 in⁴
$\frac{M}{EI}$	14.46 10^{-8} H	.47 10^{-8} H	0
$\int\frac{M}{EI}$	271.5 10^{-8} H	5.64 10^{-8} H	0

$$\iint\frac{M}{EI} = 3.26\ 10^{-5} H = \delta_1$$



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STRESS ANALYSIS OF $\frac{1}{12}$ 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 - CONT'D.

HORIZONTAL.

$\delta_1 = 3.26 \; 10^{-5} H \quad \therefore \quad \delta_2 = 3.26 \; 10^{-5} \frac{50}{48} H = 3.39 \; 10^{-5} H$

BENDING DEFLECTION OF VERTICAL MEMBER

$$\delta_3 = \frac{H \ell^3}{3EI} \qquad \text{where } \ell = 50'' \; \& \; I = 33.75 \text{ in}^4$$

$$\delta_3 = H \frac{50^3}{3 \times 30 \; 10^6 \times 33.75} = 4.12 \; 10^{-5} H$$

TOTAL HORIZONTAL DEFLECTION OF THE MODEL CENTER:

$$1.525 \; 10^{-5} H + 3.39 \; 10^{-5} H + 4.12 \; 10^{-5} H = 9.035 \; 10^{-5} H$$

SAY: $10^{-4} H = \Delta$

Thus, for a drag load of 200 lb, the deflection is

$$2 \; 10^{-4+2} = 2 \; 10^{-2} = .020''$$

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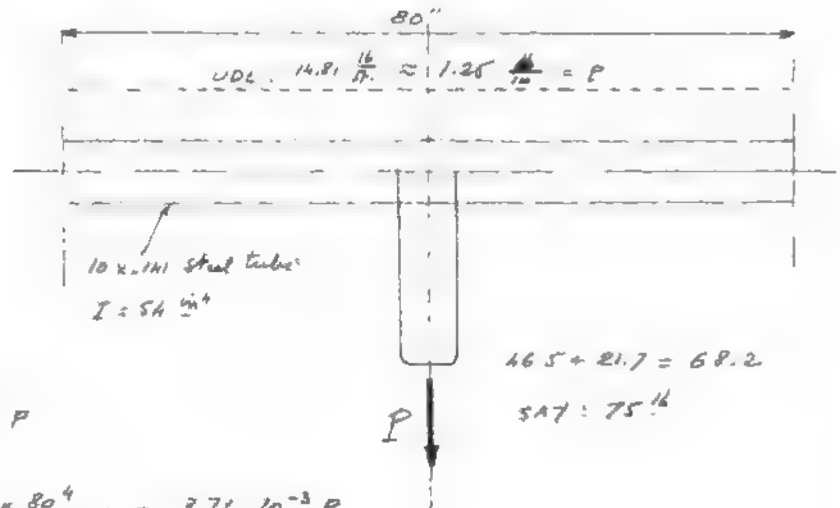
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

9.0 DEFLECTIONS

9-4 DEFLECTION OF FAIRING

9-4-1

DEFLECTION OF FAIRING TUBE UNDER STATIC LOAD. VERTICAL



$E = 30\ 10^6$ PSI

$I = 54$ in^4

$EI = 16.2\ 10^8$

46.5 + 21.7 = 68.2

SAY: 75 lb

DEFLECTION UNDER UDL p

$$\delta_1 = \frac{5}{384} p \frac{l^4}{EI} = \frac{.01302 \times 80^4}{16.2\ 10^8} p = 3.71\ 10^{-3} p$$

DEFLECTION UNDER CONCENTRATED LOAD P

$$\delta_2 = \frac{P l^3}{48 EI} = P \frac{80^3}{48 \times 16.2\ 10^8} = .734\ 10^{-5} P$$

TOTAL DEFLECTION: $\delta = \delta_1 + \delta_2 = \underline{\underline{3.71\ 10^{-3} p + 7.34\ 10^{-6} P}}$

$$\delta = 3.71\ 10^{-3} \times 1.25 + 7.34\ 10^{-6} \times 75 = .00468 + .000558$$

$$= \underline{\underline{.005238''}}$$

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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 UDL: 25 $\frac{lb}{ft}$: 2.08 $\frac{lb}{in}$ say. 2.10 $\frac{lb}{in}$ and a drag load of 80.5 lb from the fairing of the Vertical arm

Hence. Deflection

$$\delta = 3.71\ 10^{-3} \times 2.10 + 7.34\ 10^{-6} \times 80.5 =$$

$$7.79\ 10^{-3} + 5.92\ 10^{-4} = \underline{.008382''}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

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:

.0142 − .0052 = .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 lb i.e. an extra 346 lb on the static case which would induce an additional deflection: $1.525 \cdot 10^{-5} \times 346 = .00527$"

Then, the relative motion becomes:

.009 + .00527 = .01427" about 14% of the clearance provided.

All other clearances are larger hence less critical than the above

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

10-0 CALIBRATION

10-0-1 INTRODUCTION

In this section, the symbols and sign convention used in the rest of the report have been replaced by those of report AVRO/SPG/TR 98 " Test Specifications 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 purpose by noting that : 1/ angle $\alpha = 0$
2/ Pressure and suction are off
The reduced equations are given in 10-1-2

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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

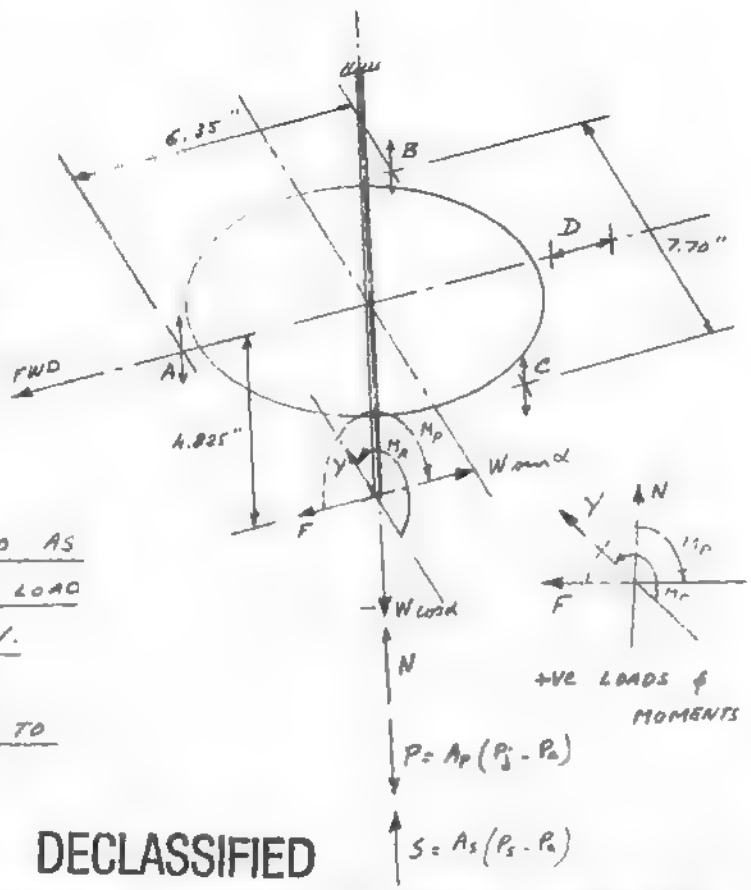
GAGE	A	B	C	D	
WEIGHT	$.196\,W(1-\cos\alpha)$	$.182\,W(1-\cos\alpha)$	$.182\,W(1-\cos\alpha)$	$-W\sin\alpha$	
PRESSURE	$4.47(P_j-P_a)$	$4.09(P_j-P_a)$	$4.09(P_j-P_a)$	0	$A_P = 22.8$ in²
SUCTION	$2.87(P_s-P_a)$	$2.625(P_s-P_a)$	$2.625(P_s-P_a)$	0	$A_S = 14.5$ in²
NORMAL LOAD	$-.196\,N$	$-.182\,N$	$-.182\,N$	0	
DRAG LOAD	$-.760(F-W\sin\alpha)$	$+.380(F-W\sin\alpha)$	$+.380(F-W\sin\alpha)$	F	
SIDE LOAD	0	$-.626\,Y$	$+.626\,Y$	0	
PITCHING MT	$-.1575\,M_P$	$+.07875\,M_P$	$+.07875\,M_P$	0	
ROLLING MT	0	$.130\,M_R$	$-.130\,M_R$	0	

POSITIVE GAGE LOAD IS TENSION.

NOTE
Pressures $(P_j - P_a)$ and $(P_s - P_a)$ 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 + 2.278 W.
NORMAL LOADS OF THIS MAGNITUDE ARE NOT EXPECTED TO OCCUR DURING TESTS



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STRESS ANALYSIS OF $\frac{1}{12}$ 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 6-1-3 : Rod deflection : $\delta_r = 2.42 \; 10^{-5} W$

Gage system deflection : $\delta_g = 1.895 \; 10^{-5} W$

From the equation $\Delta W = W_1 + 1.278 W_1 = 2.278 W_1$
where W_1 is the weight of the model and $\Delta W = N$.
we have

$$N = 2.278 \times 200 = 456 \text{ lb}$$

MAX. & MIN LOADS APPLICABLE ON THE SYSTEM TO REACH RATED GAGE LOADS

NORMAL LOAD N.

GAGE A: Equations:

$$\underset{\text{COMPR.}}{-800} \leq -.35(N-200)\Big/^{N \geq 456} \leq \underset{\text{TENS}}{800}$$

$$\underset{\text{COMPR.}}{-800} \leq -.196 N\Big/^{N \leq 456} \leq \underset{\text{TENS.}}{800}$$

Gage load at $N = 456$ lb

$$G_1 = -.35 \times (456-200) = -.35 \times 256 = -89.6 \text{ lb}$$

$$G_2 = -.196 \times 456 = -89.6 \text{ lb}$$

at Min Gage load. $G = -.196 N$

$$N = \frac{800}{-.196} = -4040 \text{ lb}$$

at Max Gage load $G = -.35 (N-200)$

$$N = (-800/-.35) + 200 = 2485 \text{ lb}$$

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STRESS ANALYSIS OF $\frac{1}{12}$ 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

Equations: $-350 \leq -.325\,(N-200)\Big/^{N \geq 456} \leq 350$

$-350 \leq -.182\ N \quad \Big/^{N \leq 456} \leq 350$

Gage load at $N = 456$ lb

$G_1 = -.325\,(456-200) = -.325 \times 256 = -83.2$ lb

$G_1 = -.182 \times 456 = -83.2$ lb

at min. gage load

$G = -.182\ N$

$\therefore\ N = \frac{350}{-.182} = \underline{\underline{-1925}}$ lb

at Max. gage load $G = -.325(N-200)$

$\therefore\ N = \frac{350}{-.325} + 200 = \underline{\underline{1275}}$ lb

PITCHING MOMENT Mp.

GAGE A:

Equation: $.1575\ M_p = G_A = \pm 800$ lb

$\therefore\ M_p = \frac{\pm 800}{.1575} = \pm 5080$ in.lb

GAGE B & C:

Equation: $.07875\ M_p = G_B = \pm 350$ lb

$\therefore\ M_p = \frac{\pm 350}{.07875} = \underline{\underline{\pm 4440}}$ in.lb.

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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 M_R.

GAGE B & C ONLY.

Equation: $\pm .130\, M_R = G$

$$\therefore \quad \frac{350}{\pm .130} = \pm 2690 \text{ in.lb}$$

SUMMARY-

The max. and min. loads and moments that can be applied on the system must no 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	Fore aft	± 150 lb	
Y:	Side "	± 50 lb	
N·	UP: 1275 lb		DOWN −1925 lb
M_P:	Pitching Mt.	± 4440 in.lb	
M_R·	Rolling Mt	± 2690 in.lb	

NOTE: F & Y are limited by design consideration rather than gage strength

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STRESS ANALYSIS OF $\frac{1}{12}$ 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 - M_P & M_R FOR $\alpha = 0$

Under calibration loads, P_j, P_s and $\alpha = 0$ then eq. given in 10-1-1 become

GAGE A

$$-800 \leq -.35(N+W)^{N \geq -2.278W} -.76F -.1575 M_P \leq 800 \quad \text{(rod disengaged)}$$

$$-800 \leq -.196N^{N \leq -2.278W} -.76F -.1575 M_P \leq 800 \quad \text{(rod engaged)}$$

GAGE B & C

$$-350 \leq -.325(N+W)^{N \geq -2.278W} +.38F \mp .626Y + .07875 M_P \pm .130 M_R \leq 350 \quad \text{(rod disengaged)}$$

$$-350 \leq -.182N^{N \leq -2.278W} +.380F \mp .626Y +.07875 M_P \pm .130 M_R \leq 350 \quad \text{(rod engaged)}$$

GAGE D

$$-150 \leq F \leq 150$$

MAX VALUES OF APPLIED LOADS & MOMENTS

F - FORE/AFT	± 150 lb
Y - SIDE	± 50 lb
N - UP/DOWN	$+1275$ lb to -1925 lb
M_P - PITCHING MT.	± 4440 in/lb
M_R - ROLLING MT	± 2690 in/lb

NOTE. 1- Above loads (max.) apply singly when all other loads = 0
2- N may be sum of: normal load, pressure and suction load.
3- Gage readings will not differentiate between rolling Mt due to Y and M_R

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STRESS ANALYSIS OF $\frac{1}{12}$ 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 $W = -200^{lb}$

GAGE A

$$-800 \leq -.35(N-200)\Big/_{N=456}^{N=1275} - .76\,F\Big/_{F=-150}^{F=+150} - .1575\,M_P\Big/_{M_P=-4440}^{M_P=+4440} \leq 800$$

$$-800 \leq -.136\,N\Big/_{N=-1925}^{N=456} - .76\,F\Big/_{F=-150}^{F=+150} - .1575\,M_P\Big/_{M_P=-4440}^{M_P=+4440} \leq 800$$

GAGE B & C

$$-350 \leq -.325(N-200)\Big/_{N=456}^{N=1275} + .38\,F\Big/_{F=-150}^{F=150} \mp .626\,Y\Big/_{Y=-50}^{Y=+50} + .07875\,M_P\Big/_{M_P=-4440}^{M_P=+4440}$$

$$\pm .13\,M_R\Big/_{M_R=-2690}^{M_R=+2690} \leq 350$$

$$-350 \leq -.182\,N\Big/_{N=-1925}^{N=456} + .38\,F\Big/_{F=-150}^{F=+150} \mp .626\,Y\Big/_{Y=-50}^{Y=+50} + .07875\,M_P\Big/_{M_P=-4440}^{M_P=+4440}$$

$$\pm .13\,M_R\Big/_{M_R=-2690}^{M_R=+2690} \leq 350$$

GAGE D

$$-150 \leq F\Big/_{F=-150}^{F=+150} \leq 150$$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION

10-2-0 CALIBRATION PROCEDURE.

The equations on page give the relations between gage loading and the applied loads N, F & Y and the moments M_P & M_R. These equations will hold only when there is no other interaction between the gages. The purpose of calibration is to find out any such interaction 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 & moment M_P in combinations

Series 3 - Loads N, F, Y & moments M_P & M_R in combinations

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 on the

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10-0 CALIBRATION

10-2-0 CALIBRATION PROCEDURE - CONT'D.

gage reading at various gage loading level. 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 combination of N,F & MP are shown graphically on charts 3 & 4 for gage A and on charts 5 & 6 for gages B & C

Series 3 - All possible combinations of N, F, Y, MP & MR 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 MR. However, it will be necessary to observe its reading during calibration of gages B & C

SERIES 4 - Stressing 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 we may expect in operation. Loads to be applied on the calibration rig for each cases stressed in this report are given on table 8

STRESS ANALYSIS OF 1/15 SCALE NOSE CONE & TRANSITION MODEL

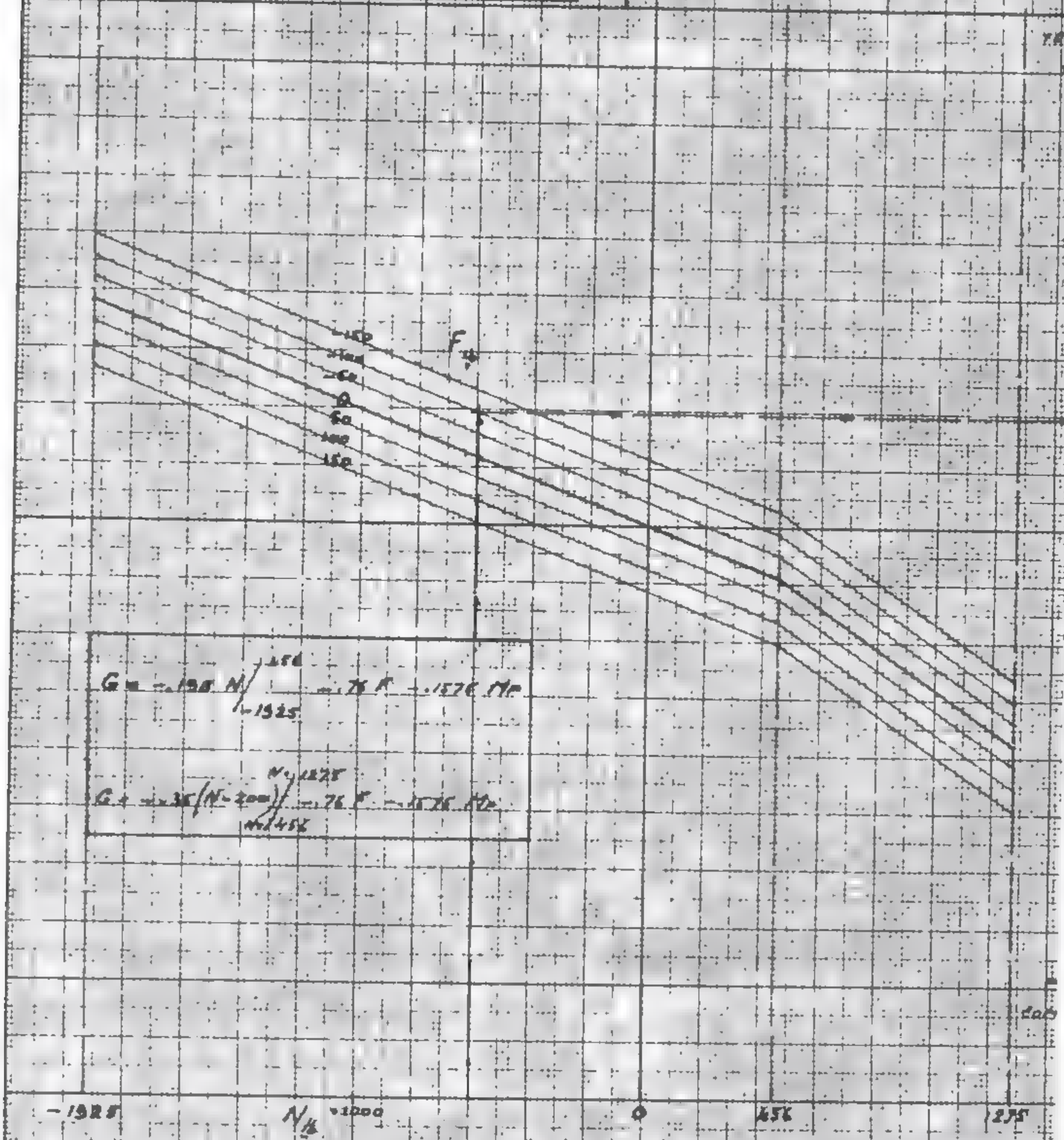
10-0 CALIBRATION

10-1 GAGE EQUATIONS FOR CALIBRATION

10-1-2 GAGE EQUATIONS & MAX. APPLIED LOADS

GAGE CALIBRATION

GRAPHICAL SOLU

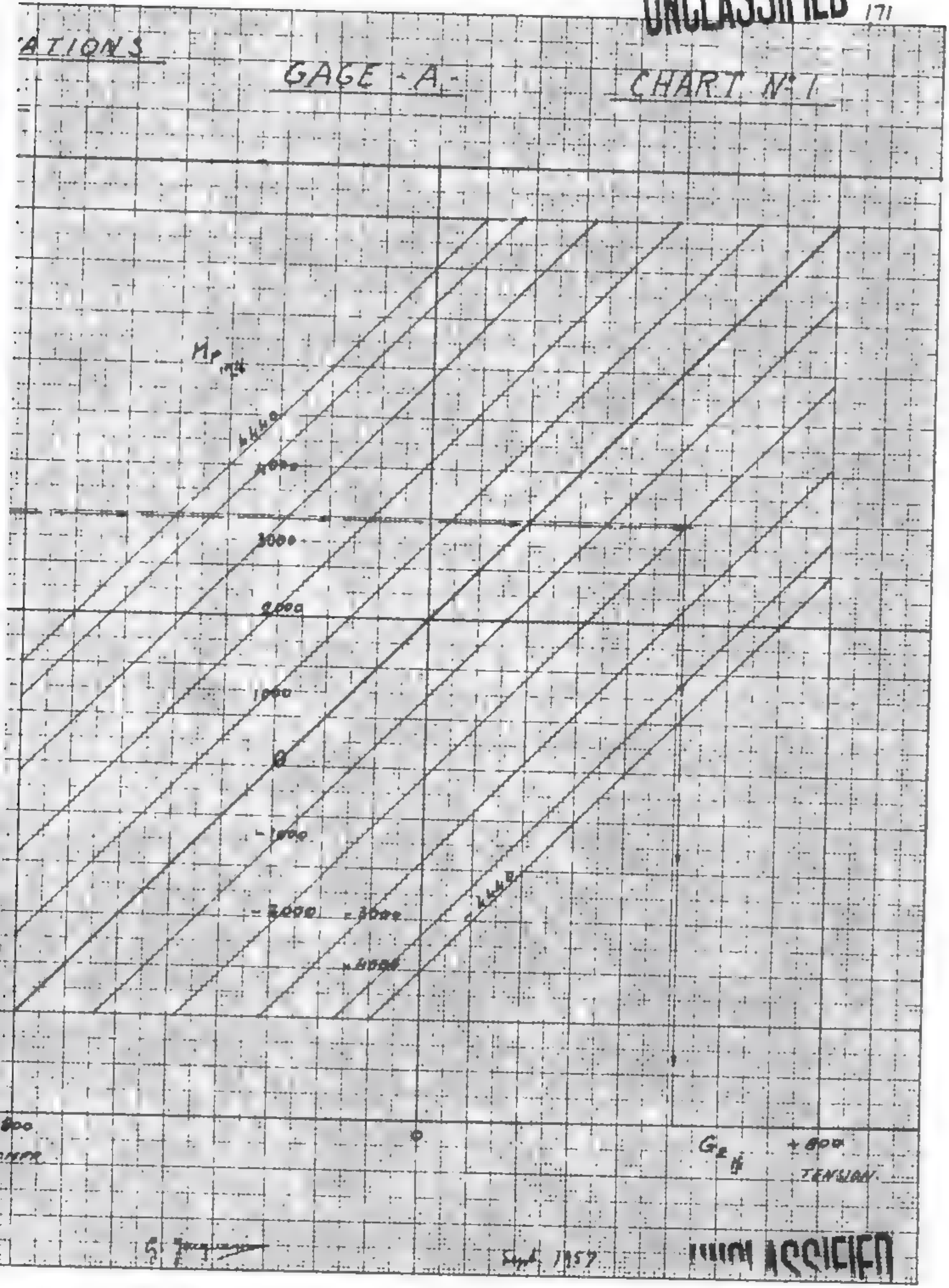


$G = -.198\ N \Big|_{-1925}^{456} - .76\ F - .1576\ M_P$

$G = -.35\,(N - 200) \Big|_{N=456}^{N=1275} - .76\ F - .1576\ M_P$

EXAMPLE : N = -600 lb F = -100 lb M_P = -2000 in-lb

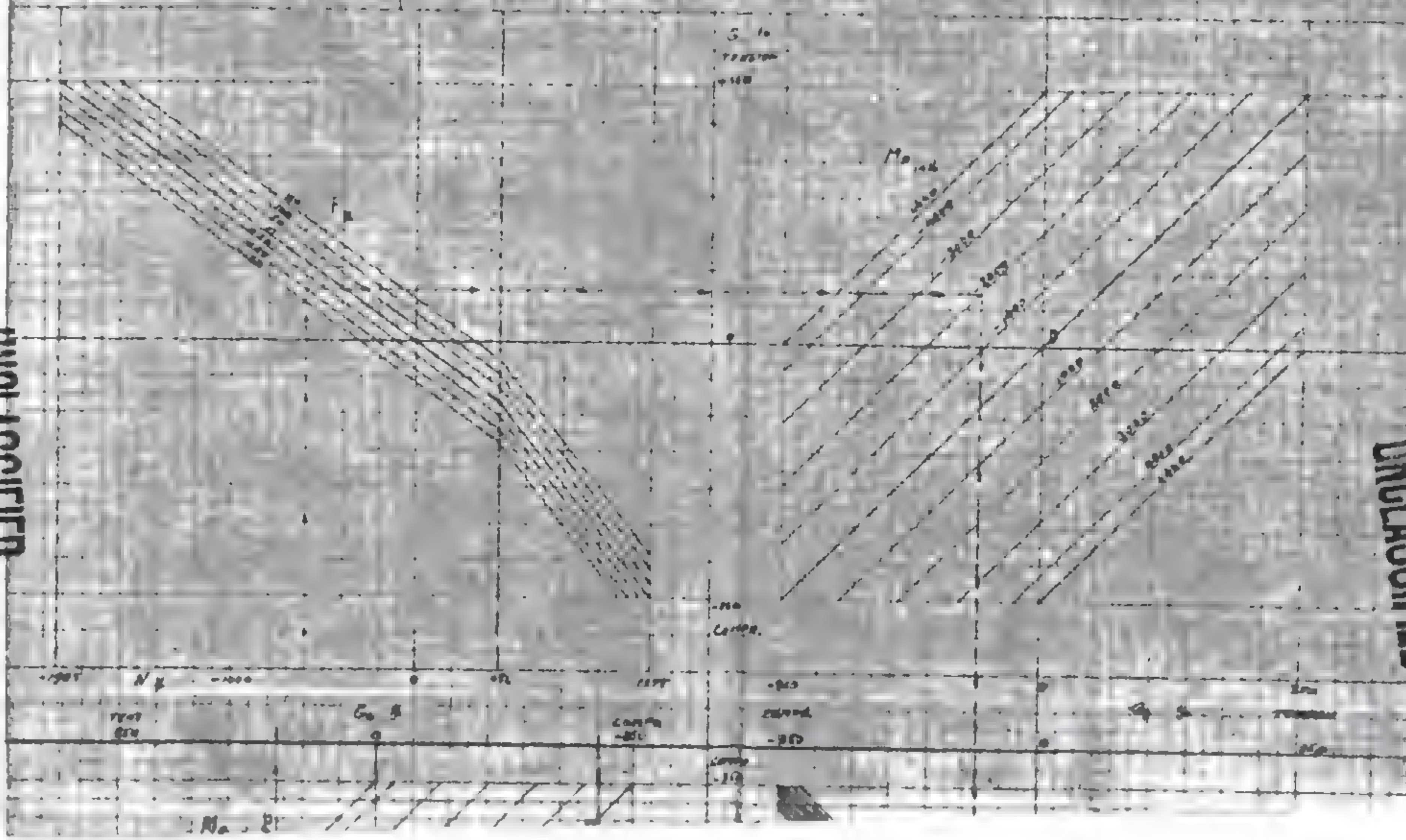
THUS GAGE A 510 lb TENSION

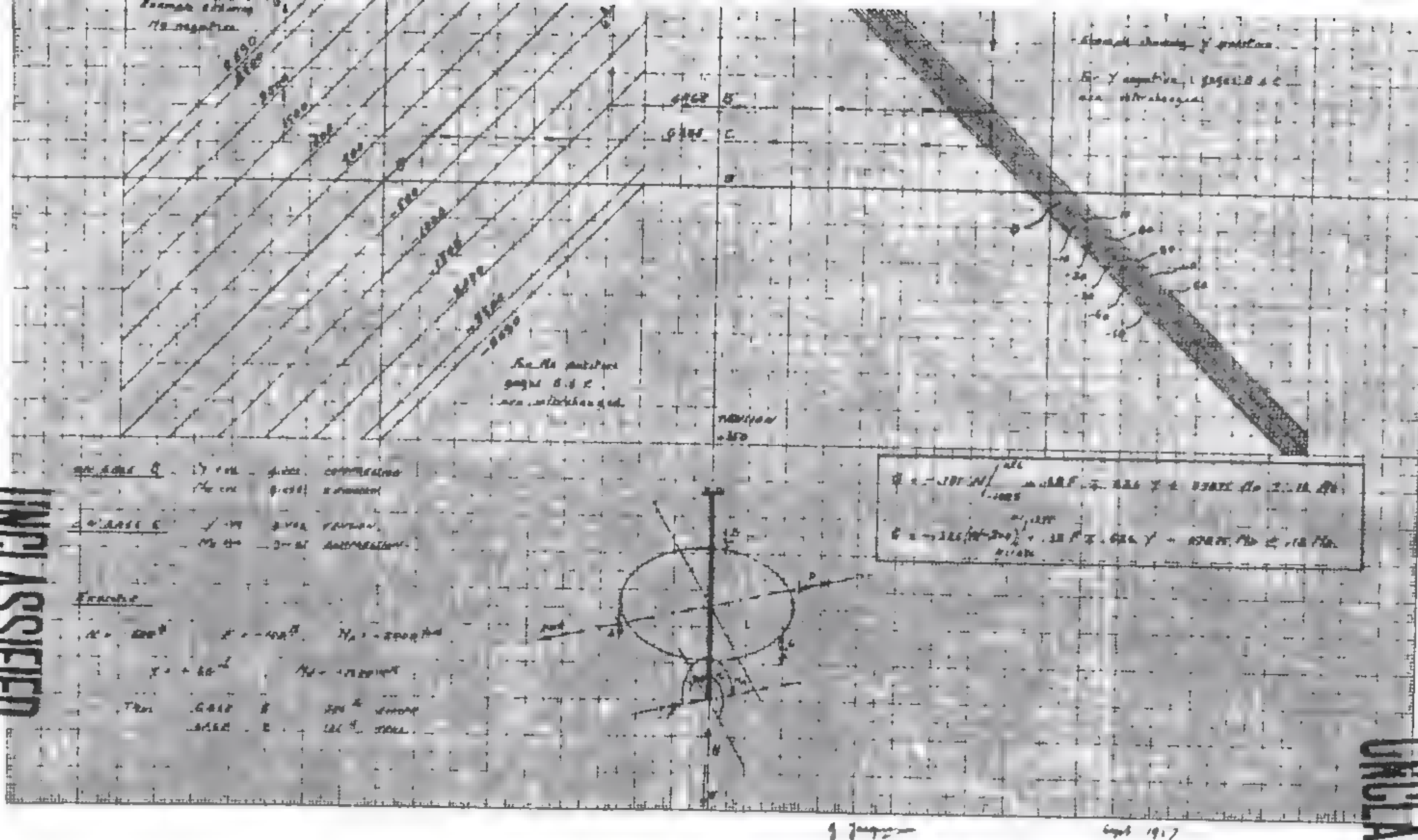

ATIONS
GAGE -A-
CHART Nº 1
4440
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
800
0
+800
TENSION
1957

GAGE CALIBRATION EQUATIONS -
GRAPHICAL SOLUTION

GAGES B/C

CHART No. 2





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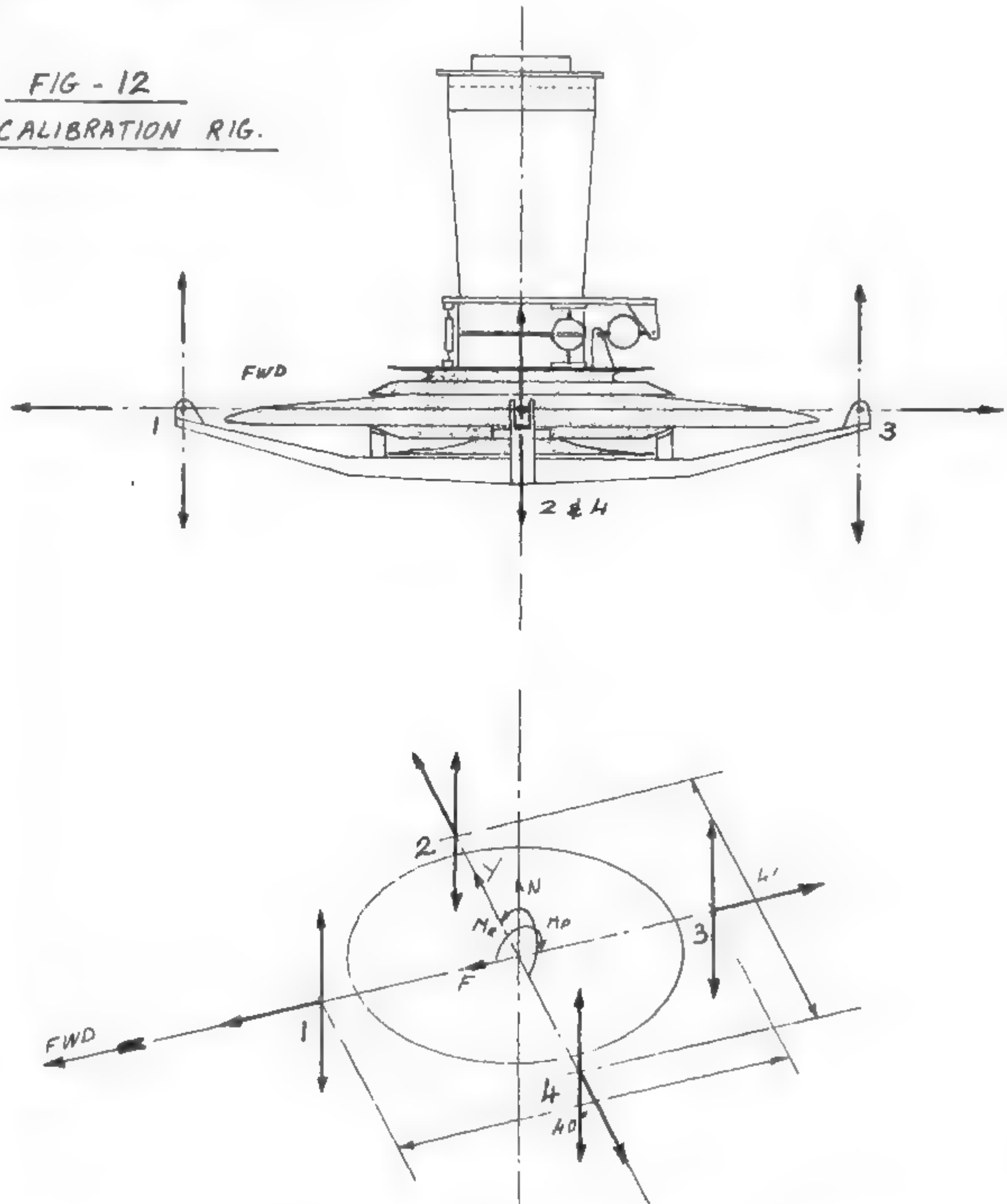
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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.

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STRESS ANALYSIS OF $\frac{1}{12}$ 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 -

LOAD	1			2			3			4		
	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN
$F\big/_{0}^{150}$	F											
$F\big/_{-150}^{0}$							F					
$Y\big/_{0}^{50}$				Y								
$Y\big/_{-50}^{0}$										Y		
$N\big/_{0}^{1375}$		$\frac{N}{4}$			$\frac{N}{4}$			$\frac{N}{4}$			$\frac{N}{4}$	
$N\big/_{-1375}^{0}$			$\frac{N}{4}$			$\frac{N}{4}$			$\frac{N}{4}$			$\frac{N}{4}$
$M_R\big/_{0}^{2690}$						$\frac{M_R}{40}$					$\frac{M_R}{40}$	
$M_R\big/_{-2690}^{0}$					$\frac{M_R}{40}$							$\frac{M_R}{40}$
$M_P\big/_{0}^{4440}$		$\frac{M_P}{40}$							$\frac{M_P}{40}$			
$M_P\big/_{-4440}^{0}$			$\frac{M_P}{40}$					$\frac{M_P}{40}$				

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION

10-2 CALIBRATION RIG

10-2-2 LOADS ON CALIBRATION RIG.

TABLE 2

SIMPLE CASE - ONE LOAD ALONE -

ALL LOADS IN lb

LOAD	1			2			3			4		
	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN
F = 150	150											
F = -150							150					
Y = 50				50								
Y = -50										50		
N = 1275		318.5			318.5			318.5			318.5	
N = -1925			481.25			481.25			481.25			481.25
M_R = 2690 in lb						67.25					67.25	
M_R = -2690 in lb					67.25							67.25
M_P = 4440 in lb		111							111			
M_P = -4440 in lb			111					111				

ABOVE LOAD F WILL BRING GAGE D TO ITS RATED LOAD.

ABOVE LOAD N WILL BRING GAGE B & C TO THEIR RATED LOADS.

ABOVE M_T M_R " " " " " " " " "

ABOVE M_T M_P " " " " " " " " "

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

10-0 CALIBRATION

10-2 CALIBRATION RIG.

10-2-2 LOADS ON CALIBRATION RIG.

TABLE 3

TEST CASES WITH NO ROLLING MOMENT OR SIDE LOAD.

APPLIED LOADS \ LOADS ON RIG				1			2			3			4		
CASE	N_{lb}	F_{lb}	M_P in lb	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN	OUT	UP	DOWN
HOVERING HORIZONTAL	-164	0	0			41			41			41			41
HOVERING 20°	-188.5	-3.8	-853			68.3			47.1	3.8		25.9			47.1
HIGH DRAG	-189.8	-10.2	-1440			83.4			47.4			11.4			47.4
MAX. THRUST	-486	+141	0	141		121.5			121.5			121.5			121.5
TRANSITION -10° 30 PSF	-546	+29.2	-4320	29.2		244.5			136.5			28.5			136.5
TRANSITION 20° 30 PSF	-30.2	-27	+1535		30.85				7.55	27		45.95			7.55
TRANSITION 35° 30 PSF	+156	+21.2	+2735	21.2	107.4			39				29.4		39	
TRANSITION 45° 18 PSF	-21	-38	+4320		102.75				5.25	38		113.25			5.25

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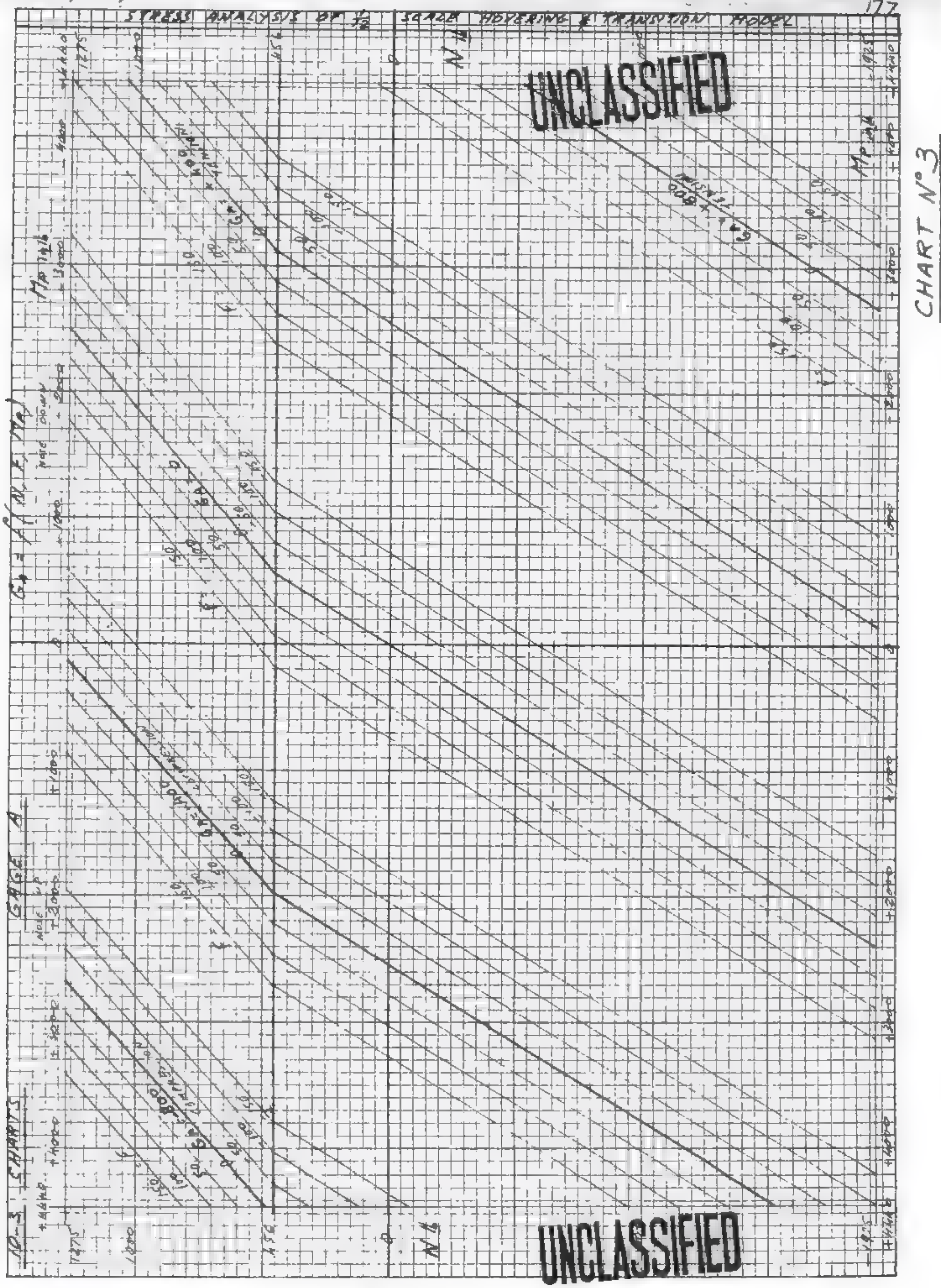

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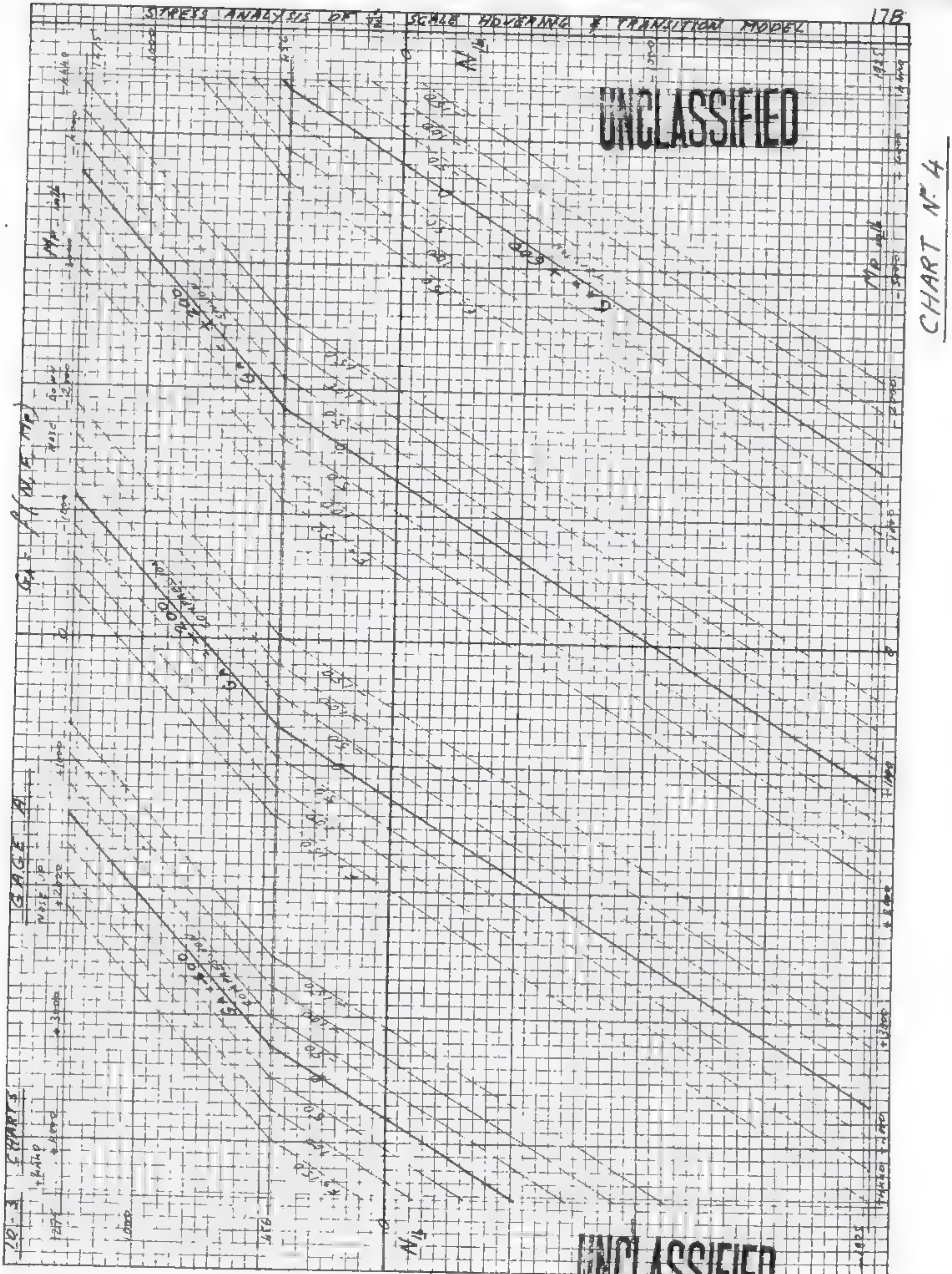

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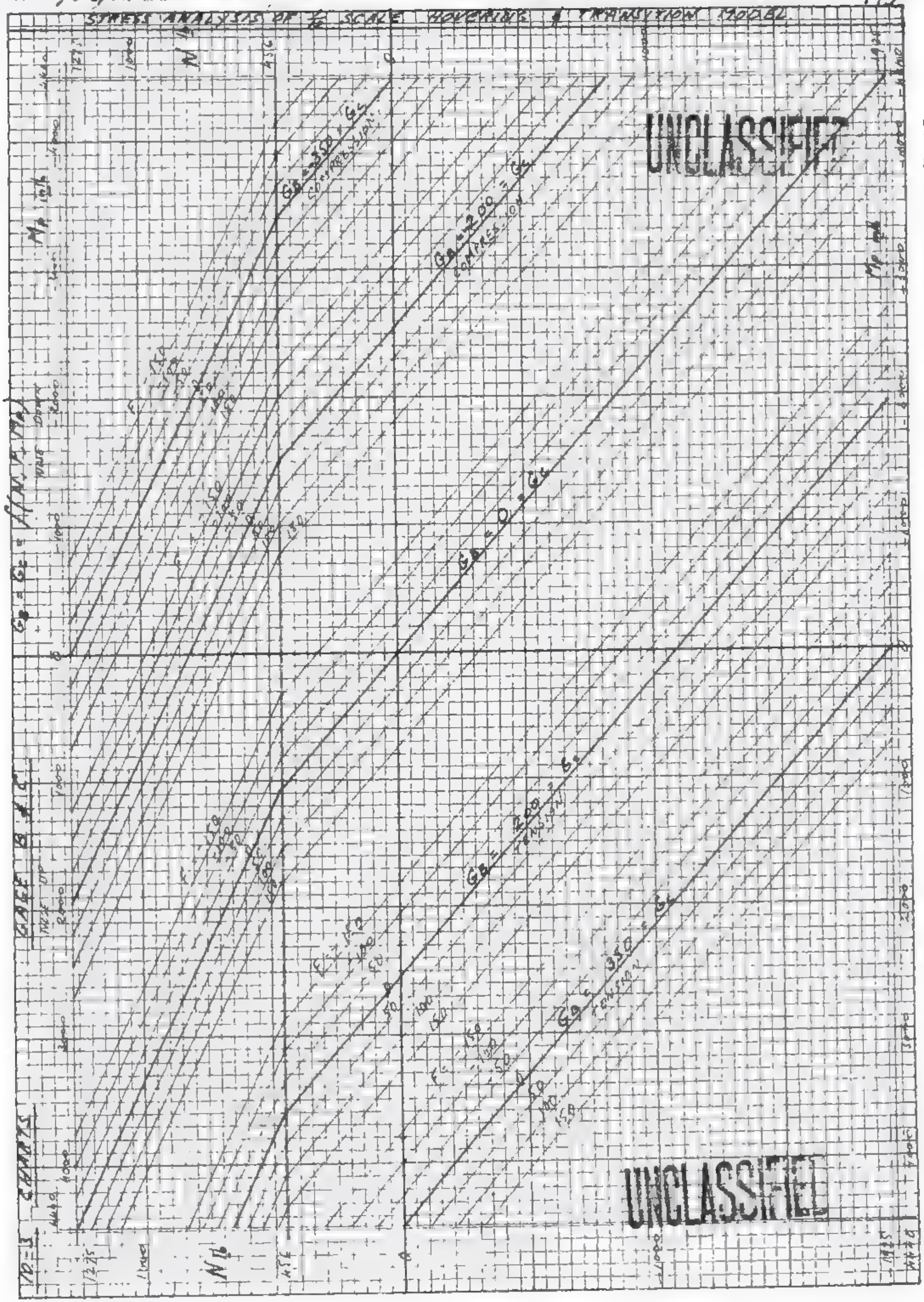
CHART N° 5



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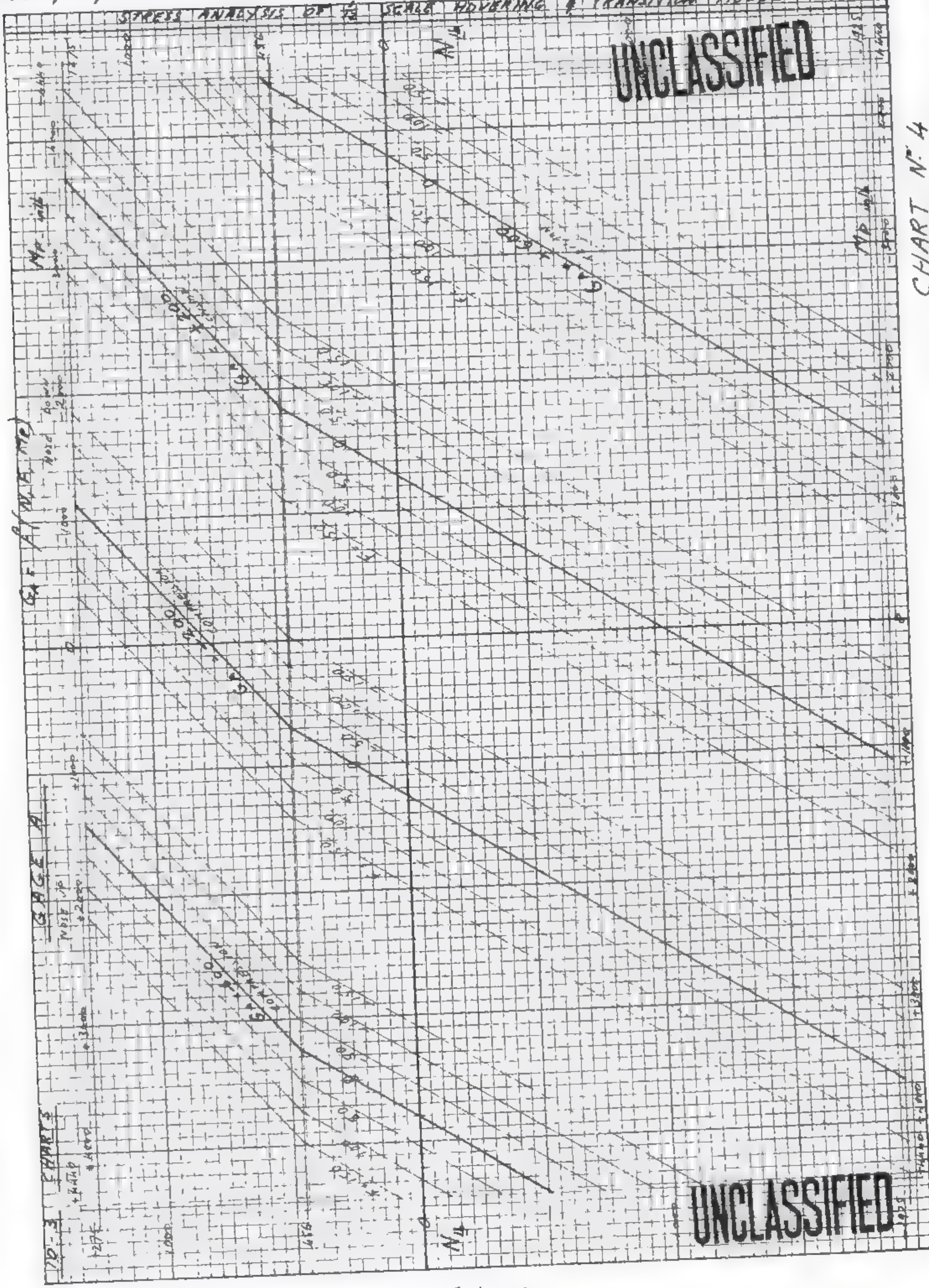
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL
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CHART No. 4
GAGE A
CHART 3
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STRESS ANALYSIS OF 1/2 SCALE HOVERING & TRANSITION MODEL

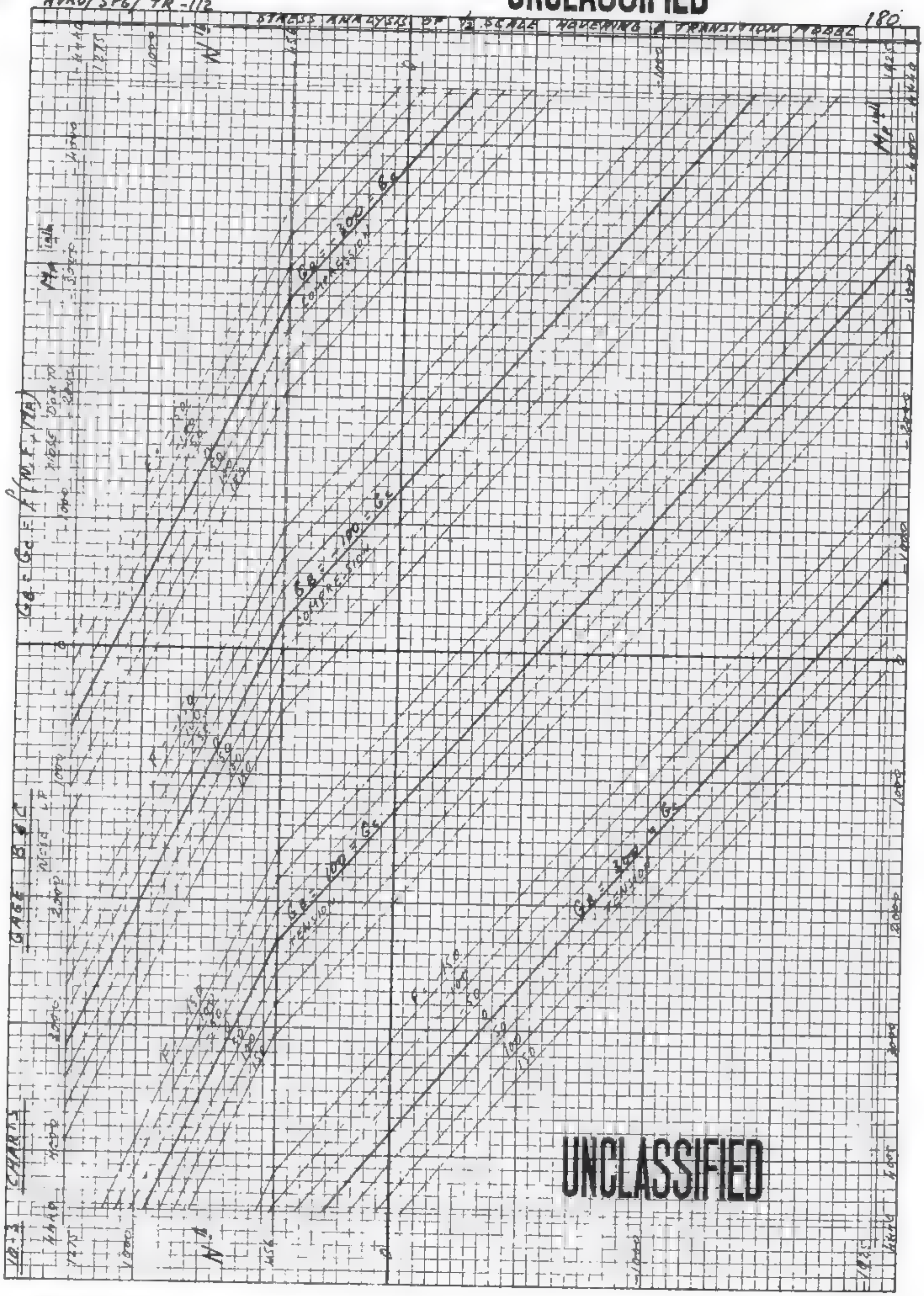

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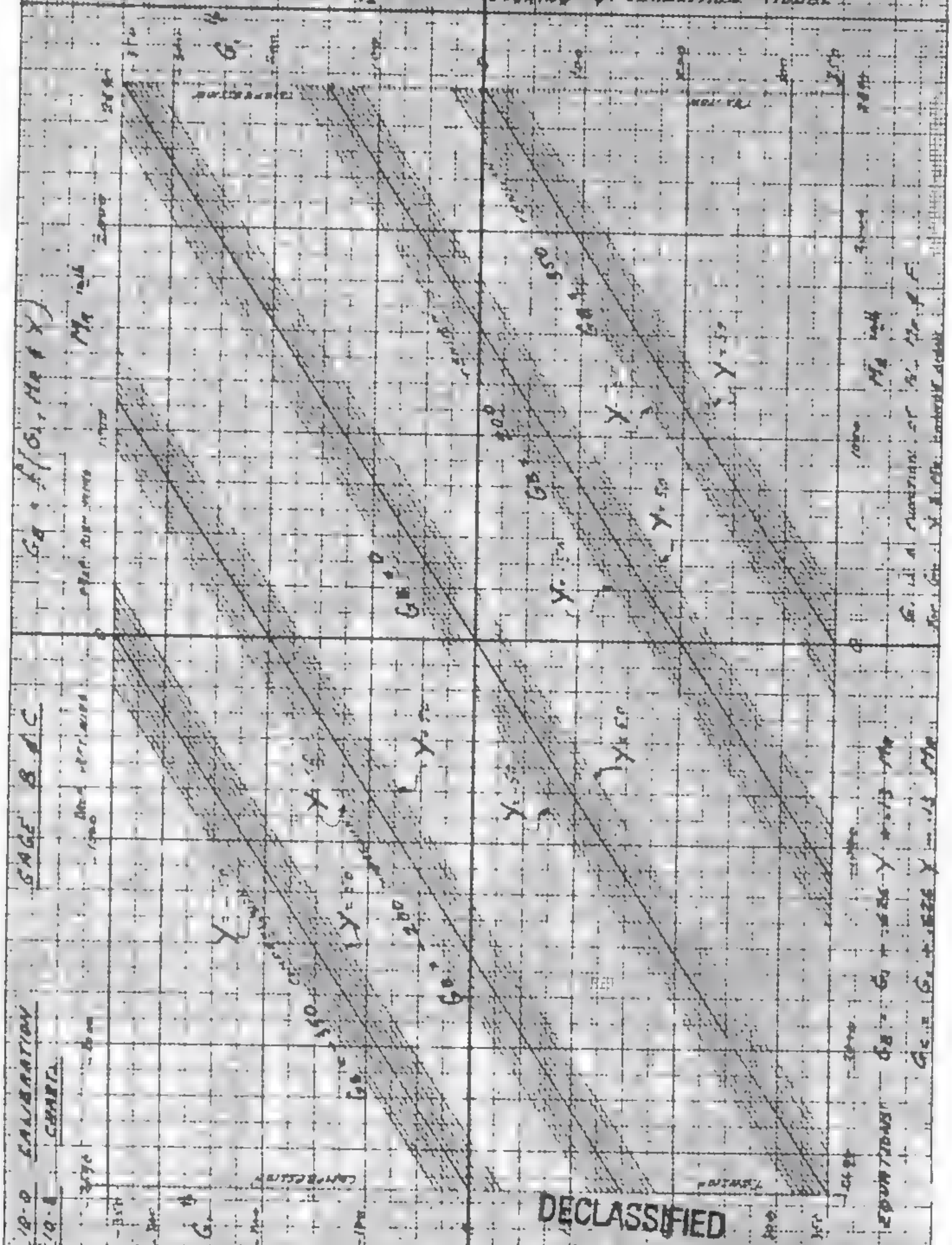
CHART No 7



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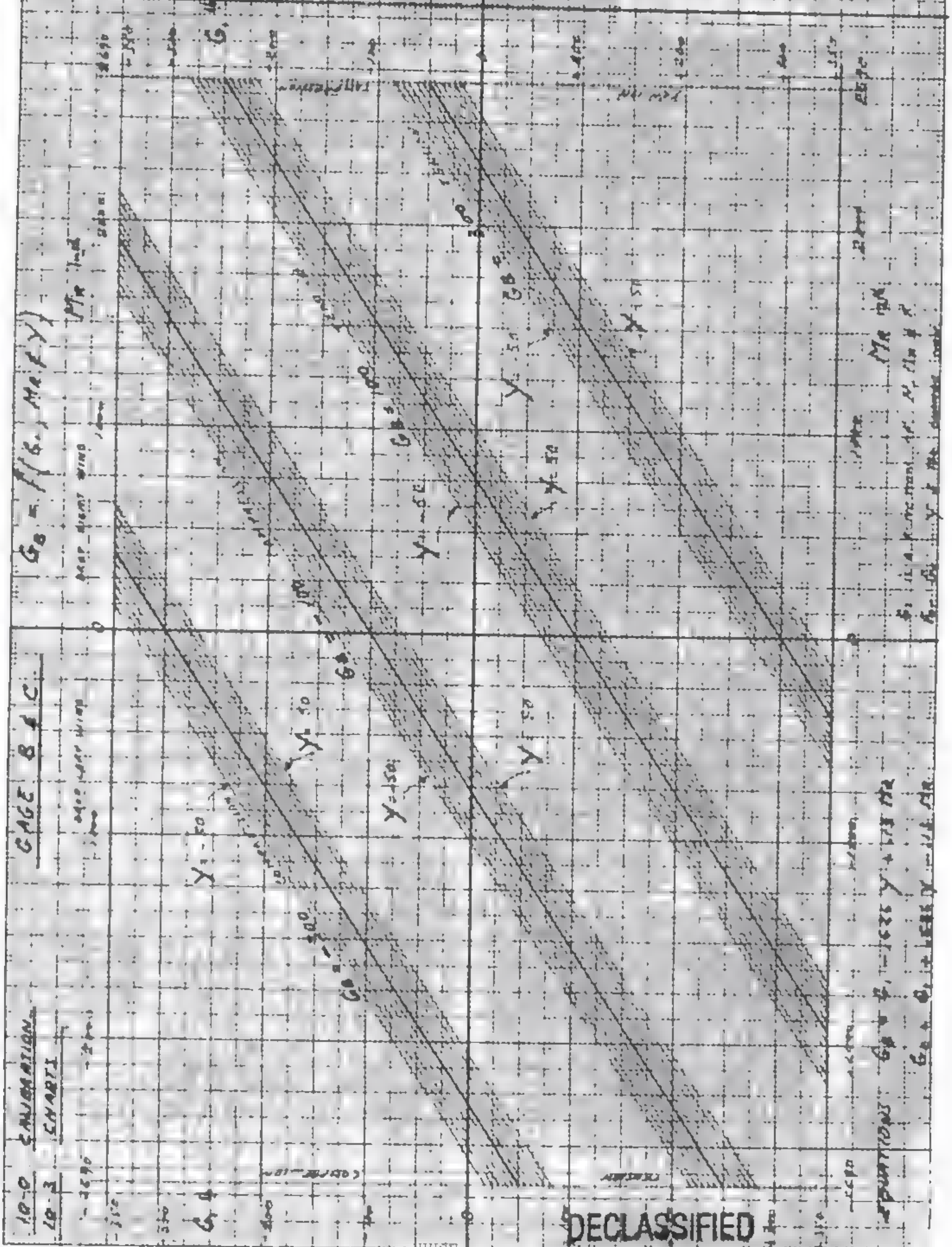
STRESS ANALYSIS OF $\frac{1}{10}$ SCALE HOVERING & TRANSITION MODEL

CHART N° 8



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

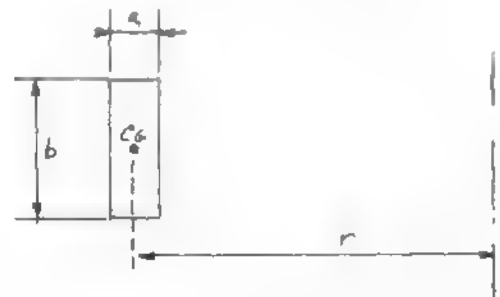
APPENDIX A - CALCULATION OF WEIGHT.

A-1 - WEIGHT OF MODEL

A-1-1 GENERAL.

Volume of an annulus: Sectional area × path of the CG

$V = a\,b\,2\pi r$



$W = \rho\, a b\, 2\pi r$

Using Simpson's rule we can fix

$a = .25''$

$\rho = .283 \frac{lb}{in^3}$ hence: the term $2\pi a \rho = 2 \times \pi \times .25 \times .283 = .445$

Hence: the weight of one element: $dW = .445\, b\, r$

and the total weight of one annular part is

$W = .445 \sum b r$

Values of br are tabulated for each part.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

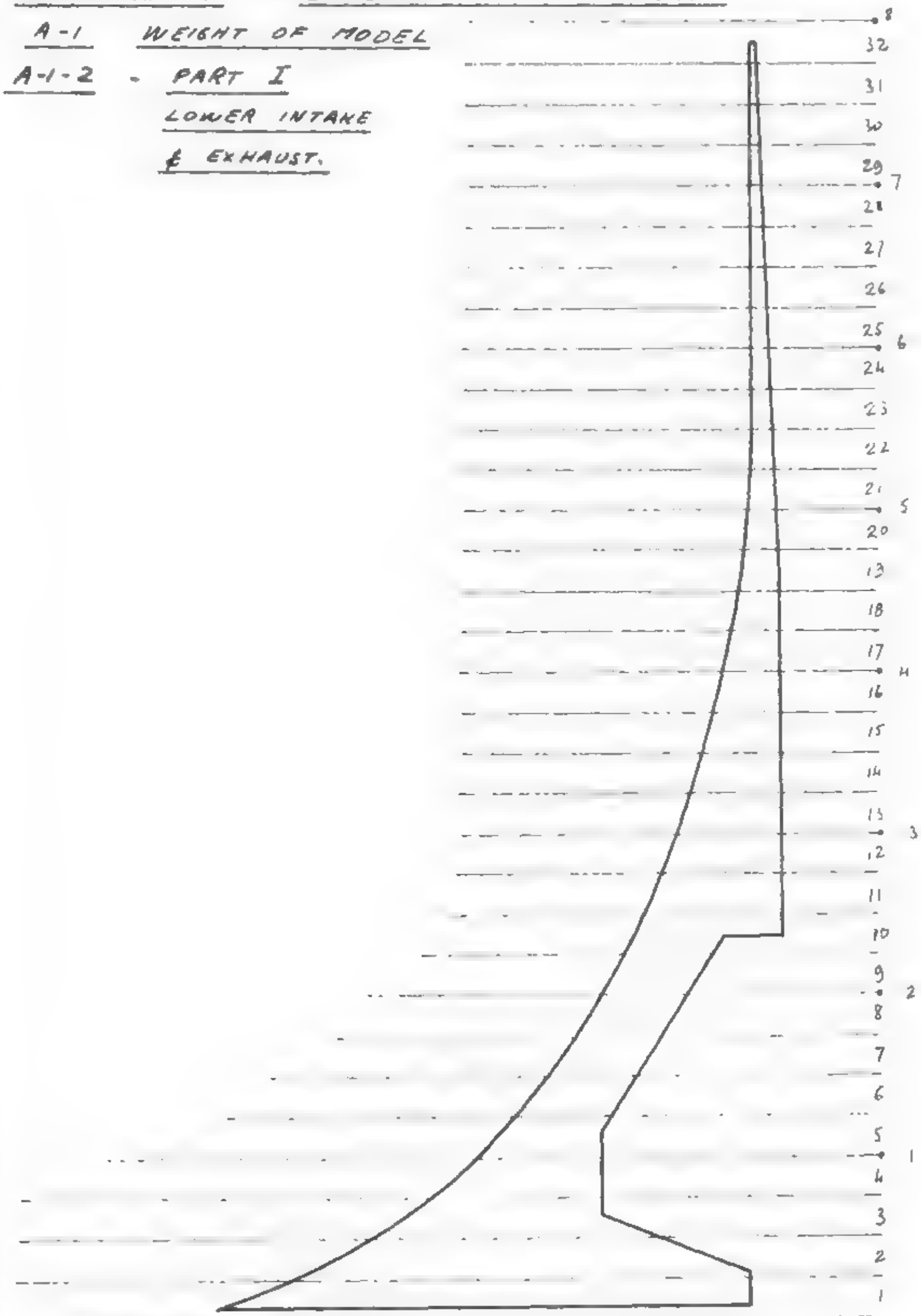
APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-2 - PART I

LOWER INTAKE

& EXHAUST.



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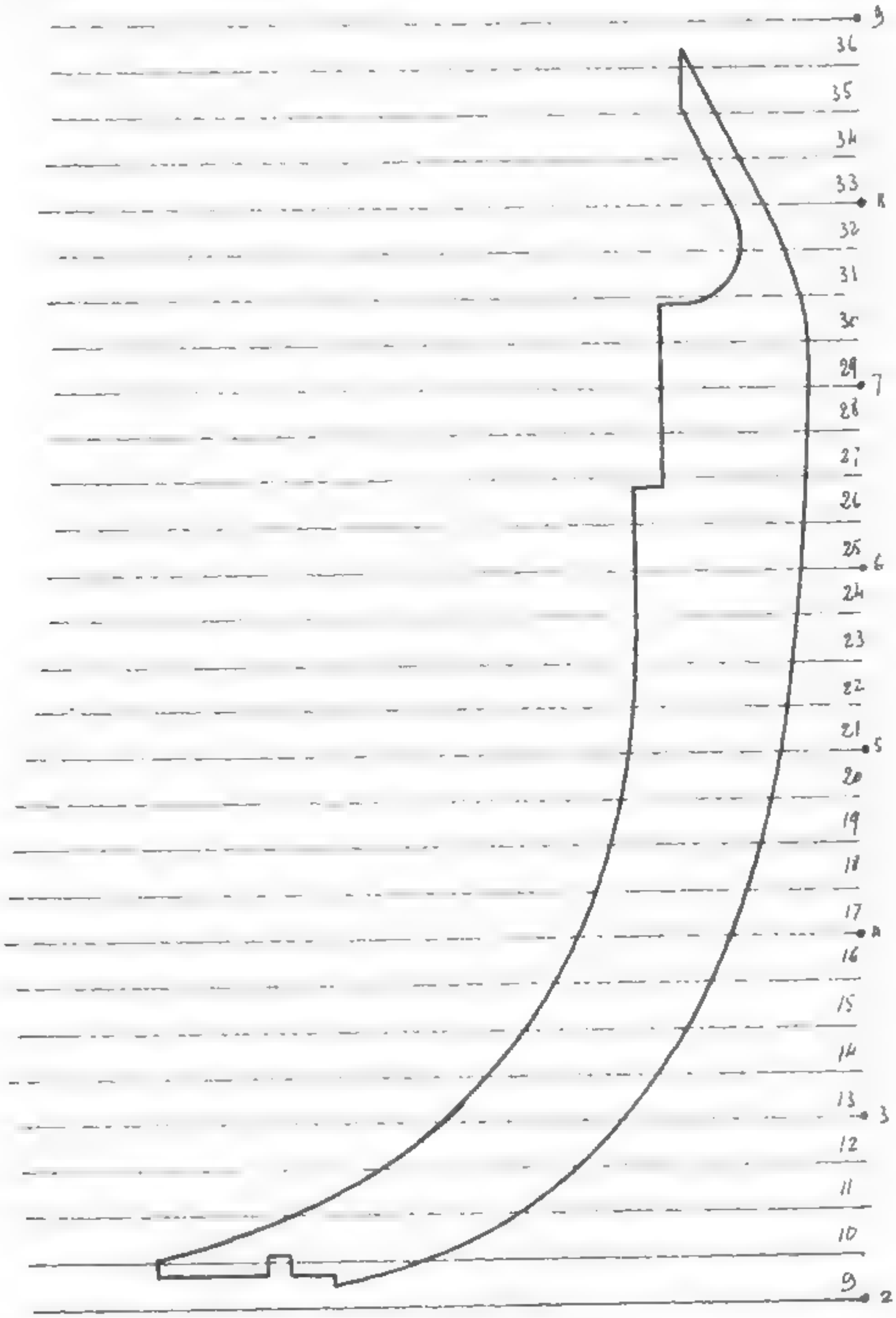
APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-3 PART II LOWER RAMP.

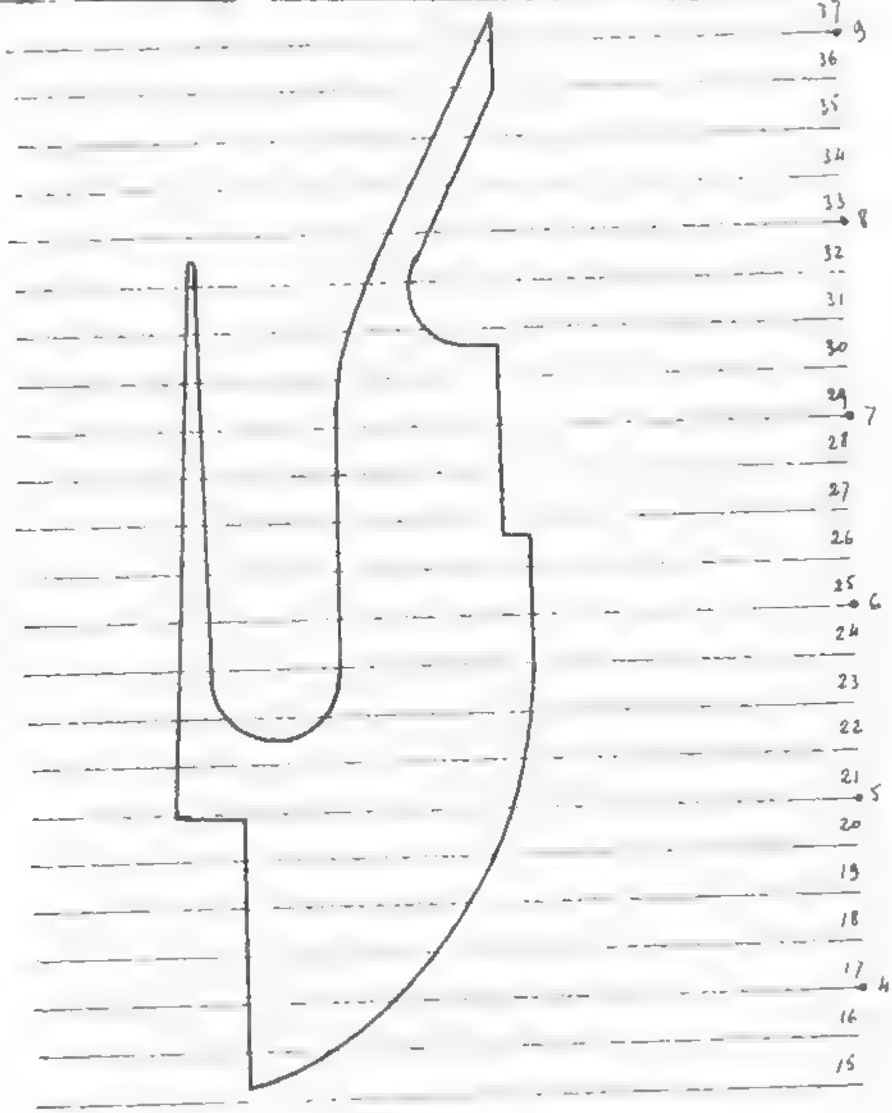


STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-4 PART III UPPER FALSE INTAKE & RAMP



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APPENDIX A - CALCULATION OF WEIGHT

A-1 WEIGHT OF MODEL

A-1-5 PART IV - WING

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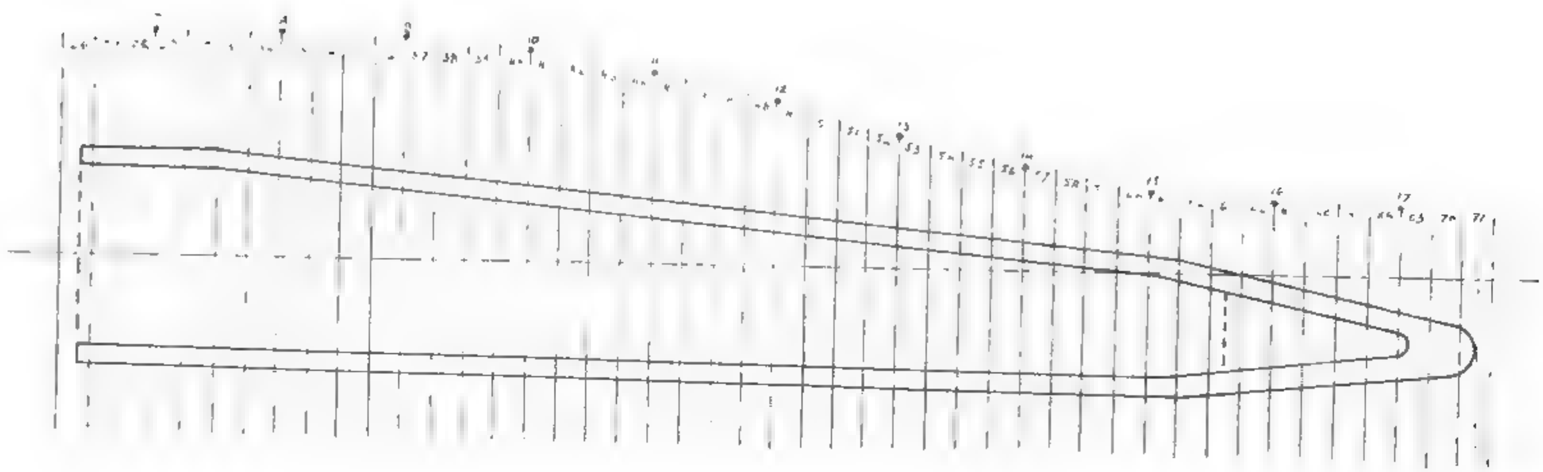

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-1-5 WEIGHT OF MODEL COMPONENTS.

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ITEM	PART I r in a	PART I b in b	PART I rb in² c	PART II r in d	PART II b in e	PART II rb in² f	PART III r in g	PART III b in h	PART III rb in² i	
1	.125	3.1	.3875							
2	.375	[illegible]	[illegible]							
3	.625	[illegible]	.[illegible]125							
4	.875	[illegible]	.2875							
5	1.125	[illegible]	[illegible]							
6	1.375	.50	[illegible]							
7	1.625	.50	.8[illegible]							
8	1.875	.51	.9560							
9	2.125	.53	1.12[illegible]	2.125	.30	.6380				
10	2.375	[illegible]	1.72[illegible]	2.375	[illegible]	3.0850				
11	2.625	[illegible]	2.1250	2.625	[illegible]	2.6250				
12	2.875	.71	2.04[illegible]	2.875	[illegible]	[illegible]				
13	3.125	.61	1.[illegible]	3.125	[illegible]	3.[illegible]				
14	3.375	.55	1.[illegible]	3.375	.83	3.[illegible]				
15	3.625	.45	1.[illegible]	3.625	.9[illegible]	[illegible]	3.625	.15	.544	
16	3.875	.38	1.4[illegible]	3.875	.83	3.2150	3.875	.60	2.3250	
17	4.125	.33	1.3625	4.125	.82	3.385	4.125	.88	3.6351	
18	4.375	.28	1.2250	4.375	.82	3.5900	4.375	1.02	4.1650	
19	4.625	.23	1.0625	4.625	.82	3.7900	4.625	1.23	5.6900	
20	4.875	[illegible]	.87[illegible]	4.875	.82	4.0000	4.875	1.35	6.5800	
21	5.125	[illegible]	.8200	5.125	.84	4.3100	5.125	1.79	9.1800	
22	5.375	.15	.8060	5.375	.85	4.5700	5.375	1.80	9.5900	
23	5.625	[illegible]	.7320	5.625	.87	4.8900	5.625	1.20	6.7500	
24	5.875	.12	.7050	5.875	.89	5.2250	5.875	1.15	[illegible]	
25	6.125	[illegible]	.6740	6.125	.9[illegible]	5.6400	6.125	1.14	6.9800	
26	6.375	.10	.6380	6.375	.93	5.9300	6.375	1.06	6.7500	
27	6.625	.09	.5960	6.625	.78	5.1700	6.625	.97	6.4200	
28	6.875	.08	.5500	6.875	.79	5.4300	6.875	.96	6.6000	
29	7.125	.07	.4980	7.125	.80	5.7000	7.125	.95	6.7700	
30	7.375	.06	.4425	7.375	.80	5.9000	7.375	.75	5.5300	
31	7.625	.05	.3510	7.625	.32	2.4400	7.625	.35	2.6700	31.3335
32	7.875			7.875	[illegible]	1.5750	7.875	.24	1.8900	17.0215
33	8.125			8.125	.18	1.4625	8.125	.22	1.7850	104.1930
34	8.375			8.375	[illegible]	1.5[illegible]	8.375	[illegible]	[illegible]	[illegible]4.5500
35	8.625			8.625	[illegible]	.9450	8.625	.22	1.9[illegible]	2345[illegible]
36	8.875			8.875			8.875	.13	1.15[illegible]	[illegible]
			31.3355			87.0215				

Form 1385

4-1-5 WEIGHT OF MODEL COMPONENTS

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PART IV				PART IV			
ITEM	r	b	rb	ITEM	r	b	rb
	in	in	in²		in	in	in²
a	b	c	d	e	f	g	h
26	[illegible]	.300	[illegible]	56	[illegible]	[illegible]	[illegible]
27	[illegible]	.300	[illegible]	57	[illegible]	[illegible]	4.215
28	[illegible]	.300	2.061	58	[illegible]	[illegible]	[illegible]
29	7.125	.300	2.135	59	[illegible]	[illegible]	[illegible]
30	[illegible]	.300	[illegible]	60	[illegible]	[illegible]	[illegible]
31	7.625	.300	2.291	61	[illegible]	[illegible]	[illegible]
32	7.875	.300	2.360	62	15.375	.300	4.615
33	8.125	.300	2.440	63	15.625	.300	4.685
34	8.375	.300	2.515	64	15.875	.300	[illegible]
35	8.625	.300	2.585	65	16.125	.300	[illegible]
36	8.875	.300	[illegible]	66	[illegible]	[illegible]	[illegible]
37	[illegible]	.300	[illegible]	67	[illegible]	[illegible]	4.985
38	9.375	.300	[illegible]	68	16.875	.300	5.065
39	9.625	.300	[illegible]	69	17.125	.466	7.97
40	9.875	.300	[illegible]	70	[illegible]	.440	7.64
41	10.125	.300	[illegible]	71	[illegible]	.300	5.26
42	10.375	.300	[illegible]				
43	[illegible]	.300	[illegible]				
44	10.875	.300	[illegible]				
45	11.125	.300	3.335				
46	11.375	.300	[illegible]				
47	11.625	.300	[illegible]				
48	[illegible]	[illegible]	[illegible]				
49	[illegible]	.300	[illegible]				
50	[illegible]	[illegible]	[illegible]				
51	[illegible]	[illegible]	[illegible]				
52	[illegible]	[illegible]	[illegible]				
53	[illegible]	.300	[illegible]				
54	[illegible]	.300	[illegible]				
55	[illegible]	[illegible]	[illegible]				

$\Sigma rb = 163.55$

[illegible] = .274 lb

[illegible] = [illegible] lb

[illegible] 163.55 + .274 + [illegible] = 73.5 lb

TOTAL WEIGHT OF MODEL: 104.3 + 73.5 = 177.8 lb

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Form 1385

Date [illegible]

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

4-1-5 WEIGHT OF MODEL COMPONENTS

Weight of ribs

Side area: $\frac{7.5}{2}(.82+1.45)+(.95\times1.45)+\frac{.685}{2}(.65+.82)=$

$$8.5+1.378+.46=10.338\ \text{in}^2$$

Weight per rib: $.283\times10.338\times.30=.887$ lb

Total weight of ribs: 24 ribs:

$$.887\times24=21.30\ \text{lb}$$

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 lb. 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**

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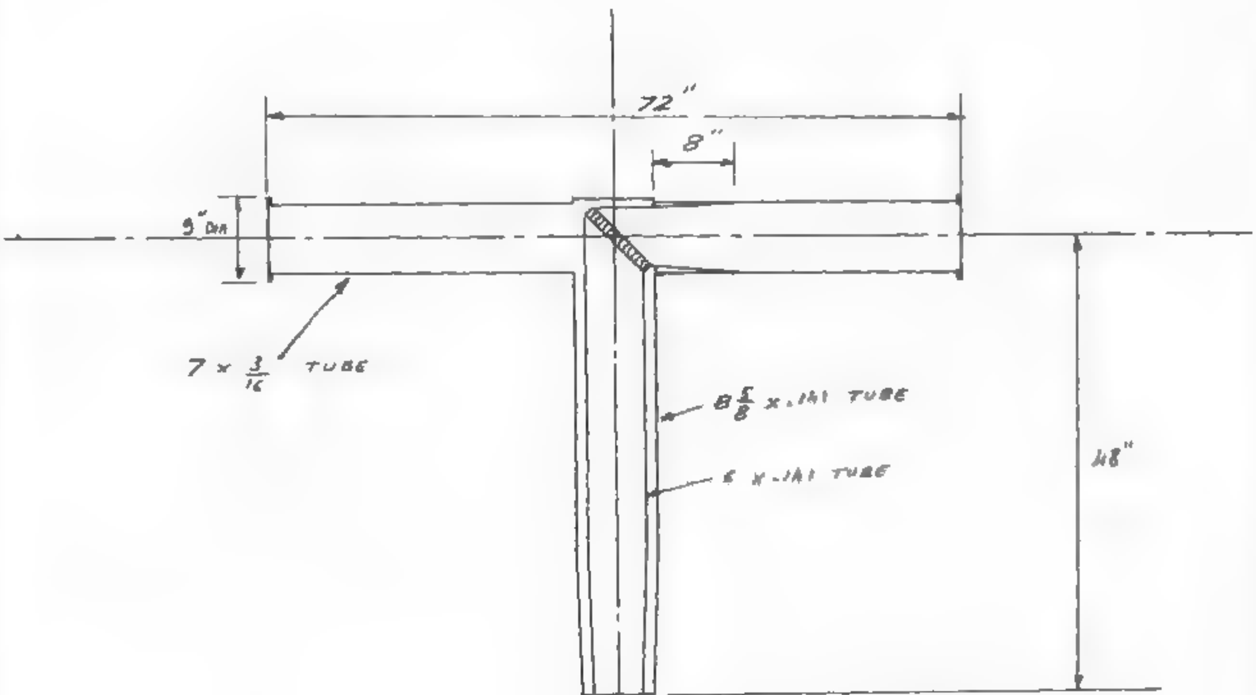
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

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.

O.D.	WALL THK.	WEIGHT/ft
6"	.141"	8.80 lb
8.625"	.141"	12.74 lb

Tube 7 × $\frac{3}{16}$ is available from stock: item: MT. 1015 cold drawn Seamless tube.

Weight per foot at .283 lb/in³

$$.283 \times 12 \times \frac{\pi}{4}\left(7^2 - 6.625^2\right) = 13.32 \ \frac{lb}{ft}$$

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APPENDIX A - CALCULATION OF WEIGHT.

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-1 MAIN TUBES.

Weight of horizontal main tube: $13.32 \frac{72}{12} = 80^{lb}$ ×

Weight of $8\frac{5}{8}$ Vertical tube: $12.74 \frac{48+8}{12} = 59.5^{lb}$ ×

Weight of 6" Vertical tube: $8.80 \frac{48}{12} = 35.20^{lb}$ ×

Tapered entry to 6" tube: assume approx. equal to 1 ft of tube $6\frac{5}{8}$ OD × .141 Wall: 9.74^{lb} say. 10^{lb} ×

Weight of cascade: assume 2^{lb} ×

End rings.

$2 \times .283 \times .375 \times \frac{\pi}{4}(9^2 - 7^2) = 5.33^{lb}$ ×

Total weight of model mounting not including incidence arm and gage mounting

$80 + 59.5 + 35.2 + 10 + 2 + 5.33 = 192^{lb}$ ××

Weight of vertical tubes: $59.5 + 35.2 = 94.7^{lb}$

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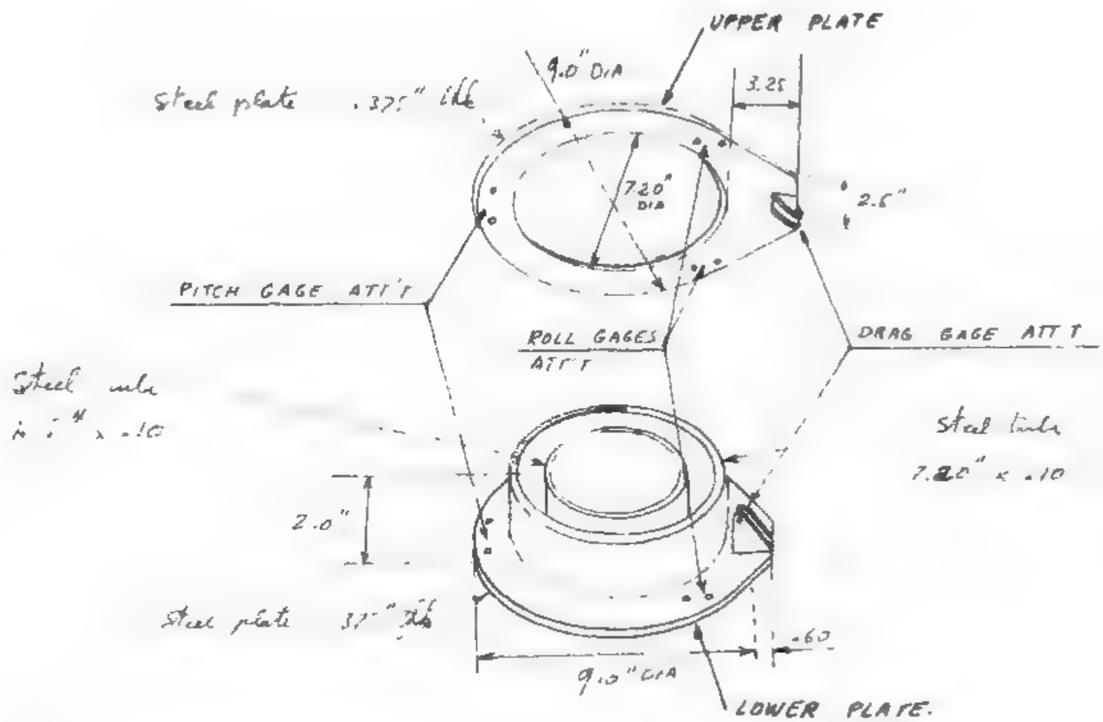
STRESS ANALYSIS OF 1/12 SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-2

LOAD GAGES ASS'Y.



UPPER PLATE

Area: measured on dwg. 37.68 in²

Weight of plate. .283 × .375 × 37.68 = 4.0 lb

LOWER PLATE

Area measured on dwg: 28.18 in²

Weight of plate: .283 × .375 × 28.18 = 3.00 lb

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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 $.283 \times 2.0 \frac{\pi}{4}(7.2^2 - 7.0^2) = 1.33^{lb}$

Smaller tube : Weight : $.283 \times 2.5 \frac{\pi}{4}(4.5^2 - 4.1^2) = .62^{lb}$

Drag gage Brackets

weight estimated at 1^{lb}

Total weight.

$$4 + 3 + 1.33 + .62 + 1 = 9.95^{lb}$$

add 10% for welds, bolts etc...

$$9.95 \times 1.1 = 10.95^{lb} \text{ say } \underline{11^{lb}}$$

WEIGHT OF RING GAGES.

GAGE A. 800^{lb} RATED LOAD.

$$W = .283\left[\frac{\pi}{4}(D^2 - d^2)\,b + 2\,b_f t_f L_f + 2\,b_p t_p L_p\right]$$

substituting $d = D - 2t$

$$W = .283\left[\pi b t(D - t) + 2 b_f t_f L_f + 2 b_p t_p L_p\right]$$

$$= .283\left[\left(\pi \times .628 \times .22(3 - .22)\right) + (2 \times .50 \times .08 \times .55) + (2 \times .50 \times .20 \times 1.50)\right]$$

$$= .436^{lb}$$

STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A – CALCULATION OF WEIGHT

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-2 LOAD GAGE ASS'Y

WEIGHT OF RING GAGES – CONT'D

GAGES B & C : RATED LOAD : 350 lb

$$W = .283\left[\left(\pi b t (D-t)\right) + 2 b_f t_f L_f + 2 b_p t_p L_p\right]$$

$$= .283\left[\left(\pi \times .50 \times .165 (3.0 - .165)\right) + (2 \times .375 \times .047 \times .55) + (2 \times .50 \times .26 \times 1.50)\right]$$

$= .298$ lb per gage : .596 lb for the 2 gages *

GAGE D : RATED LOAD : 150 lb

$$W = .283\left[\pi b t (D-t) + 2 b_f t_f L_f + 2 b_p t_p L_p\right]$$

$$= .283\left[\left(\pi \times .40 \times .10 (2 - .10)\right) + (2 \times .25 \times .030 \times .35) + (2 \times .375 \times .375 \times .50)\right]$$

$= .109$ lb *

TOTAL WEIGHT OF GAGES:

$.436 + .596 + .109 = 1.141$ lb

add 10% for bolts, leads, wiring etc:

$1.141 \times 1.1 = \simeq 1.3$ lb **

Total weight of vertical pipes

$94.7 + 11.0 + 1.3 = 107$ lb

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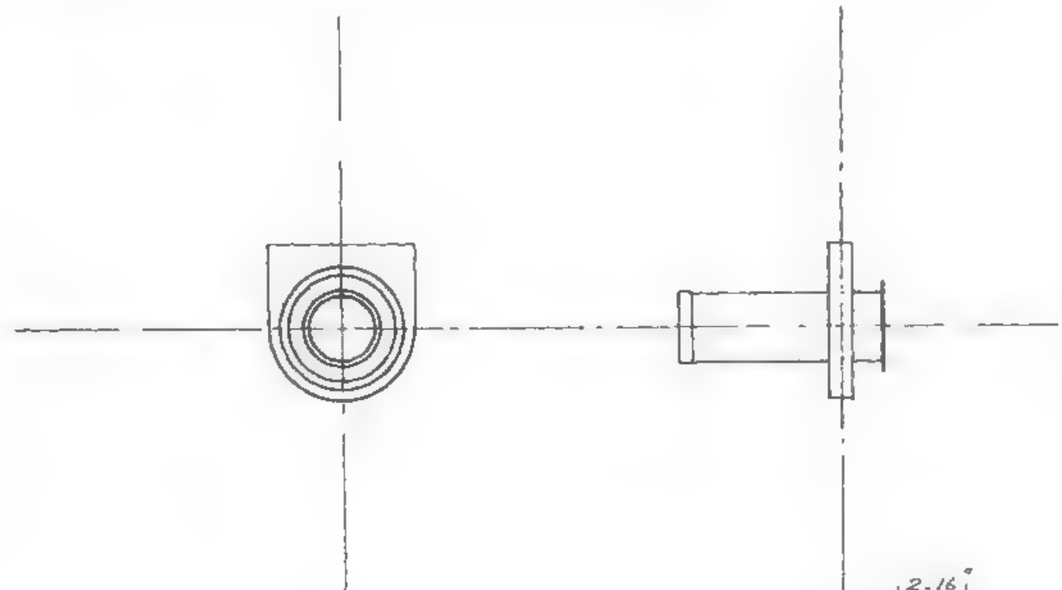
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

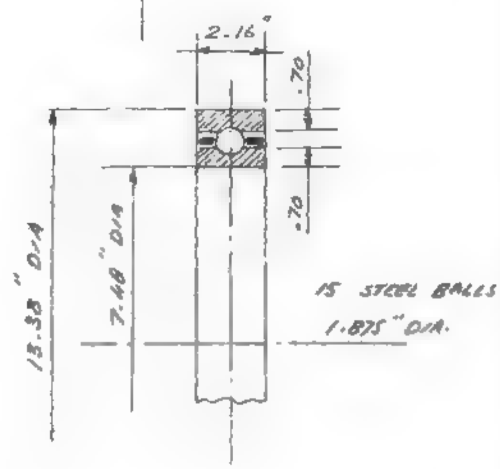
A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-3-

WEIGHT OF ATTACHMENT TO BALANCE STRUTS.



BALL-BEARING. SKF- 6238-M



Weight of balls: $V = \frac{\pi D^3}{6}$

$15 \times .283 \times \pi \frac{1.875^3}{6} = 14.68^{lb}$

Outer race.

Mean dia: $13.38 - .70 = 12.68''$

Sectional area: $2.16 \times .70 = 1.51^{in^2}$

Weight $.283 \times 1.51 \times 12.68\pi = 17.12^{lb}$

Inner race

Mean dia $7.48 + .70 = 8.18''$

Sectional area $2.16 \times .70 = 1.51^{in^2}$

Weight. $.283 \times 1.51 \times 8.18\pi = 10.95^{lb}$

Weight of Bearing: $14.68 + 17.12 + 10.95 = 42.75^{lb}$

Note. By not removing the weight of the grooves, that of the retainer is taken care off.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

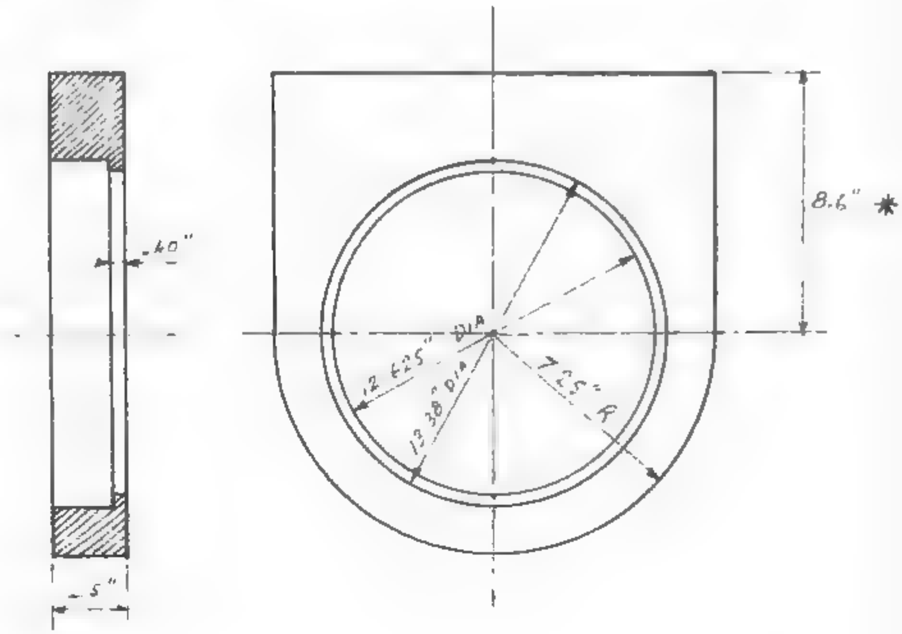
APPENDIX A - CALCULATION OF WEIGHT.

A-2 WEIGHT OF MODEL SUPPORT STRUCTURE

A-2-3

ATTACHMENT TO BALANCE STRUTS. CONT'D.

BEARING HOUSING.



Side area

$(14.5 \times 8.6) + (7.25^2 \frac{\pi}{2}) - (13.38^2 \frac{\pi}{4}) = 124.8 + 83 - 141 = 66.8 \text{ in}^2$

Weight $66.8 \times .5 \times .283 = 47.3$ lb

Retainer ring

$.283 \times .40 \times \frac{\pi}{4}(13.38^2 - 12.625^2) = 1.70$ lb

Total weight $47.3 + 1.70 = 49$ 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.

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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". $7 \times \frac{3}{16}$ Tube. Steel
weight. 13.32 lb per ft

Tube weight: $13.32 \times \frac{21.5}{12} = 23.9$ lb

Flange 5.33 lb (Ref page B-)

Ball bearing mounting ring. assumed 12 lb

End rings assumed 6 lb

Total weight $23.9 + 5.33 + 12 + 6 = 47.23$ lb

add 10% for welds, bolts, etc
$47.23 \times 1.10 = 52$ lb

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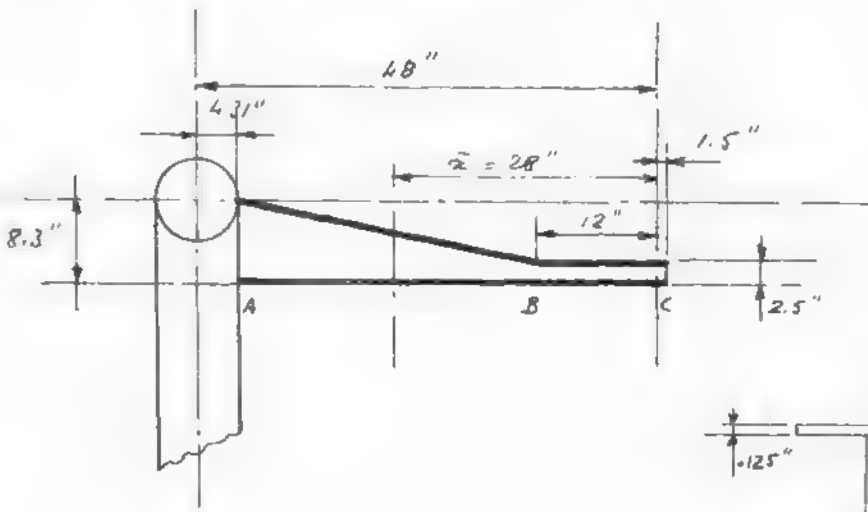
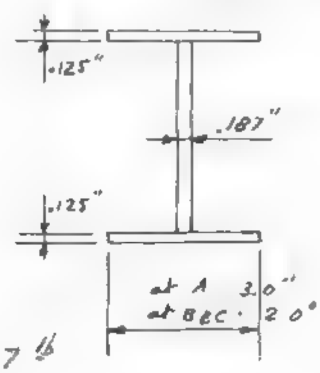
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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 + 32.3 = 64"

Weight of tapered flange: 64 × 2.5 × .125 × .283 = 5.67 lb

Total length of constant width flange (12 + 1.5) 2 = 27"

Weight of constant width flange: 27 × 2 × .125 × .283 = 1.91 lb

WEB

Rectangular part: Side area. (2.5 − .25)(12 + 1.5) = 30.4 in²

weight: 30.4 × .187 × .283 = 1.6 lb

Trapezoidal part: Side area: $(8.05 + 2.25)\,\frac{48-12-4.31}{2}$ = 163.5 in²

weight: 163.5 × .187 × .283 = 8.65 lb

Weight of web: (163.5 + 30.4) × .187 × .283 = 10.25 lb

Total weight of arm 10.25 + 1.91 + 5.67 = 17.83 lb

then $\bar{x} = \frac{(33 \times 14.32) + (6 \times 3.51)}{17.83} = 28"$

Weight of rear balance strut connecting link ≈ 3.5 lb

Total weight of arm: 17.83 + 3.5 = 21.35 say 21.50 lb

add 10% for welds: 23.70 lb say 24.0 lb

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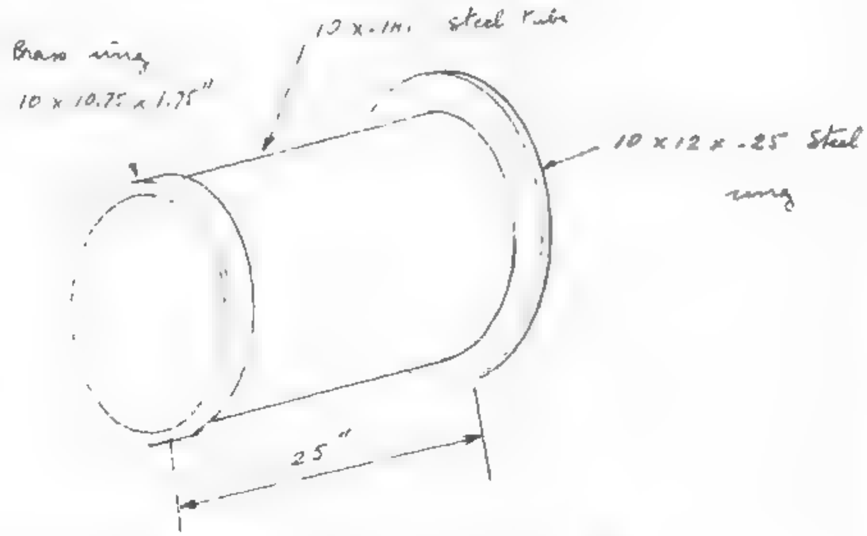
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL.

APPENDIX A – CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING.

A-3-1

FAIRING – OUTER SECTION.



Weight of 10" tube: Ref. [illegible] catalog 14.81 lb/ft.

Weight of tube: $14.81 \frac{25}{12} = 30.9$ lb.

Weight of steel ring:
$.283 \times .25 \frac{\pi}{4}(12^2 - 10^2) = 2.44$ lb

Weight of brass ring
$.30[illegible] \times 1.75 \frac{\pi}{4}(10.75^2 - 10^2) = 6.53$ lb

Total weight: $30.9 + 2.44 + 6.53 = 39.87$ lb

add 10% for welds, bolts, etc....
$39.87 \times 1.10 = 43.85$ lb

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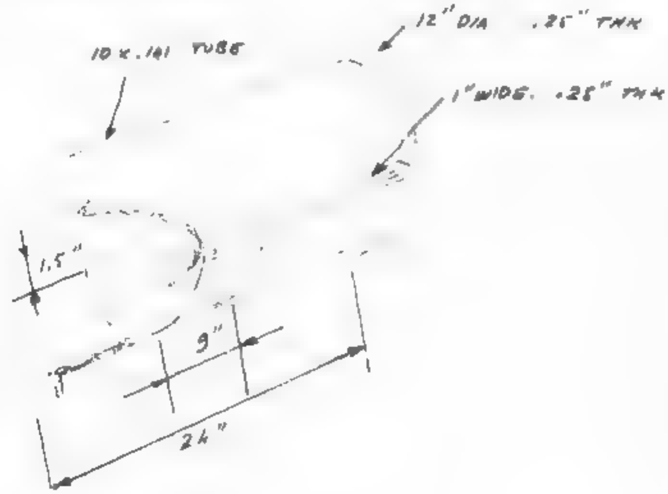
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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. $14.81 \frac{lb}{ft}$

Weight of uncut tube: $14.81 \frac{24}{12} = 29.62$ lb

Weight removed by cut arc 165°

$$14.81 \frac{9}{12} \frac{165}{360} = 5.10 \text{ lb}$$

Total weight of tube $29.62 - 5.10 = 24.52$ lb

Weight of rings $2 \times .283 \times \frac{\pi}{4}(12^2 - 10^2).25 = 4.87$ lb

Weight of side strips $4 \times .283 \times 1.0 \times .25 \times 23.5 = 6.65$ lb

Total weight of component

$$24.52 + 4.87 + 6.65 = 36.04 \text{ lb}$$

add 10% for welds, bolts, etc: $36.04 \times 1.1 = 39.7$ lb

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

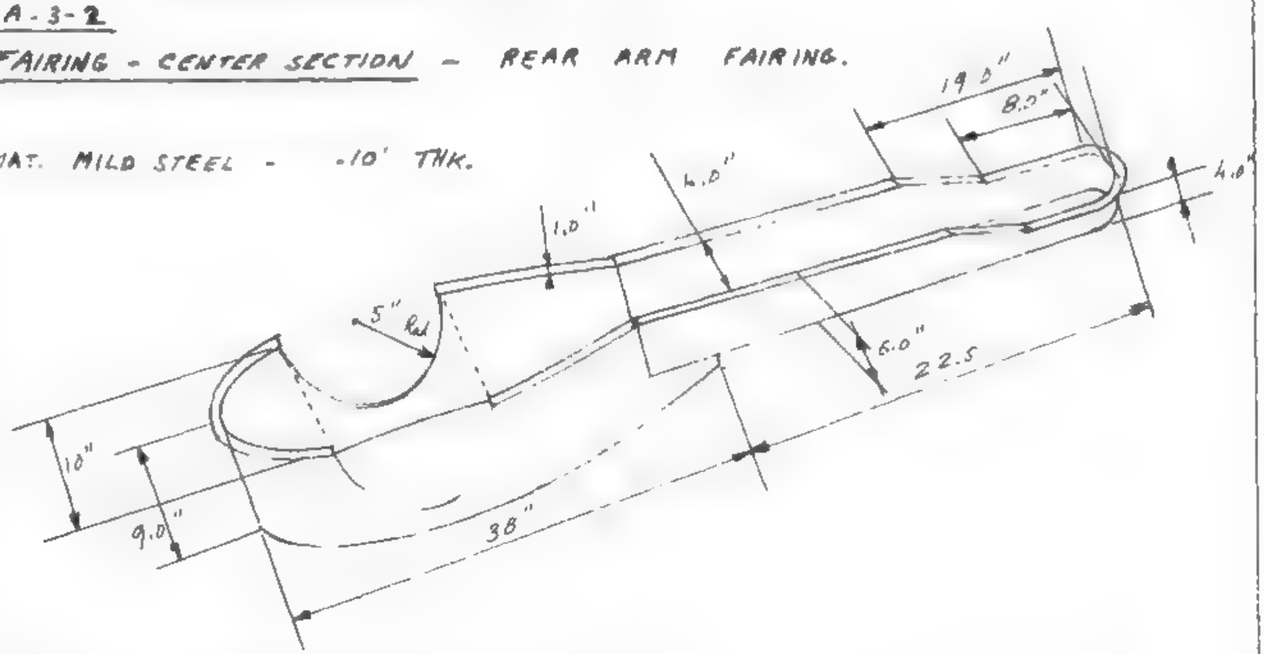
APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-2

FAIRING - CENTER SECTION - REAR ARM FAIRING.

MAT. MILD STEEL - .10" THK.



Developed length of streamlined part. 82"

Lateral area of developed part: $(82 \times 9.0) - \pi \times 5^2 = 738 - 78.5$
$= 659.5 \text{ in}^2$

Arm fairing:

Sides: area: $6.0(2 \times 22.5 + 4.0) = 294 \text{ in}^2$

Bottom: $22.5 \times 6 = 135 \text{ in}^2$

Edge: 1.0" wide. total length measured on dwg 105"

Area: 105 in^2

Cover plates Front plate. $\approx \frac{1}{2}$ circle rad 3.0" 14 in^2

Rear plate $\approx \frac{25 \times 12}{2} = 150 \text{ in}^2$

$+ 25 \times 6 = 150 \text{ in}^2$

Total area of plate: $659.5 + 294 + 135 + 105 + 150 + 150 = 1493.5 \text{ in}^2$

Weight of plate: $.283 \times .10 \times 1493.5 = 42.3 \text{ lb}$

add 10% for welds, bolts, etc.

$42.3 \times 1.1 = 46.50 \text{ lb}$

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING.

A-3-2.

FAIRING - CENTER SECTION - ALUMINUM PART.

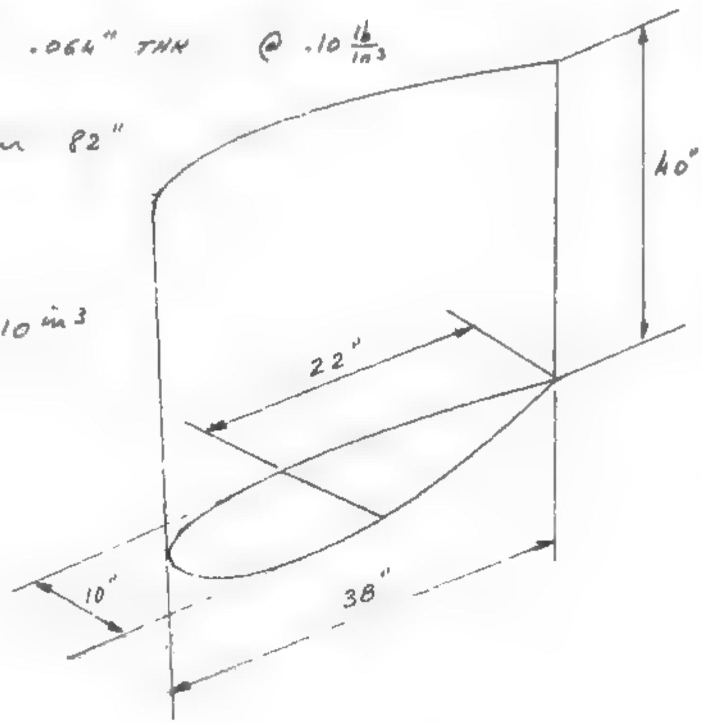
MAT. 24 ST. AL. ALL : .064" THK @ .10 $\frac{lb}{in^3}$

Developed length of contour 82"

Lateral area of sheet:
$82 \times 40 = 3280 \ in^2$

Volume: $3280 \times .064 = 210 \ in^3$

Weight of sides
$210 \times .10 = 21 \ lb$



Bottom part:
approx area:
$10 \times \frac{22}{2} = 110 \ in^2$

Weight. $.10 \times .064 \times 110 = .70 \ lb$

Total weight of aluminum fairing : $21 + .70 = 21.70 \ lb$

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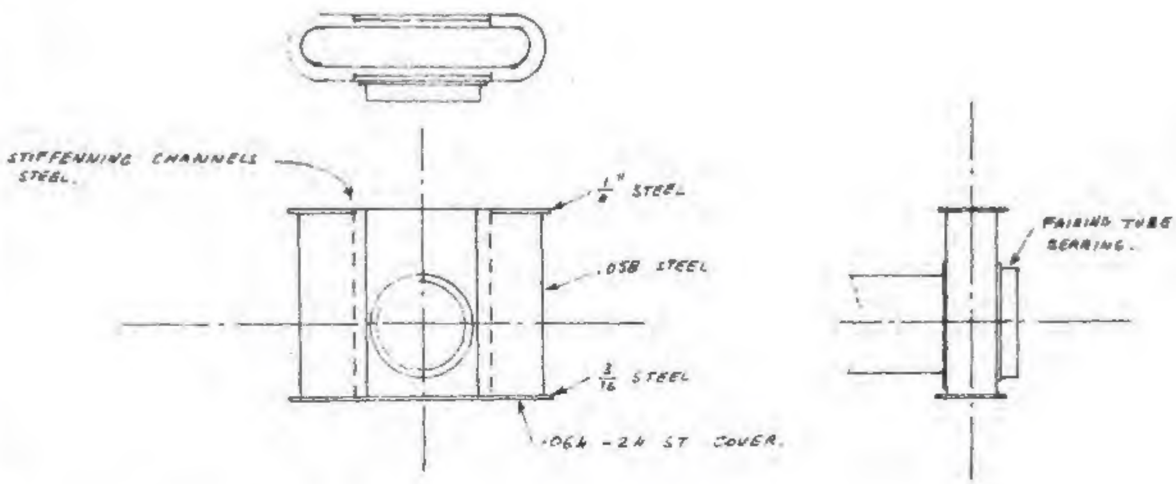
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-3

ATTACHMENT TO BALANCE STRUTS - FAIRING -.



LOWER BORDER. $\frac{3}{16}$ STEEL.

Thickness: .187" - width: .875" mean length: 54"

weight: .283 × .187 × .875 × 54 = 2.5 lb ×

UPPER BORDER. $\frac{1}{4}$" STEEL.

Thickness: .250" width .875" mean length. 31.2"

Weight: .283 × .25 × .875 × 31.2 = 1.93 lb ×

STIFFENNING CHANNELS.

Thickness: .058" - developped width: 2.4" length: 19×4 = 76"

Weight: .283 × .058 × 2.4 × 76 = 2.99 lb ×

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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-3

ATTACHMENT TO BALANCE STRUTS - FAIRING - CONT'D.

LOWER COVER PLATE. .064" - 24 ST.

Thickness: .064" - width 5.5" mean length: 11.60" × 2

Weight .10 × .064 × 5.5 × 23.2 = .81 lb ×

FRONT & REAR SHEETING. .058" STEEL

Thickness: .058" developed width: 16.8" length 19"

Weight: 2 × .283 × .058 × 16.8 × 19 = 10.5 lb ×

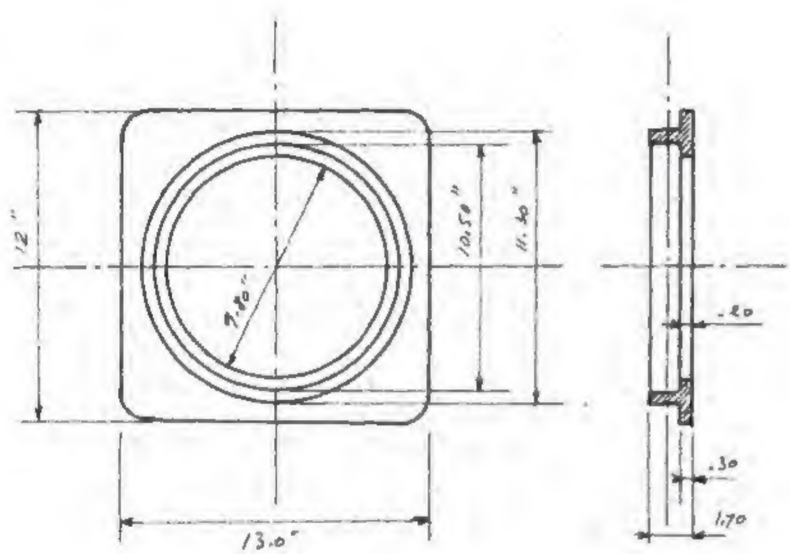
SIDE SHEETING. .072" STEEL.

Thickness: .072" Side area: $(13 \times 19) - (\frac{\pi}{4} 10^2) = 169$ in²

Weight: 2 × .283 × .072 × 169 = 6.9 lb ×

FAIRING TUBE BEARING.

MAT. STEEL.



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STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

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: .30 in

Area: $(12 \times 13) - \frac{\pi}{4}(10.50)^2 = 69 \text{ in}^2$

Weight: $.283 \times .30 \times 69 =$ 5.86 lb *

Cylinder:

Weight: $.283 \ \frac{\pi}{4}\left(11.30^2 - 10.50^2\right) 1.50 = 6.02$ lb *

Retainer ring

Weight: $.283 \ \frac{\pi}{4}\left(10.50^2 - 9.5^2\right) .20 = .622$ lb *

Retainer ring - external:

Weight: $.283 \ \frac{\pi}{4}\left(11.30^2 - 9.70^2\right) .187 = 1.33$ lb *

Total weight: $5.86 + 6.02 + .622 + 1.33 = 13.83$ lb

add 10% for bolts, welds, etc....

$13.83 \times 1.10 = 15.25$ lb **

TOTAL WEIGHT OF FAIRING.

$2.5 + 1.93 + 2.99 + .81 + 10.5 + 6.9 + 13.83 = 39.46$ lb

add 10% for welds, bolts, etc:

$1.10 \times 39.46 = 43.50$ lb **

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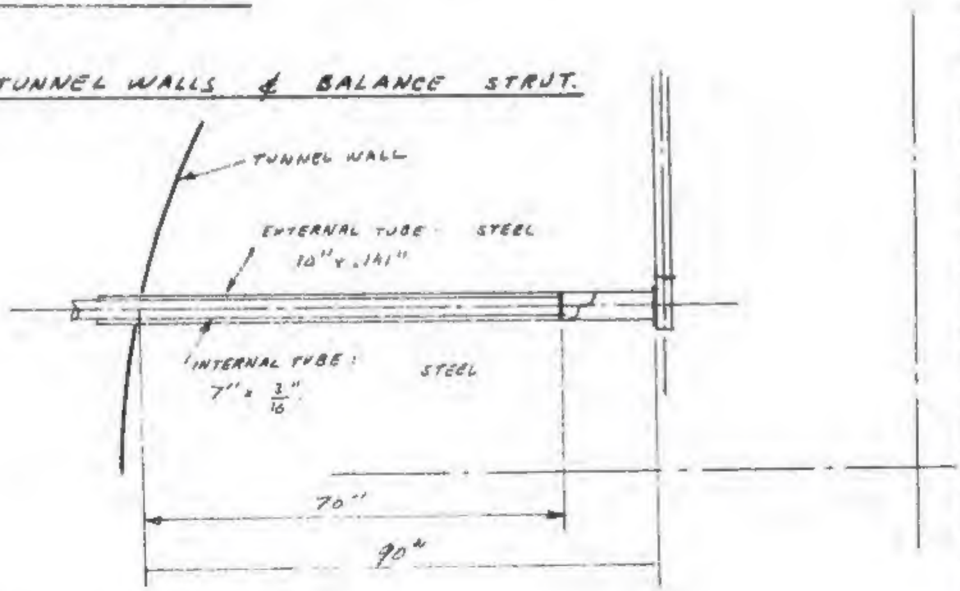
STRESS ANALYSIS OF $\frac{1}{12}$ SCALE HOVERING & TRANSITION MODEL

APPENDIX A - CALCULATION OF WEIGHT

A-3 WEIGHT OF FAIRING

A-3-4

TUBES BETWEEN TUNNEL WALLS & BALANCE STRUT.



EXTERNAL TUBE : $14.81 \frac{lb}{ft}$

Weight: $\frac{90}{12} \times 14.81 = 111^{lb}$ x

INTERNAL TUBE : $13.32 \frac{lb}{ft}$

Weight: $\frac{70}{12} \times 13.32 = 77.7^{lb}$ x

TOTAL WEIGHT OF TUBES.

$111 + 77.7 = 188.7^{lb}$ x

Assume $\frac{1}{2}$ the total weight is applied on the strut fairing $+ 10^{lb}$ for miscellaneous parts:

$94.35 + 10 = 104.35$ say 105^{lb} xx

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