UNCLASSIFIED

CF-105

N.A.E. SPINNING TUNNEL TESTS,

DATA FOR DYNAMIC BALANCING

G. K. Dimock

National Research Council Canada
Conseil national de recherches Canada

Canada Institute for Scientific and Technical Information
J.H. Parkin Branch

Institut canadien de l'information scientifique et technique
Annexe J.H.Parkin

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B.J. Petzinger
B.J. Petzinger
Deputy Coordinator
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AVRO AIRCRAFT LIMITED

TECHNICAL DEPARTMENT (Aircraft)

REPORT No:

SHEET No. 6

AIRCRAFT:

A. U. W.

COMPONENT

PREPARED BY

DATE

CHECKED BY

DATE

$W_s = .173$ lb $k_s^2 = .052106$ ft^2 $L_s = .153333$ ft.

$\frac{W_s}{W_m} k_s^2 = .001423$ $\frac{W_s}{W_m} L_s = .004188$

$\frac{4\pi^2}{g} = 1.226038$

$$T_x^2 = 1.226038 \left(\frac{.068106 + .373932 + .001423}{.611500 + .004188} \right)$$

$$= 1.226038 \left(\frac{.443461}{.615688} \right) = .883077$$

$T_x = .939722$ $T_{50x} = 46.9861$ sec.

$$T_y^2 = 1.226038 \left(\frac{\overset{.680918}{.305563 + .375355}}{.415688} \right) = 1.355932$$

$T_y = 1.164445$ $T_{50y} = 58.2222$ sec.

FORM 1318A

C-105 SPINNING MODEL

DYNAMIC BALANCING

LOAD CASE I 10,000'

$L_m = .5940'$

$T^2 =$

$4\pi^2/g = 1$

$A = L$

$B = L$

$T_x^2 = .8$

% ERROR IN L_m	1 L'_m ft	2 L'^2_m	3 A	4 B	5 $\frac{4\pi^2}{g} \times A$	6 BT_x^2	7 ⑥-⑤	8 $k_x'^2 = \frac{⑦}{4\pi^2/g}$	9 k'_x	% ER
									$k_x = .2753$	
1	.599940	.359928	.361987	.605999	.443810	.533295	.089485	.072987	.270161	— 1.8
2	.605880	.367090	.369149	.611939	.452591	.538523	.085941	.070096	.264756	— 3.
3	.611820	.374324	.376383	.617879	.461460	.543750	.082290	.0671186	.259013	— 5.
4	.617760	.381627	.383686	.623819	.470414	.548977	.078563	.064079	.253138	— 8.

$$T^2 = \frac{4\pi^2}{g}\left[\frac{k^2 + A}{B}\right]$$

$4\pi^2/g = 1.226038$

$A = L_m^2 + .002059$

$B = L_m + .006059$

$T_x^2 = .880027$ $T_y^2 = 1.620951$

$L_m = P_{ny} + 5.43"$

$P_{ny} = 1.369" + \bar{V}_m$

$\bar{V}_m = \frac{\bar{V} - 120}{24} = .329"$

$(MAC)_m = 15.108996"$

AVRO A

TEC

AIRCRAFT

WEIGHT

C. G. POSITIC

8	9	10	11	12	13	14	15	16	17	18	19	20	21
$k_x'^2 = \frac{⑦}{4\pi^2/g}$	k_x'	% ERROR IN k_x	BT_y^2	⑪ − ⑤	$k_y'^2 = \frac{⑫}{4\pi^2/g}$	k_y'	% ERROR IN k_y		L_m' inches	P_{ny}' ⑰ − 5.43	$\bar{V}_m'$ ⑱ − 1.369"	% ERROR IN $\bar{V}_m$	Σ ERRO AS A % (MAC)
	$k_x = .275347'$					$k_y = .662153$							
.072987	.270161	− 1.883	.982295	.538485	.439207	.662727	.0867		7.199	1.769	.400	.071 21.58	.47
.070096	.264756	− 3.846	.991923	.539332	.435898	.663248	.165		7.270	1.840	.471	.142 43.16	.94
.0671186	.259013	− 5.910	1.001552	.540092	.440518	.663715	.236		7.342	1.912	.543	.214 65.04	1.42
.064079	.253138	− 8.066	1.011180	.540766	.441068	.664129	.30		7.413	1.983	.614	.285 86.6	1.89

5.43"

$+ \bar{V}_m$

$\frac{20}{4} = .329''$

.108996"

AVRO AIRCRAFT LIMITED

MALTON, ONTARIO

TECHNICAL DEPT. (AIRFRAME)

AIRCRAFT - -

WEIGHT - -

C. G. POSITION -

REPORT NO. -

SHEET - -

DATE - - DEC '56

PREPARED BY - G.K.D.

17	18	19	20	21	22	23	24	25	26	27	28	29
L'_m inches	P'_{xy} ⑰ − 5.43	$\bar{V}'_m$ ⑱ −1.365"	% ERROR IN $\bar{V}_m$	Z ERROR AS A % $(MAC)_m$	ERROR IN $\bar{H}_m$	X ERROR % $(MAC)_m$	P'_{xy} + 5.39	Z BALANCE ㉔ × 4.378	Z BALANCE ERROR in lb	35.36 − $\bar{H}'_m$ + 5.39	X BALANCE ㉗ × 4.378	X BALANCE ERROR in lb
				$\bar{H}_m$ = 22.64"				31.031 in lb				79.285 in lb
1.199	1.769	.400	.071 21.58	.47	.0755	.5	7.159	31.342	.311	18.035	78.957	− .328
7.270	1.840	.471	142 43.16	.94	.151	1	7.230	31.653	.622	17.959	78.624	− .661
7.342	1.912	.543	214 65.04	1.42	.227	1.5	7.302	31.968	.937	17.883	78.292	− .993
1.413	1.983	.614	.285 86.6	1.89	.302	2.0	7.373	32.279	1.248	17.806	77.963	− 1.322

O. R. L.

AVRO AIRCRAFT LIMITED
MALTON – ONTARIO

TECHNICAL DEPARTMENT

REPORT NO.

SHEET NO.

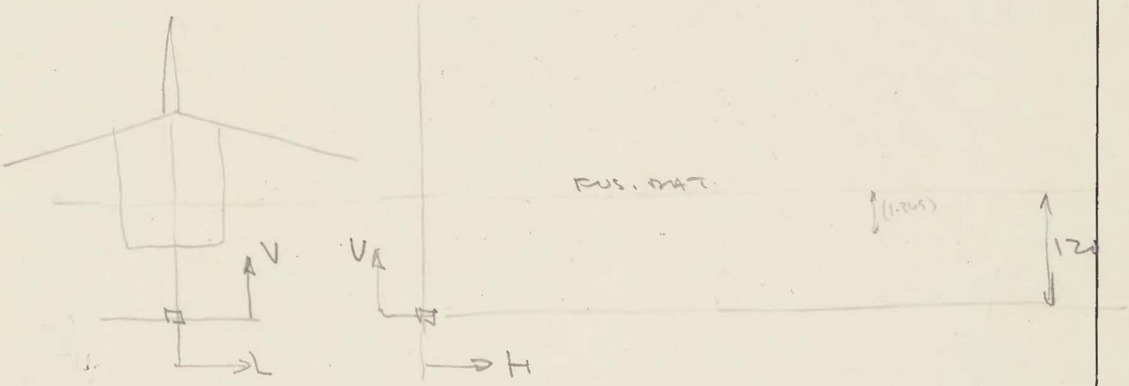
PREPARED BY:

DATE:

CHECKED BY:

DATE:

AIRCRAFT



BOTTOM PLUG V PLUG FACE = 1.369 in
below fus. datum line

REAR PLUG H PLUG FACE =

SUMMARY

This note includes descriptions of the gear used in dynamic balancing of models for the NAE spinning tunnel, a summary of the conditions of similitude, and charts for use in adjusting the centre of gravity and moment of inertia of models.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 SPINNING MODEL DYNAMIC BALANCING GEAR

1.1 In order to adjust the moments of inertia of a spinning model for dynamic similarity to the full-scale aircraft the model is supported as a compound pendulum and its mass distribution is adjusted until its period of oscillation about three axes successively bears the appropriate relation to the calculated moment of inertia of the system:

$$T = 2\pi\sqrt{\frac{I}{WL}}$$

where T = period of oscillation
I = moment of inertia about swinging axis of model and support system.
W = weight of model and support system.
L = distance from centre of gravity of model and support system to swinging axis.

The centre of gravity of the model is adjusted on a special balance before adjustment of the moment of inertia. This note records measured values of particulars of the support systems.

1.2 Centre of Gravity Balance

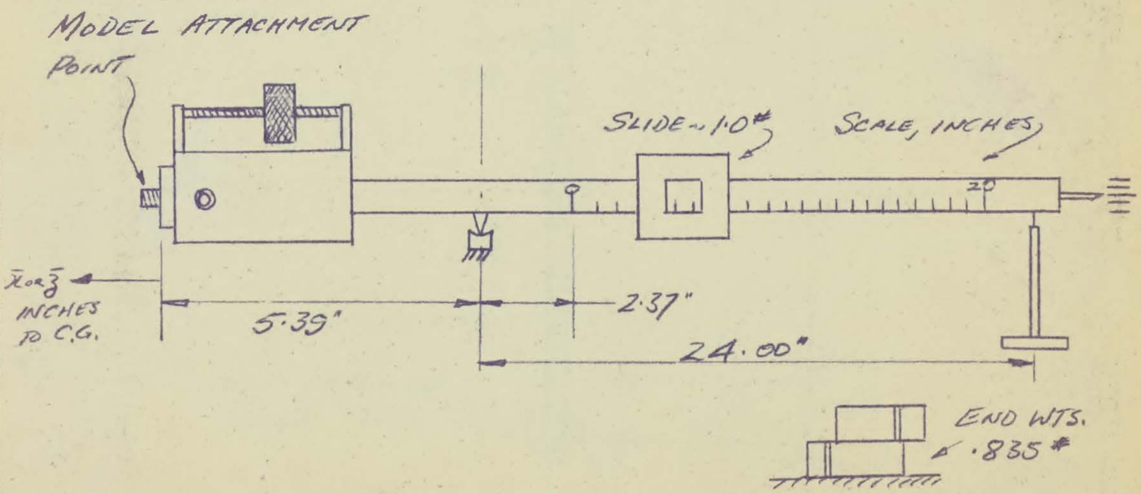


FIG. 1

Procedure:

1. Balance without model but with attachments in place, slide at zero, and no balance weights.

2. Add model.

3. Movement of slide gives inch-pounds directly, required moment having been determined from Fig. 4.
4. Addition of each end weight gives 20 in. lb.

1.3 X-axis and Y-axis Attachment

I = 0.00028 slug-ft^2 re swinging axis
W = 0.173 lb.
L = 1.84 in. = 0.153 ft.
WL = 0.026 ft.-lb.

$I = md^2$

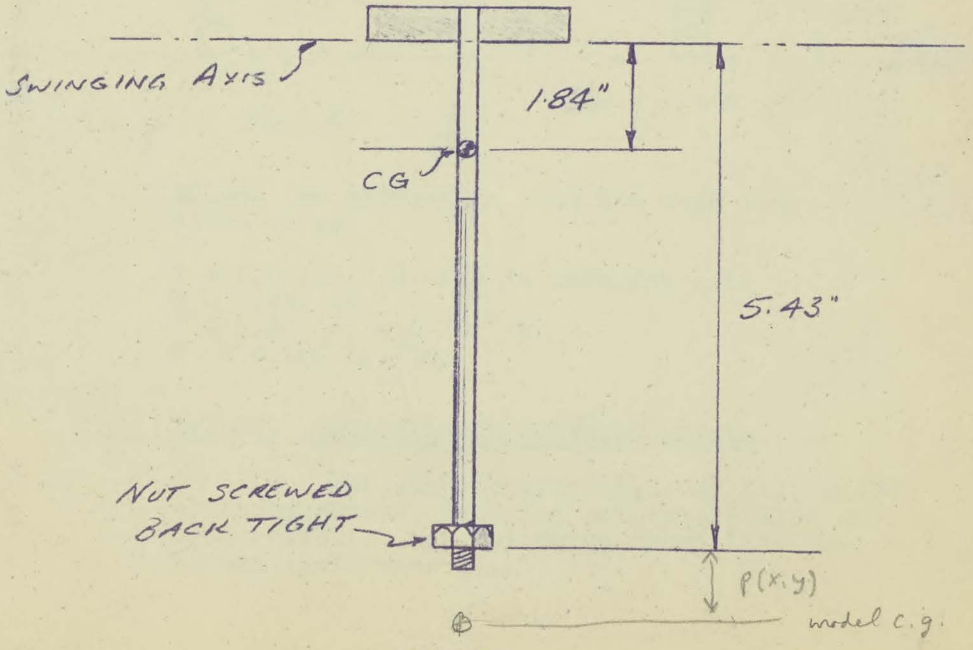


FIG. 2

1.4 Z-axis Attachment

Values for attachment alone:

$I = 0.00134$ slug-ft^2 re swinging axis
$W = 0.441$ lb.
$L = 3.33$ in. $= 0.278$ ft.
$WL = 0.123$ ft.-lb.

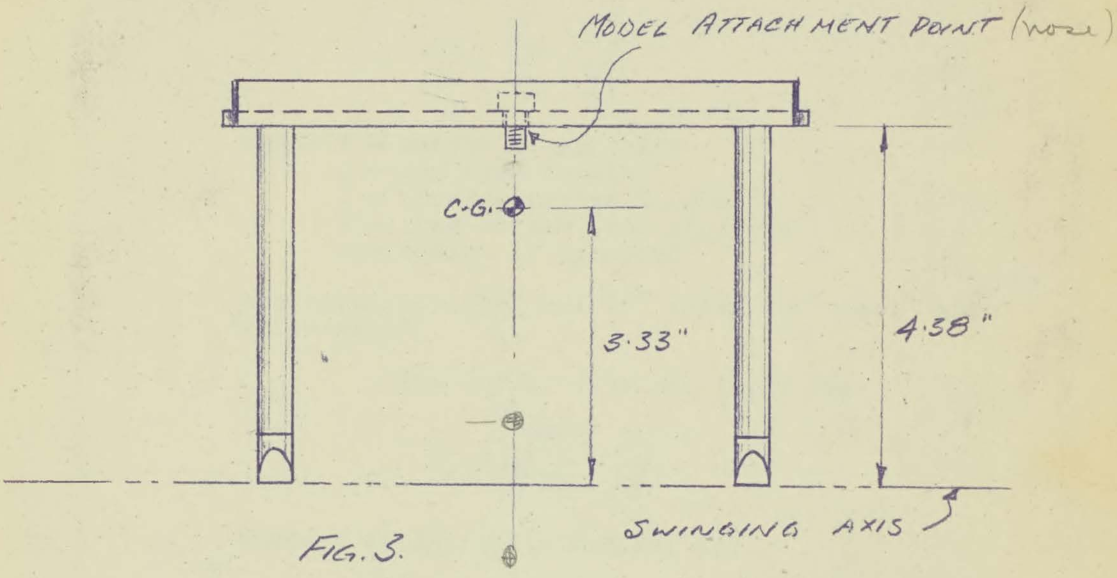


FIG. 3.

Values for attachment plus 5/8 inch long Allen screw:

$I = 0.00139$ slug-ft^2 re swinging axis
$W = 0.454$ lb.
$L = 3.38$ in. $= 0.282$ ft.
$WL = 0.128$ ft.-lb.

2.0 DYNAMIC SIMILITUDE IN SPINNING MODELS

For dynamic similitude of full-scale spins by models, ignoring compressibility and scale effects, the following conditions must obtain (Reference 1).

$$\frac{W_m}{\rho_m \ell_m{}^3} = \frac{W_f}{\rho_f \ell_f{}^3}$$

$$\frac{W_m}{\rho_m \ell_m{}^2 V_m{}^2} = \frac{W_f}{\rho_f \ell_f{}^2 V_f{}^2}$$

$$\frac{k_m}{\ell_m} = \frac{k_f}{\ell_f}$$

where W = weight of aircraft
ρ = air mass density
ℓ = representative length
V = free stream true airspeed
k = radius of gyration

and subscripts "m" and "f" refer to "model" and "full-scale".

The above relations imply that

$$V_m = V_f \sqrt{\frac{\ell_m}{\ell_f}} = \frac{V_f}{\sqrt{n}}$$

where n is the scale factor, and

$$W_m = \frac{\rho_m}{\rho_f} \frac{W_f}{n^3}$$

and also:

$$I_m = \frac{\rho_m}{\rho_f} \frac{I_f}{n^5}$$

3.0 ADJUSTMENT OF MOMENT OF INERTIA

The determination of the required period of oscillation of the model as a compound pendulum has been reduced to graphical form depending on the weight, radius of gyration, and moment arm of the model. The period of the pendulum system is

$$T = 2\pi\sqrt{\frac{I}{WL}} = 2\pi\sqrt{\frac{k^2}{gL}}$$

where k = radius of gyration of system
L = moment arm of system

This relation may be written

$$T^2 = \frac{4\pi^2}{g}\left(\frac{k^2_{m_{c.g.}} + L_m{}^2 + \frac{W_s}{W_m}k_s{}^2}{L_m + \frac{W_s}{W_m}L_s}\right)$$

$$\text{or } T^2 = \frac{4\pi^2}{g}\left[\frac{k^2_{m_{c.g.}} + L_m{}^2}{L_m} \cdot \frac{1 + \frac{W_s k_s{}^2}{W_m(k^2_{m_{c.g.}} + L_m{}^2)}}{1 + \frac{W_s}{W_m}\frac{L_s}{L_m}}\right]$$

where $k_{m_{c.g.}}$ = radius of gyration of model about model c.g.

L_m = moment arm of model c.g. about swinging axis

W_s = weight of suspension gear

k_s = radius of gyration of suspension gear about swinging axis.

The function

$$T_1{}^2 = \frac{4\pi^2}{g}\left[\frac{k^2_{m_{c.g.}} + L_m{}^2}{L_m}\right]$$

is plotted in Fig. 5 and the effect of the suspension is given as a correction

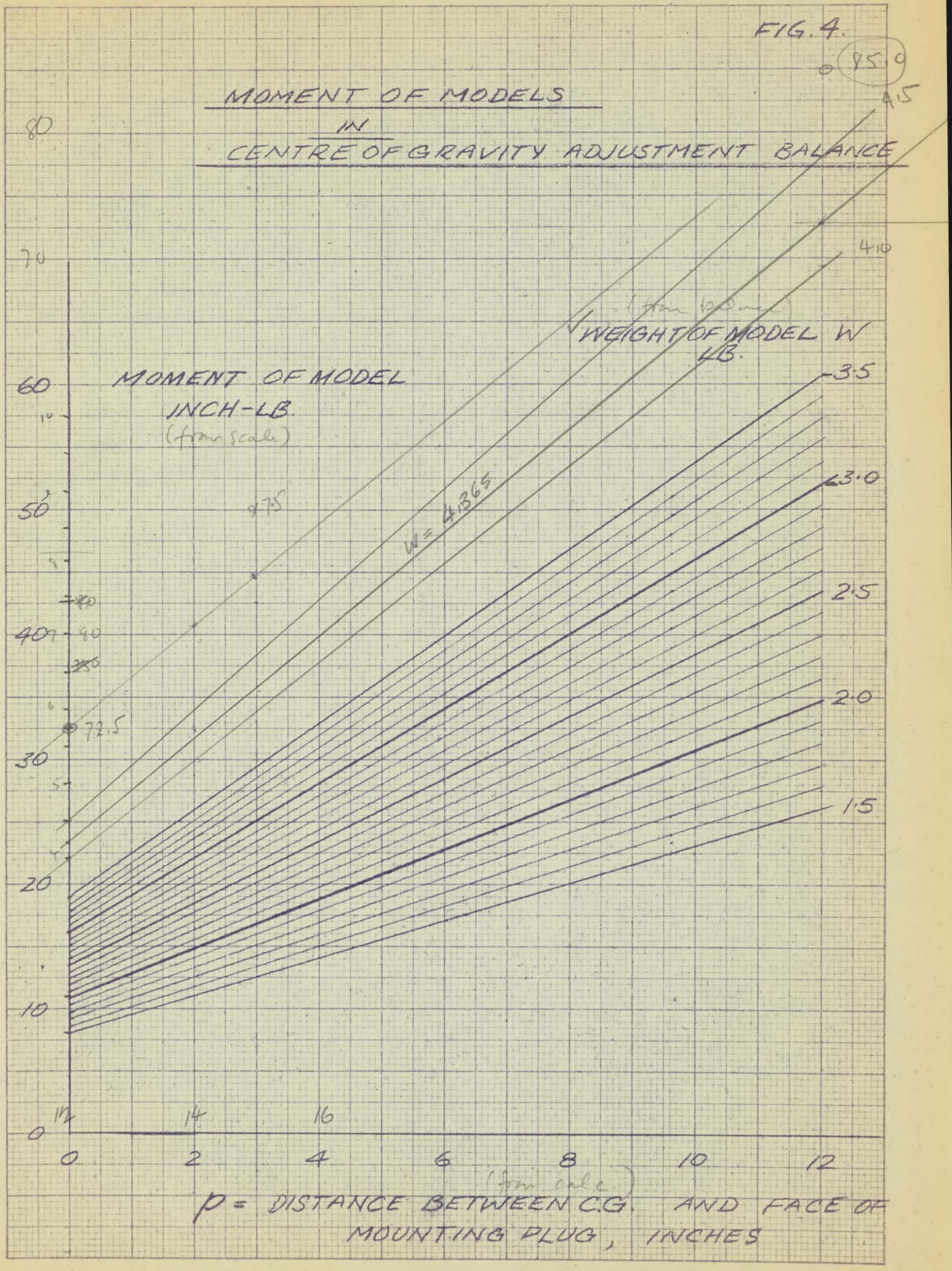
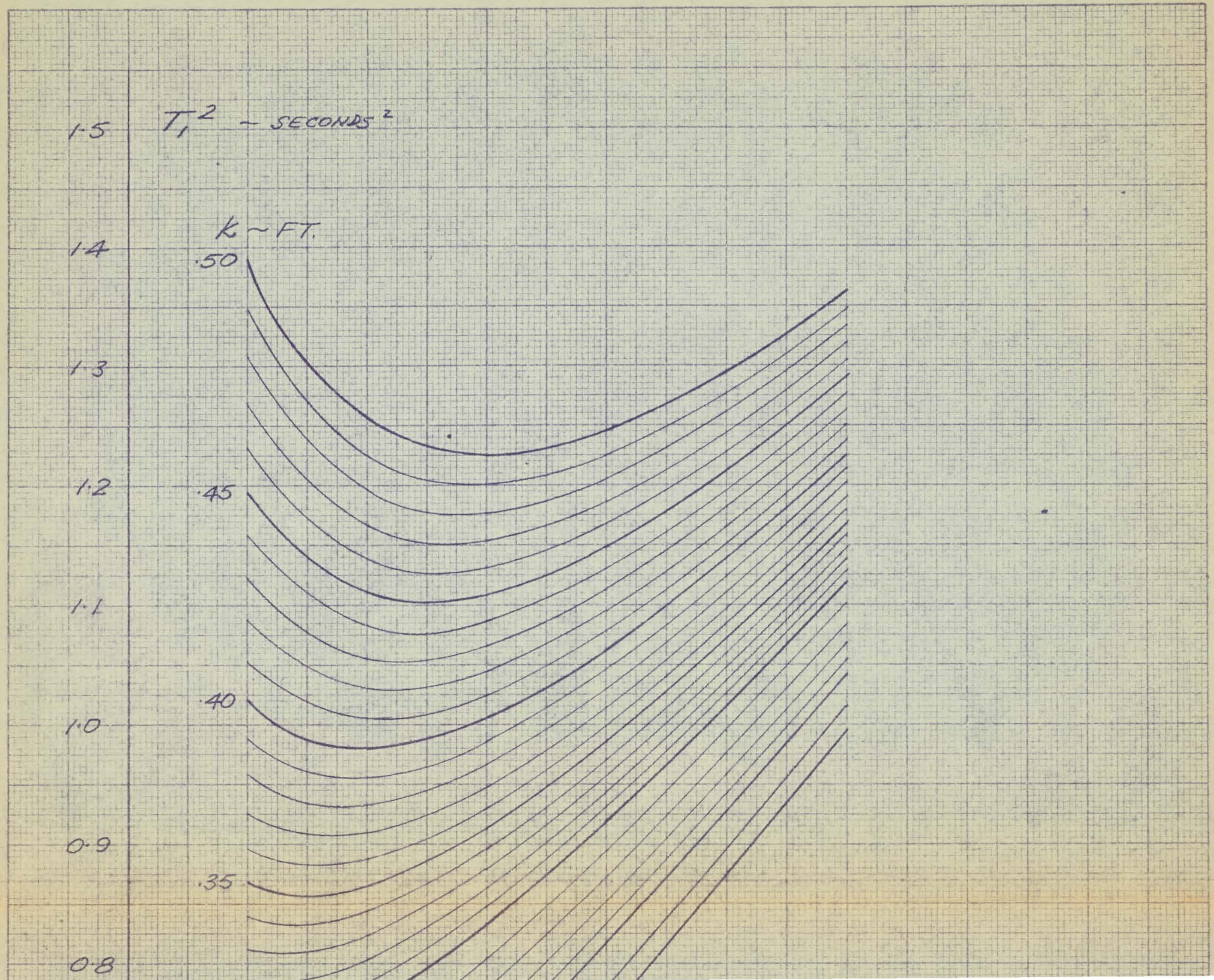


FIG. 4.

MOMENT OF MODELS IN CENTRE OF GRAVITY ADJUSTMENT BALANCE


T_1^2 ~ SECONDS^2
k ~ FT.
1·5
1·4
1·3
1·2
1·1
1·0
0·9
0·8
·50
·45
·40
·35

Case I . $h = 10000'$ $\sigma = 0.\overset{.7384}{\cancel{7268}}$

$W = 64657$ lb.

$K_x = 75.16$

$K_y = 159.20$

10047

model weight

$$W_m = \frac{W}{\sigma \eta^3} = \frac{64657}{\underset{.7384}{\cancel{.7268}} \times 13824} = 6.4355 \text{ lb}$$

(1.419)

model radii of gyration

Roll $K_{x_m} = \frac{K_x}{\eta} = \frac{75.16}{24 \times 12} = 0.261$ ft

Pitch $K_{y_m} = \frac{K_y}{\eta} = \frac{159.2}{24 \times 12} = 0.5526$ ft.

model Radius arm

$$\left.\begin{aligned} L_x &= 0.6020 \text{ ft} \\ L_y &= 0.6023 \text{ ft} \end{aligned}\right\} 6115$$

Roll

$$\frac{.4419}{.6115} = .7226$$

$$T^2 = \lambda T_1^2$$

$$T_1^2 = \frac{4\pi^2}{g}\left[\frac{K^2+L^2}{L}\right]$$

$$= 1.226\left[\frac{(.261)^2 + (.602)^2}{.602}\right]$$

$$= 1.226\left[\frac{.068 + \overset{(.3739)}{.3624}}{\underset{.6115}{.602}}\right]$$

$$\begin{array}{r} .5624 \\ .0680 \\ \hline .4304 \end{array}$$

$$= 1.226 \times \overset{4304}{.3692} \times 1.661$$

$$T_1^2 = 0.7518 \quad .8765 \quad = \quad .8859 \quad \frac{1.0032}{1.00[illegible]}$$

$$\lambda = \frac{1 + \dfrac{.009}{6.4355(\overset{.4304}{.3692})}}{1 + \dfrac{.026}{6.4355(.6020)}} = \frac{1 + \dfrac{.009}{6.4355 \times .4419 \;\; 2.8149}}{1 + \dfrac{.026}{6.4355 \times .6115 \;\; 3.8953}}$$

$$= \frac{1 + .00316}{1 + .0066} =$$

$T^2 = \Lambda T_1{}^2$

$= .8859 \times .99\overset{65}{71}$

$= .8833 \quad .8823$

$T = .9399$
$(.9393$

$$\boxed{T_{50_x} = \begin{array}{l} 46.995 \\ 46.965 \end{array}}$$

$D = C_D \frac{1}{2} \rho v^2 S$

$=$

$T^2 = \Lambda T_1{}^2$

$= .8859 \times .99\overset{65}{71}$

$= .8833 \quad .8823$

$T = .9399$

$(.9393$

$$\boxed{\begin{aligned}T_{50_x} &= 46.995\\ & 46.965\end{aligned}}$$

$D = C_D \frac{1}{2} \rho v^2 S$

$=$

$$\Lambda = \frac{1 + \dfrac{.009}{1.6078\ (2.7698)}}{1 + \dfrac{.026}{2.6217\ 2.88}} \qquad \frac{1.00325}{1.0067}$$

$= \quad 1 + \quad .009 \times .6211$