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Report No. E-666-47

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From: Military Attache, London, England

Date: 3 February 1947

Source: Ministry of Supply

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Area Reported On: Great Britain

Subject: EXPERIMENTS ON THE EFFECT OF
TUNED DAMPING DEVICES ON WIND
FLEXURE-AILERON FLUTTER

ATI No. **9550**

0344989

SUMMARY

The summary of the attached report is quoted: "The effect on flexure-aileron flutter of a tuned damping device attached to the aileron was investigated experimentally. The results obtained confirm the theoretical conclusion that the use of an aileron-carried damper would not be a reliable flutter preventative."

ANAA COMMENT

This report will be of interest to the AC-ASA, Nq AAF; the N. A. C. A., and the U. S. Navy.

An extra copy of this report is included for transmission, with 1 copy of the inclosure, to Air Materiel Command, Wright Field, Dayton, Ohio

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ATI No. 9550

Experiments on the Effect of Tuned Damping
Devices on Wing Flexure-Aileron Flutter

- By -

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and P. M. Ray, B.A.,
of the Aerodynamics Division, N.P.L.

0344989

13th August, 1946

Summary

The effect on flexure-aileron flutter of a tuned damping device attached to the aileron was investigated experimentally. The results obtained confirm the theoretical conclusion that the use of an aileron-carried damper would not be a reliable flutter preventative.

Introduction

§1. Range and Purpose of the Investigation

Report 8106¹ describes tests on the effect on flexure-aileron flutter of artificial damping applied directly to the aileron by a damper carried in the wing. The amount of damping for flutter prevention indicated by these experiments could probably be supplied by dampers of small mass as compared with the balance mass which the dampers replace, but the damping forces to be overcome during normal operation of the control column would be too great. A tuned damping device attached to the control surface which would normally offer little resistance to movements of the control was suggested as a possible alternative. A theoretical investigation on the effect of tuned dampers has been carried by Frazer and Jones^{2,3}. The present report describes a parallel experimental investigation.

A balanced aileron-carried damper was tested under conditions corresponding to zero altitude, and to an altitude of 30,000 ft.: a few tests on an unbalanced aileron carried damper were also made.

§2. Description of the Model

(1) Degrees of Freedom

- (i) Wing flexure with linear mode of displacement from the wing root.
- (ii) Aileron angular movement about the hinge line.
- (iii) Angular movement about an axis coincident with the aileron hinge axis of the damper disc⁴.

(2/)

'42' REPORT

⁴The damper disc corresponds to the damper casing of 8584.

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Military Attache, London. A.M.E.

(2) Scales.- The linear and speed scales of the model were chosen to be $1/20$ and $1/\sqrt{20}$ of full scale respectively. Hence the scales for moments and products of inertia, frequencies, elastic stiffness (moment per radian) and damping coefficients (moment per radian per second) were respectively $1/20^2$, $\sqrt{20}$, $1/20^4$ and $1/20^4\sqrt{20}$.

(3) Construction of the Model.- The plan form and the full scale dimensions of the wing are shown in Fig. 1.

The model wing was a light rigid structure with plan form and section similar to that proposed for B-26 airplane type 167 but without camber. It was attached at its root to a mock fuselage by ball bearings which permitted wing flexural movement only. The mock fuselage was fixed to the tunnel wall and the wing was supported in a horizontal position by the helical springs which provided the flexural stiffness.

The rigid aileron, with the damper casing fixed to its inboard end, was attached to the wing by two small ball bearings. From the outboard tip of the aileron a balance arm, which was also used for the attachment of aileron stiffness springs, projected into a cut-out in the wing. The aileron section had straight sides and a D-nose which fitted closely into the shroud.

The arrangement of the tuned damper is shown in Fig. 3. The brass disc A was enclosed by the damper casing B and was carried by a spindle supported on two small ball bearings fitted to the damper casing. One end of the spindle projected outside the casing and carried a fitting C to which one end of a spiral spring was clamped. The other end of the spiral spring was clamped to the outside of the casing by fitting D. The casing was provided with filler and drainage plugs to enable various damping fluids to be introduced into the casing. Thus the disc rotated relative to the casing about an axis coincident with the aileron hinge axis; the motion being resisted by the elastic forces of the spiral spring and by the damping forces due to the fluid. The spiral springs used were made from steel wire of various diameters and were wound with either 1 or $1\frac{1}{2}$ complete turns. The inertial values of the disc could be varied by balance masses placed on two small arms attached to the fitting C.

When the balance masses were symmetrically placed about the rotation axis the device corresponded to the "mass balanced-aileron carried damper" as defined in 8581.

§3. Definition of Symbols

Symbol	Significance
ξ	Aileron angle
ψ	Damper disc angular displacement relative to aileron
ρ	Wing displacement in flexure
$I_{\rho\rho}$	Moment of inertia of wing, including aileron, about wing root as measured in still air at $h = 0$
$I_{\xi\xi}$	Moment of inertia of aileron excluding damper disc about the hinge line as measured in still air at $h = 0$

$I_{\psi\psi}$

- I_{yy} Polar moment of inertia of damping disc and associated balance masses, including the virtual mass effect of the damping fluid
- I_{ps} Product of inertia of aileron excluding the damper disc with respect to the aileron hinge axis and the wing root, as measured in still air at $h = 0$
- I_{ψ} Product of inertia of damping disc with respect to the disc axis and the wing root
- l_{ϕ} Elastic stiffness of wing in flexure expressed as moment per radian
- n_{ϕ} Natural frequency of wing in flexure
- l_{ξ} Elastic stiffness of aileron expressed as the aileron hinge moment per radian deflection
- l_{ψ} Elastic stiffness of damper disc expressed as moment per radian
- μ Artificial damping coefficient between damper disc and casing expressed in moment per radian per second. The values quoted are those obtained from forced oscillation experiments on the disc with the casing stationary
- n $2\pi \times$ natural frequency of the undamped disc
- h Altitude
- V_{co}, f_{co} Critical speed and frequency respectively for the onset of flutter (lower critical speed and frequency)
- $\bar{V}_{co}, \bar{f}_{co}$ Critical speed and frequency at which the existing flutter is suppressed (upper critical speed and frequency)

*These symbols are barred when they refer to the effective values at the upper critical speed (see §4.)

§4. Method of Test

The lowest value of μ was obtained with the damper casing empty; higher values were obtained by filling the damper casing with oils of various viscosities. The oils used ranged from light machine oil to heavy gear oil. For each value of μ , critical speeds and frequencies were measured in the usual way for a range of values of n obtained by changing the damper spring. To keep the value of I_{yy} constant it was necessary to correct for the difference between the virtual moment of inertia of the disc when immersed in oil and in air. This correction was made by adjustment of the balance masses on the disc arms. A measure of the value of μ for each oil was obtained by a forced oscillation experiment on the disc while the casing was held stationary. When applied to the flutter tests this value must be regarded as qualitative since it may not be truly applicable to the conditions obtaining in flutter, when both disc and casing rotate. Since the value of μ was found to be dependent on frequency μ was always measured at a frequency close to the flutter frequency. The value of n was calculated from the measured values of I_{yy} and l_{ψ} .

In/

In order to correlate the experiments with the theoretical work of Fraser and Jones^{2,3}, the effective model inertial and stiffness coefficients were adjusted to correspond approximately with those assumed in the theoretical work. For tests applicable to zero altitude the actual model values of $I_{\phi\phi}$ and $I_{\xi\xi}$ were too high and recourse was made to additions to the elastic stiffnesses to obtain effectively the required inertial values. The effective value of $I_{\xi\xi}$ for antisymmetrical flutter ($i_{\xi} = 0$) and the effective value of $I_{\phi\phi}$ associated with a wing flexural stiffness l_{ϕ} are given respectively by the following relations:

$$I_{\xi\xi} = T I_{\xi\xi} - T l_{\xi} / 4\pi^2 f^2$$

$$I_{\phi\phi} = T I_{\phi\phi} - (T l_{\phi} - l_{\phi}) / 4\pi^2 f^2$$

where symbols with the prefix T refer to test values and f is the flutter frequency. Due to the slight difference between f_0 and \bar{f}_0 , the values of $I_{\xi\xi}$ and $I_{\phi\phi}$ corresponding to V_0 and \bar{V}_0 differed by about 5 per cent.

The effect of altitude was simulated on the model by increasing the non-aerodynamic coefficients (inertia, damping, stiffness) by ρ_0/ρ_h where ρ_0, ρ_h are respectively the air densities at the altitude of the test and at altitude h . It was not practicable to increase the moment of inertia of the damper disc to the desired value but the results were referred to the desired effective value of $I_{\psi\psi}$ associated with an effective stiffness given by

$$l_{\psi} = T l_{\psi} - 4\pi^2 f^2 (T I_{\psi\psi} - I_{\phi\phi}).$$

The effect of the difference between f_0 and \bar{f}_0 was to give different values of $I_{\psi\psi}$ and hence different values of n corresponding to the lower and upper critical speeds.

5. Results

All values quoted throughout the report refer to the full scale aircraft and are expressed in slug-foot-second units.

(a) $h = 0$, balanced damper

The results are given in Table 1. Curves of critical speed against $1/n$ for constant values of μ are plotted in Fig. 4. For a small range of the disc natural frequency near the natural frequency of the wing in flexure flutter was prevented for values of $\mu < 51$. This range was narrower than that predicted theoretically (see Fig. 6, 8581) and did not show much variation with μ . For $\mu = 71$ and over flutter occurred for all natural frequencies of the damper disc.

(b) $h = 30,000$ ft. balanced damper

The results are given in Table 2 and are plotted in Fig. 5. Flutter occurred for all the variations of n and μ tested. A

small/

small increase in V_0 was found when the natural frequencies of the damper disc and of the wing in flexure were nearly equal. These experimental results agree qualitatively with the theoretical results plotted on Fig. 9, 8581.

(c) $h = 0$, unbalanced damper (Table 3, Fig. 6)

For these tests mass was placed on the disc arm forward of the axis. The mass used was not quite sufficient to eliminate flutter when the damper disc was locked to aileron, and flutter occurred over a small range of wind speed. With the damper disc spring constrained to the aileron, flutter was not obtained for any finite value of μ tested when n was greater than $2xf_0$ but was present over a wide range of wind speed for certain values of n less than $2xf_0$.

§.6 Conclusions

(1) The experiments provide qualitative confirmation of the theoretical results given in 8581 and 9946 and support the conclusion that the use of an aileron-carried damper would not be a reliable flutter preventative.

References

1. C. Scruton Flexural-Aileron Flutter Tests on a Model of B.M.C. Wing Type 167: The Effect of Artificial Aileron Damping. 8106, O.455.
 2. R. A. Fraser and The Influence of Tuned Damping Devices on
W. P. Jones Flexural Aileron Flutter. 8581, O.480.
 3. W. P. Jones Some further Calculations on the Influence of Tuned Damping Devices on Flexure-Aileron Flutter. 9946, O.607.
-

Table 1/

Table 1

Results for Antisymmetrical Flutter with a Balanced Aileron-Carried Damper - Zero Altitude

General Conditions

(a) Stiffnesses $I_{\xi\xi} = 0$

$I_{\phi\phi} = 1.892 \times 10^8$

(b) Inertias $I_{\psi\psi} = 5.73$, $I_{\psi\phi} = 0$

$I_{\xi\xi} = 44.8$ ($I_{\psi\psi} = 0.128 I_{\xi\xi}$)

$\bar{I}_{\xi\xi} = 48.1$ ($I_{\psi\psi} = 0.119 \bar{I}_{\xi\xi}$)

$I_{\phi\phi} = 22.4 \times 10^5$ ($\bar{I}_{\phi\phi} = 1.46$)

$\bar{I}_{\phi\phi} = 25.3 \times 10^5$ ($\bar{I}_{\phi\phi} = 1.38$)

$I_{\xi\phi} = 836$

Test No.	1/n	μ	Speed Range for Flutter		Critical frequencies	
			V_0	\bar{V}_0	f_0	\bar{f}_0
1	0.052	28	120	195	1.45	1.52
2	0.061		121	195	1.46	1.53
3	0.073		117	191	1.46	1.52
4	0.077		123	193	1.46	1.52
5	0.095		138	201	1.46	1.52
6	0.107		139	185	1.45	1.52
7	0.107		134	208	1.45	1.50
8	0.112		No flutter		-	-
9	0.126		98	162	1.46	1.50
10	0.133		96	161	1.48	1.51
11	0.145		105	166	1.47	1.51
12	0.158		104	171	1.46	1.51
13	0.183		106	171	1.46	1.51
14	0.284		107	176	1.46	1.52
15	0.052	32	128	189	1.45	1.52
16	0.061		128	190	1.44	1.52
17	0.073		136	186	1.46	1.50
18	0.077		130	191	1.46	1.51
19	0.095		140	179	1.46	1.50
20	0.107		No flutter		-	-
21	0.112		No flutter		-	-
22	0.126		119	155	1.47	1.50
23	0.133		112	156	1.47	1.50
24	0.145		107	167	1.47	1.51
25	0.158		108	172	1.46	1.51
26	0.183		112	177	1.47	1.52
27	0.284		111	179	1.46	1.52
28	0.052	51	126	197	1.45	1.53

Table 1 Continued/

Table 1 Continued

Test No.	1/n	μ	Speed Range for Flutter		Critical frequencies	
			V_c	V'_c	f_c	f'_c
29	0.061	51	126	197	1.45	1.52
30	0.070		133	198	1.46	1.53
31	0.077		131	198	1.45	1.52
32	0.094		146	186	1.47	1.52
33	0.107			No flutter	-	-
34	0.112			No flutter	-	-
35	0.126		117	157	1.47	1.51
36	0.133		114	167	1.47	1.51
37	0.145		111	173	1.46	1.51
38	0.158		110	177	1.46	1.52
39	0.183		113	177	1.46	1.52
40	0.284		113	184	1.46	1.52
41	0.052	71	126	199	1.46	1.54
42	0.061		127	197	1.46	1.53
43	0.073		130	194	1.46	1.52
44	0.077		130	197	1.46	1.53
45	0.094		131	190	1.47	1.52
46	0.107		132	190	1.46	1.52
47	0.112		131	185	1.47	1.52
48	0.126		127	186	1.46	1.52
49	0.133		128	185	1.46	1.51
50	0.145		125	185	1.46	1.51
51	0.158		122	185	1.46	1.51
52	0.183		124	187	1.46	1.52
53	0.284		126	188	1.46	1.52
54	0.052	280	130	193	1.46	1.53
55	0.061		123	193	1.46	1.52
56	0.077		125	192	1.46	1.52
57	0.094		123	192	1.47	1.53
58	0.107		123	193	1.48	1.52
59	0.112		123	195	1.45	1.52
60	0.126		122	192	1.45	1.52
61	0.133		125	192	1.46	1.53
62	0.145		124	194	1.45	1.53
63	0.158		125	193	1.45	1.53
64	0.183		124	197	1.46	1.53
65	0.284		125	197	1.46	1.54

Table 2/

Table 2

Results for Antisymmetrical Flutter with a Balanced Aileron-Carried Damper - Altitude 30,000 ft.

General Conditions

(a) Stiffnesses

$$I_{\psi} = 0$$

$$I_{\phi} = 1.892 \times 10^8$$

(b) Inertias

$$I_{\psi\psi} = 5.73, I_{\psi\phi} = 0$$

$$I_{\xi\xi} = 44.8 \quad (I_{\psi\psi} = 0.128 I_{\xi\xi})$$

$$I_{\phi\phi} = 22.5 \times 10^5 \quad (I_{\phi} = 1.46)$$

$$I_{\xi\phi} = 836$$

Test No.	μ	Lower Critical Speed			Upper Critical Speed		
		V_c	f_c	$1/n$	V_c'	f_c	$1/n$
66	11	166	1.46	0.0724	347	1.75	0.068
67		165	1.46	0.081	350	1.76	0.075
68		168	1.49	0.087	348	1.76	0.081
69		165	1.47	0.093	356	1.76	0.085
70		173	1.44	0.104	380 app.	-	-
71		177	1.43	0.110	346	1.59	0.102
72		185*	1.47	0.110	334	1.74	0.098
73		153	1.46	0.115	331	1.73	0.099
74		155	1.45	0.119	333	1.73	0.104
75		157	1.49	0.120	336	1.74	0.105
76		157	1.47	0.124	333	1.76	0.107
77	159	1.47	0.1313	336	1.76	0.111	
78	19	172	1.47	0.072	349	1.74	0.069
79		170	1.44	0.082	351	1.74	0.076
80		170	1.44	0.088	350	1.74	0.081
81		171	1.47	0.093	357	1.74	0.085
82		175	1.45	0.103	342	1.70	0.086
83		175	1.47	0.108	336	1.77	0.079
84		157	1.48	0.109	333	1.72	0.099
85		152	1.47	0.114	333	1.73	0.101
86		153	1.46	0.116	334	1.73	0.103
87		154	1.47	0.118	335	1.74	0.103
88		156	1.46	0.122	336	1.74	0.106
89		156	1.46	0.125	337	1.74	0.107
90	160	1.45	0.133	339	1.74	0.112	
91	25	170	1.44	0.073	352	1.74	0.069
92		169	1.45	0.088	350	1.75	0.081
93		169	1.45	0.103	346	1.73	0.093
94		166	1.45	0.111	343	1.73	0.098
95		164	1.47	0.114	342	1.73	0.100
96		164	1.46	0.119	342	1.73	0.104
97		164	1.46	0.125	343	1.72	0.109
98		164	1.48	0.131	341	1.75	0.112

*Intermittent flutter between 125 and 185 f.p.s.

Table 3

Results for Antisymmetrical Flutter with an Unbalanced Aileron-Carried
Damper - Zero Altitude

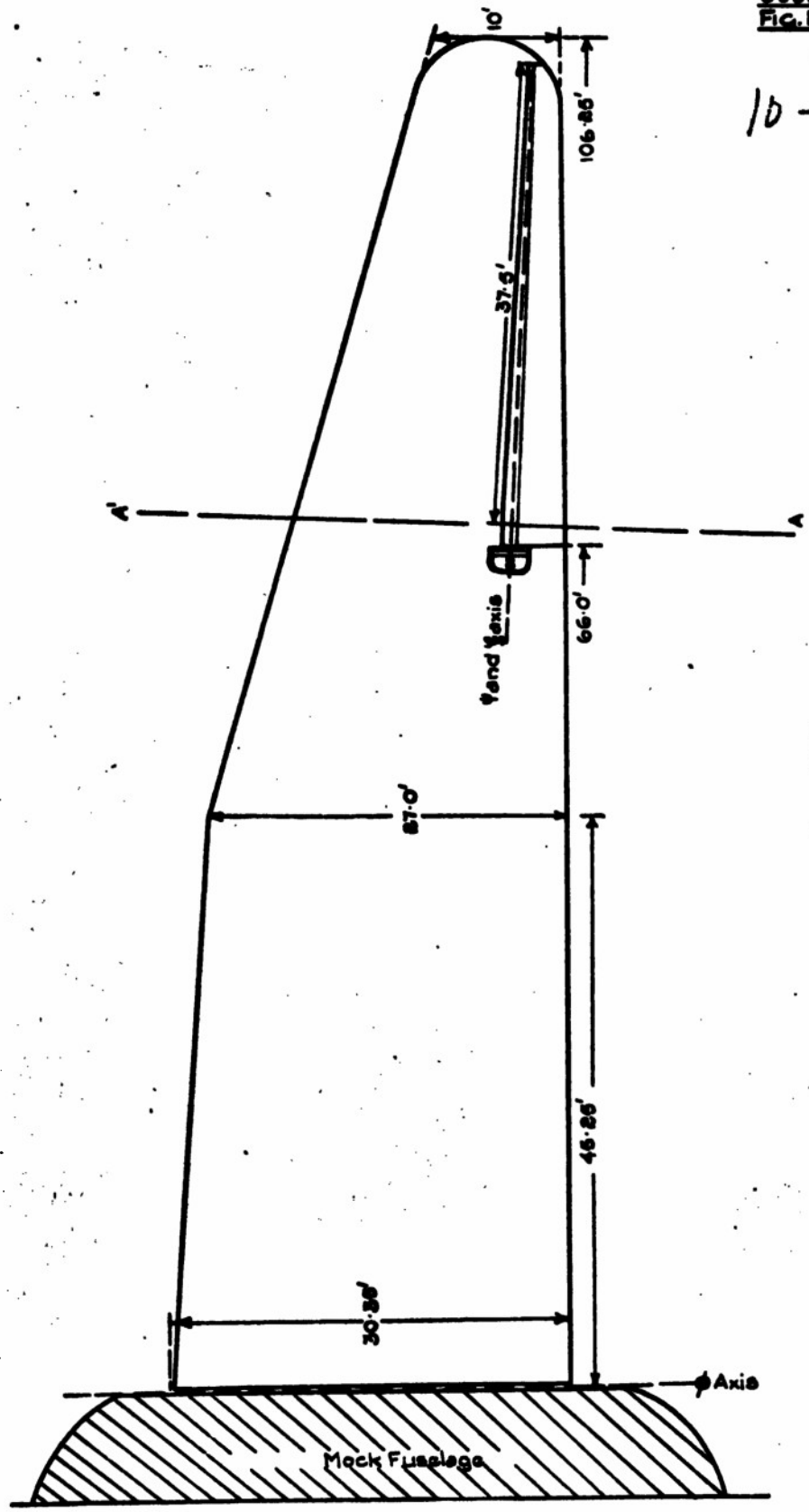
General Conditions

- (a) Stiffnesses $I_{\xi} = 0$
 $I_{\phi} = 1.892 \times 10^8$
- (b) Inertias $I_{\xi\xi} = 46.1$
 $\frac{I_{\xi\xi}}{I_{\phi\phi}} = 50.9$
 $I_{\phi\phi} = 23.2 \times 10^5$ $f_{\phi} = 1.46$
 $\frac{I_{\psi\psi}}{I_{\phi\phi}} = 26.2 \times 10^5$ $\bar{f}_{\phi} = 1.35$
 $I_{\xi\phi} = 836$
 $I_{\psi\phi} = -297$

Test No.	1/n	μ	Speed range for Flutter		Critical frequencies	
			V_o	V_o'	f_o	f_o'
$I_{\psi\psi} = 12.64$						
99	0.091	28	No flutter		-	-
100	0.159		No flutter		-	-
101	0.167		126	190	1.47	1.57
102	0.198		90	187	1.48	1.55
103	0.272		103	183	1.47	1.55
104	0.421		106	182	1.47	
$I_{\psi\psi} = 13.25$						
105	0.079	32	No flutter		-	-
106	0.105		No flutter		-	-
107	0.162		82	186	1.48	1.57
108	0.172		91	189	1.47	1.56
109	0.203		97	187	1.47	1.55
110	0.431		111	183	1.47	1.58
111	0.058	71	No flutter		-	-
112	0.162		No flutter		-	-
113	0.172		117	167	1.48	1.52
114	0.203		119	172	1.49	1.54
115	0.431		118	181	1.46	1.52
116	0.058	280	No flutter		-	-
117	0.203		No flutter		-	-
118	0.278		136	176	1.47	1.56
119	0.431		131	180	1.47	1.57
120	Damper disc locked to aileron		148	164	1.48	1.49

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Fig. 1.

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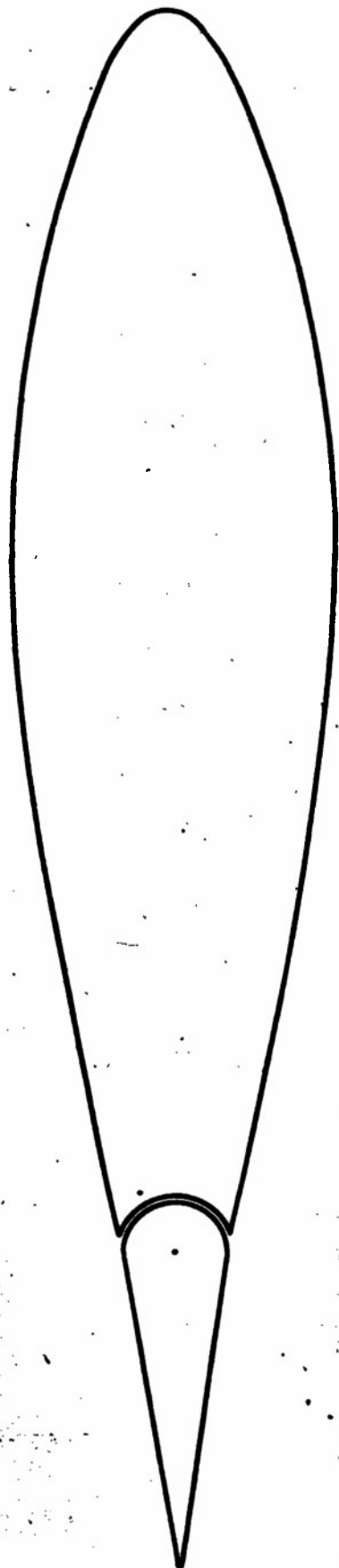


Plan of Wing.

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FIG. 2.

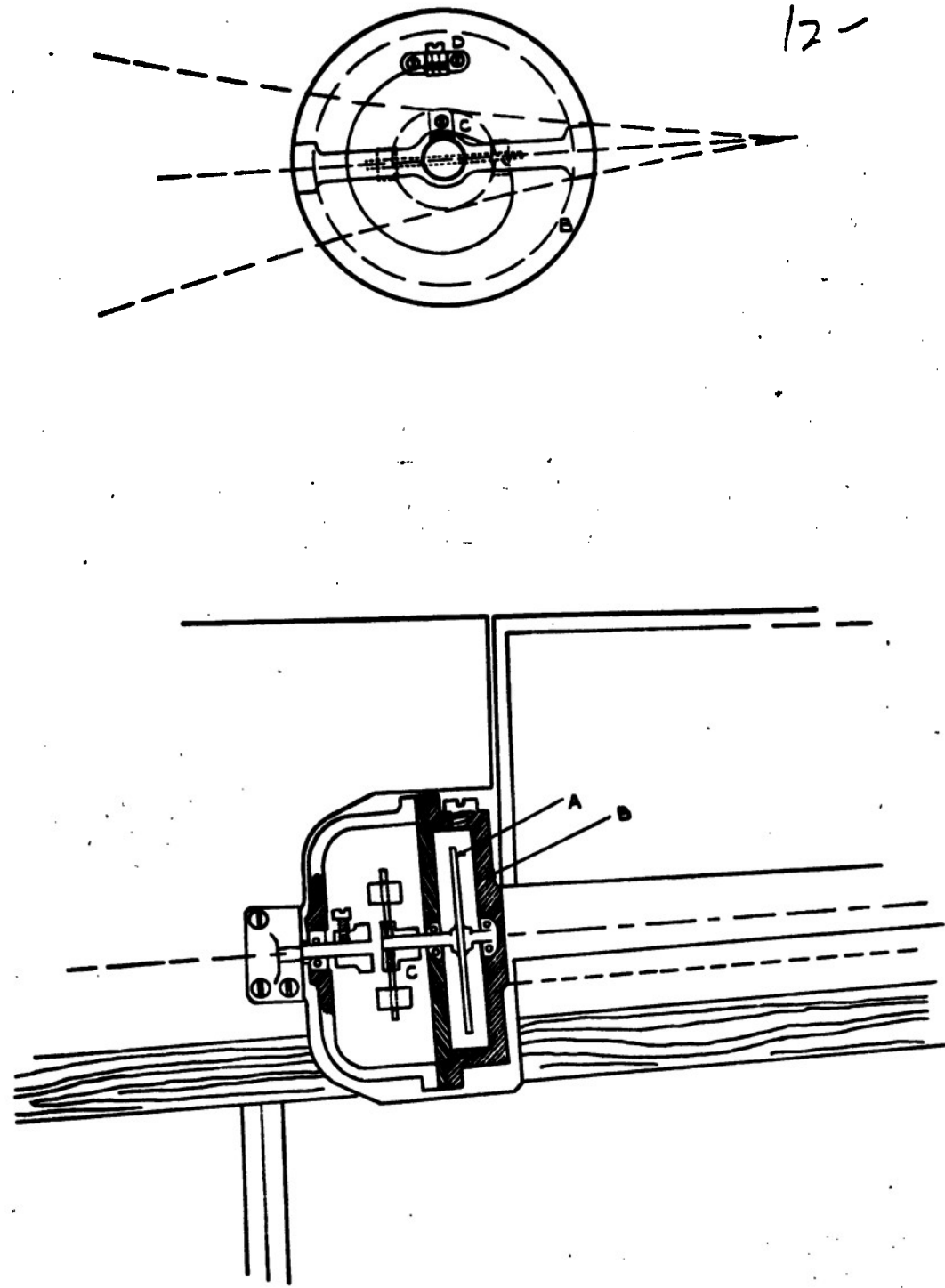
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Profile at Section A-A' of FIG. 1.



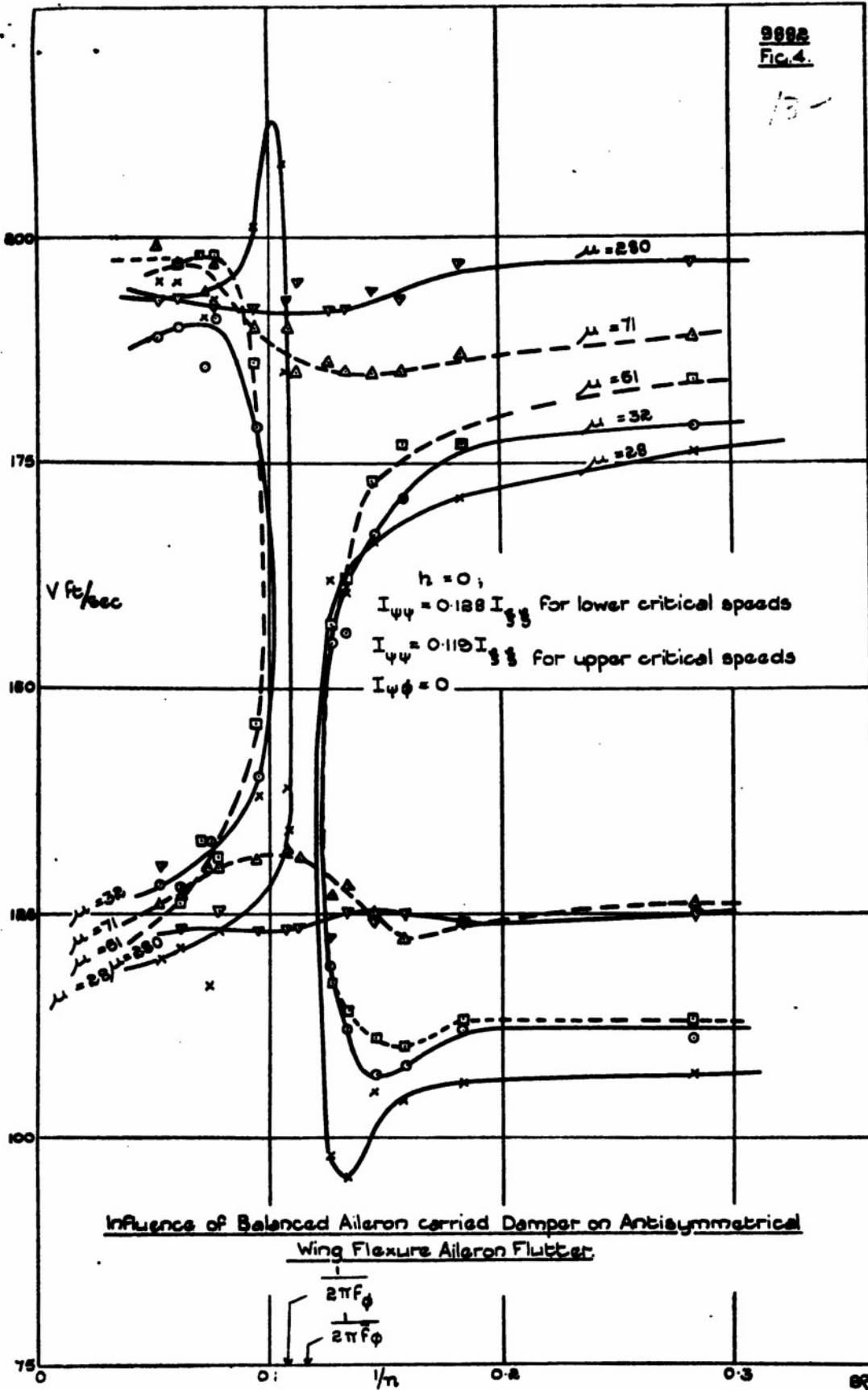
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Fig. 3.

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Arrangement of Damper.

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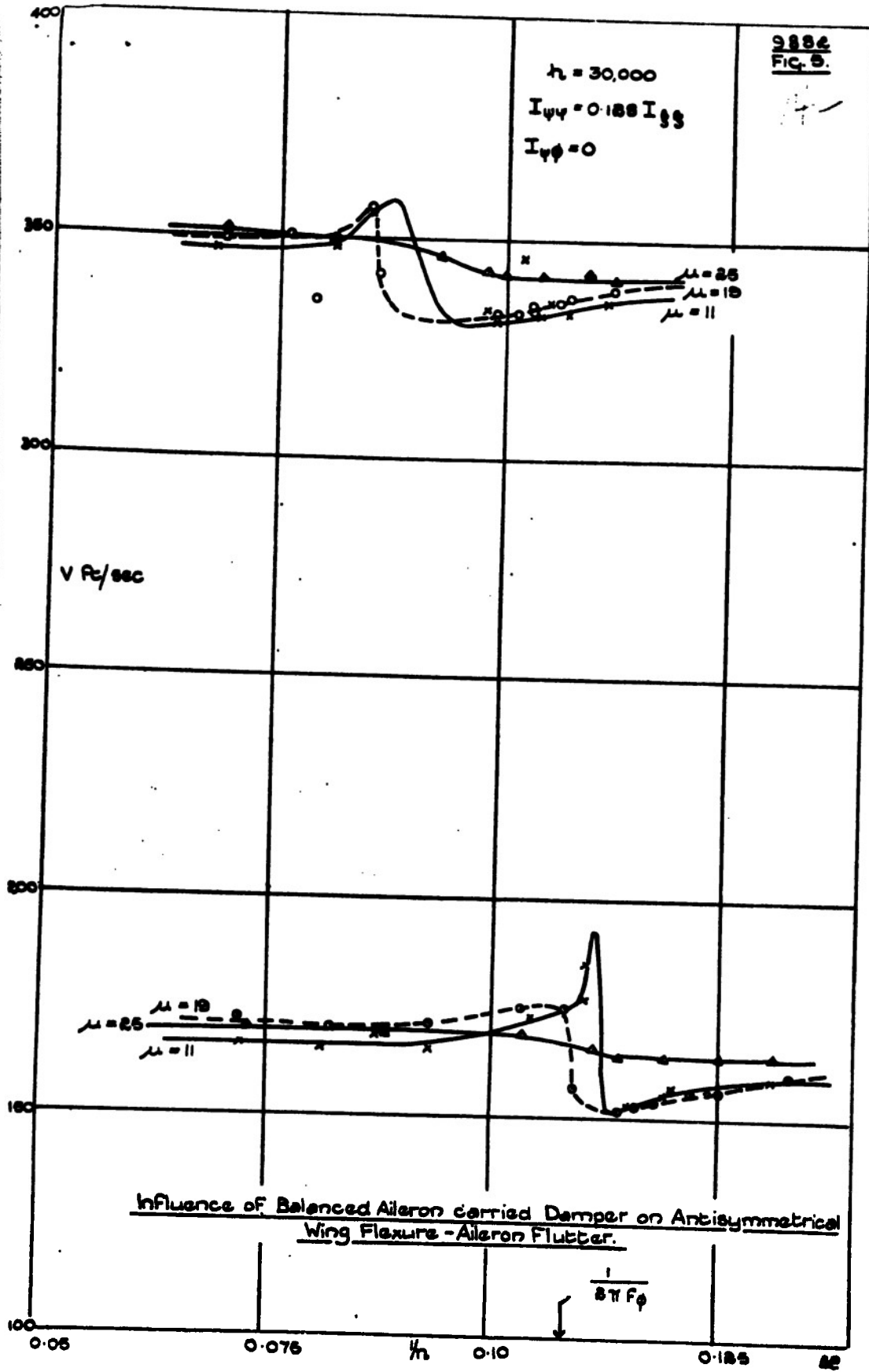


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FIG. 5.

$$h = 30,000$$

$$I_{\psi\psi} = 0.188 I_{\beta\beta}$$

$$I_{\psi\phi} = 0$$



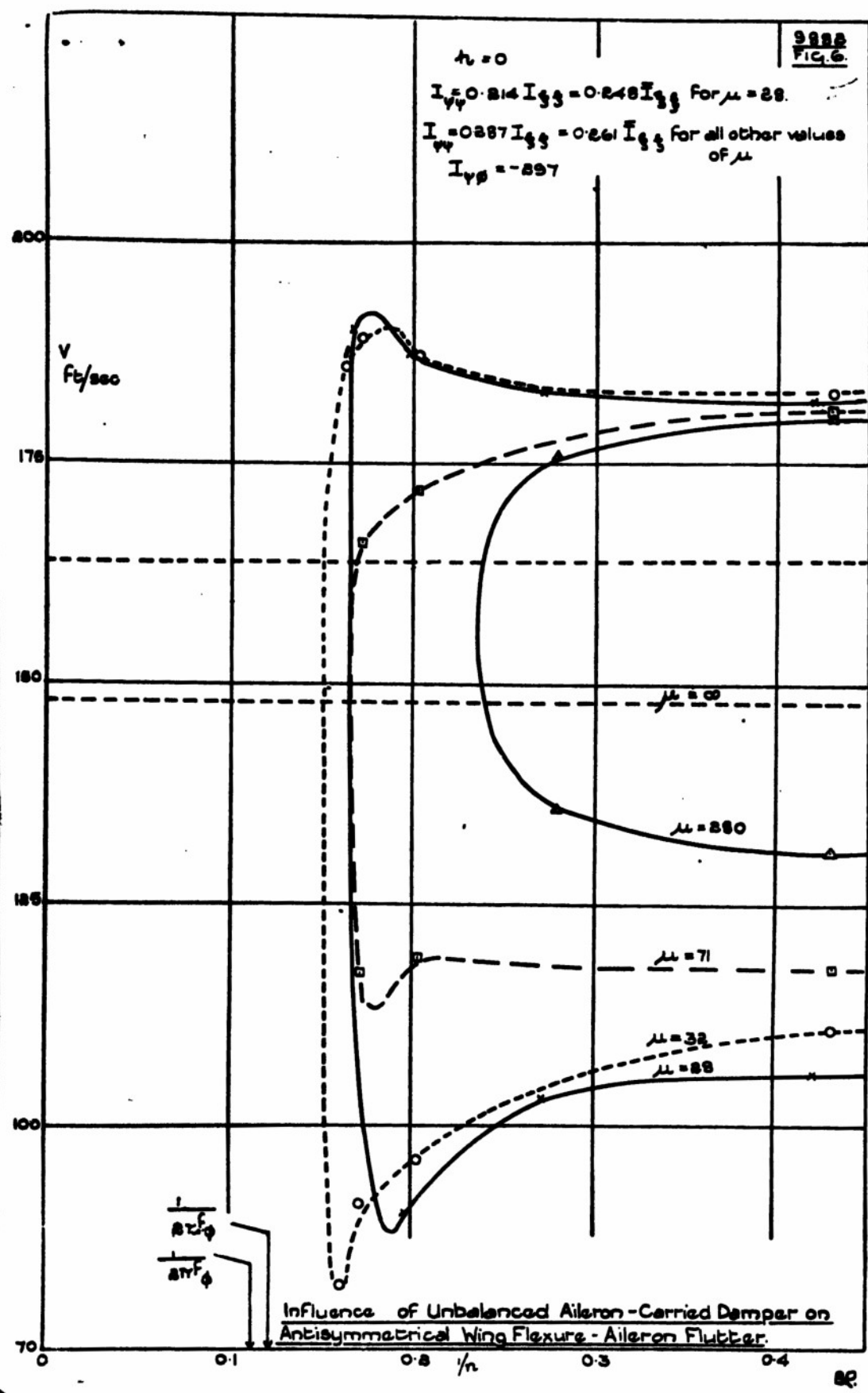
Influence of Balanced Aileron carried Damper on Antisymmetrical Wing Flexure - Aileron Flutter.

$\mu = 0$

$I_{yy} = 0.214 I_{zz} = 0.248 I_{zz}$ for $\mu = 28$.

$I_{yy} = 0.287 I_{zz} = 0.261 I_{zz}$ for all other values of μ

$I_{y\beta} = -297$



Influence of Unbalanced Aileron-Carried Damper on Antisymmetrical Wing Flexure-Aileron Flutter.

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A.T.I.

9 5 5 0

Scruton, C.
Dunsdon, D.W.
Ray, R.H.

DIVISION: Aerodynamics (2)
SECTION: Boundary Layer (5)
CROSS REFERENCES: Flutter (41700); Ailerons - Oscillation (63215); Control surfaces - Aerodynamic balancing (25500)

ORIG. AGENCY NUMBER
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REVISION

AUTHOR(S)

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ORIGINATING AGENCY: Aeronautical Research Council, Oscillation Sub-Committee

TRANSLATION:

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ABSTRACT

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NOTE: Copies of this report may be obtained only by U.S. military organizations.

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