C.P. No. 185
(16,090)
A.R.C. Technical Report

C.P. No. 185
(16,090)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL

CURRENT PAPERS

The Effect of Compressibility on Elevator Flutter

By

D. E. Williams, B.A.

LONDON: HER MAJESTY'S STATIONERY OFFICE

1954

Price 1s. 6d. net

C.P. No. 185

U.D.C. No. 533.6.013.422 : 533.691.155.33.011.7

Technical Note No. Structures 112

March, 1953

ROYAL AIRCRAFT ESTABLISHMENT

The effect of compressibility on elevator flutter

by

D. E. Williams, D.A.

SUMMARY

The effect of compressibility on elevator flutter is investigated by using two-dimensional control surface derivatives for Mach numbers of 0 and 0.7. It is shown that compressibility may have a considerable effect when the stick is fixed, but that the effect is small when the stick is free.

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

---

1 Introduction

In 1942 Fraser and Skan[1] investigated the effect of compressibility on wing flexure-torsion flutter, using two-dimensional derivatives, and found that it was small for normal wing densities. They were unable to investigate the effect on control-surface flutter because of the lack of suitable control-surface derivatives. These derivatives did not become available until 1948 when Turner and Rabinowitz[2] published tables of control-surface derivatives for a Mach number of 0.7, for various frequency parameters, and various ratios of the control-surface chord to the main-surface chord. These derivatives, which are given in English notation by Minhinnick[3], have been used here to investigate the effect of compressibility on the flutter of a simple tailplane-elevator system.

2 Symbols

c	tailplane chord
c_o	tailplane root chord
c_m	tailplane mean chord
c_e	elevator chord
s	tailplane semi-span
ρ	air density
$m_o = 10\, c_o^2 \rho$	is a unit of mass per unit length
V	flutter speed
M	Mach number
ω_f	natural frequency of fuselage vibration in radians/sec
u	(distance aft of wing trailing edge)/3.6 c_o $u = 1$ at tailplane inertia axis
z	displacement at tailplane inertia axis
z_f	displacement of a point on the fuselage

3 The tailplane elevator system

The tailplane (see Fig.1) has aspect ratio 4 and taper ratio 2/3. It has a fill span elevator without aerodynamic balance, and the elevator chord is one third the tailplane chord i.e. $c_e = 1/3\, c$. The length of fuselage from the wing trailing edge to the tailplane inertia axis is 3.6 c_o. Points on the fuselage are defined by a parameter u which varies from 0 to 1 between the wing trailing edge and the tailplane inertia axis.

The inertia axis of the tailplane is 0.4 c aft of the leading edge and the radius of gyration of a chordwise section of the tailplane about its C.G. is $\frac{1}{4}\, c$. The inertia axis of the elevator is 0.3 c_e aft of the hinge line and the radius of gyration of a chordwise section about its C.G. is $\frac{1}{4}\, c_e$. The concentrated mass balance is at the mean chord, on an arm whose length, $5/36\, c_o$, is half the elevator chord at that point.

The mass per unit length of the tailplane is $m_t = m_o (c/c_o)^2$, and the mass per unit length of the elevator is $m_e = m_o (c_e/c_o)^2$. The static mass balance on each half of the elevator is $0.80\rho c_o^3$.

The degrees of freedom are elevator rotation and one of two fuselage modes, which are called modes A and B. In mode A the tailplane oscillates in vertical translation and does not pitch. Mode B is parabolic flexure of' the fuselage, encastré at the wing root. With this mode the tailplane oscillates in vertical translation and pitch with a tailplane nodal point 2.16 c_m ahead of the elevator hinge line. The frequency of the tailplane motion in either mode is denoted by ω_f and is left as an unknown. The frequency of the elevator control-circuit is 1.5 ω_f.

The fuselage deflection in mode A is not defined and so in calculations with this mode it is assumed that the contribution of the fuselage fin and rudder 'cc the kinetic energy cf the system is equivalent to that of a mass 2 sm_o placed on the tailplane. For calculations with mode B the mass per unit length of the fuselage is $63.62\rho c_o^2 (1 - u^2)$ and the mass at the root of the tailplane inertia axis to simulate the effect of the fin and rudder is 0.764 sm_o.

This fuselage mass distribution can be used in calculations with mode A if the form of the mode is known. So far it has only been defined at the tailplane. If the fuselage deflection in mode A is given by $z_f = \frac{1}{2} z (1 - \cos \pi u)$ then the equivalent mass at the tailplane is 2.72 sm_o, but a slight change in the form of the mode could give the assumed value of 2 sm_o. A few calculations were made for mode A, with the frequency kept constant, to find what difference would have been made if a mass of 2.72 sm_o hss been used Instead of the original mass 2 sm_o. The difference was found to be small.

4 Description of the calculations

The variation of the flutter speed with mass balance was Investigated for both mode A and mode B with derivatives for $M = 0$ and $M = 0.7$ for two stick conditions:

(1) stick free, no elevator circuit stiffness,

(2) stick fixed, with an elevator circuit frequency 1.5 ω_f.

No stick fixed flutter was found in mode A or mode B with positive mass balance. The calculations for mode B stick fixed mere repeated with the moment of inertia of the elevator doubled but with the elevator mass moment about the hinge unchanged in the expectation that this new system would flutter for positive mass balance. Mode B was chosen in preference to node A because, for the original system, the curves for mode B stick fixed were nearer the positive quadrant than the corresponding curves for mode A. (See Figs.2, 3, 5 and 6).

The derivatives used for both $M = 0$ and $M = 0.7$ were two-dimensional derivatives and no aspect ratio corrections were applied. The calculations for M = G.7 could not be taken beyond a frequency parameter of 1.4 because derivatives for higher frequencies were not available.

5 Results

In each of Flgs.2 to 6 flutter curves are drawn of $V/\omega_f c_m$ against a non-dimensional mass balance parameter. On each figure are two curves, one for $M = 0$ and one for $M = 0.7$.

The curve for M = 0.7 may be interpreted in two ways. The speed can be considered constant to agree with the Mach number of the curve and the fuselage frequency then varies along the ordinate. The curve will then give the mass balance needed to prevent flutter at M = 0.7 for any fuselage frequency. If, on the other hand, ω_f is constant, then V must vary along the ordinate. The curve is no longer a flutter curve because the Mach number of the flutter speed does not agree with the Mach number of the derivatives, except at a few points. The flutter curve is the locus of these points as the Mach number varies. Only those points on the flutter curve for which the Mach number is 0.7 can be found from the given curves. Nevertheless those curves can give some indication of the shape of the true flutter curve.

In Figs. 2 and 3 the stick free curves are given : in mode A the compressibility effect is slightly beneficial and in mode B the effect is negligible. The stick fixed cases are given in Figs. 5 and 6; for both modes flutter is impossible with positive mass balance, but the effect of compressibility is to move the curves towards the positive quadrant. In Fig.4, curves are given for mode B stick fixed with the elevator inertia doubled. Flutter is now possible for M = 0 and M = 0.7, and compressibility gives worse flutter characteristics. Doubling the elevator inertia gives the effect of altitude at 22,000 ft if the speed in the ordinate is read as the equivalent airspeed, because although theoretically it is necessary to double all the structural inertia terms it has been found sufficient in practice to double only the elevator terms.

Although the calculations have been made for elevator flutter they can also give some indication of the effect of compressibility on some other kinds of flutter, namely fuselage lateral bending - rudder flutter and wing flexure - aileron flutter. The position of the main surface nodal point differs for each kind of flutter. For wing flexure-aileron flutter the nodal point is at infinity; for rudder and elevator flutter, the nodal point is between the wing and the tailplane. In the resonance modes the tailplane nodal point in the fundamental vertical bending mode is nearer the tail unit than is the fin nodal point in the fundamental lateral bending mode and it is probable that this will also be so for the corresponding flutter modes. The theoretical reason for this is that the inertia of the wings is greater in yaw than in pitch.

In mode A the tailplane has a nodal point at infinity and can be used to give information about wing flexure-aileron flutter. The mass placed on the tailplane can then be assumed to give the dynamic effect of the inboard end of the wing, the engines, or the fuel tanks. In mode B the tailplane has a nodal point a little over two tailplane mean chords ahead of the elevator hinge line and can be used to give information about rudder flutter.

The results can also give some qualitative information about wing torsion-aileron flutter and fuselage torsion-rudder flutter.

6 Conclusions

The effect of compressibility on the elevator flutter of the system considered is small when the stick is free but is important when the stick is fixed. The flutter characteristics are then worse for compressible flow than for incompressible flow.

The results of unpublished calculations on actual aircraft confirm the conclusions when the stick is free but show that when the stick is fixed no general conclusions can be drawn.

REFERENCES

No.	Author	Title, etc.
1	R.A. Frazer and S.W. Skan	Influence of compressibility on the flexural-torsional flutter of tapered. cantilever wings R & M 2553, June 1942
2	M.J. Turner and S. Rabinowitz	Aerodynamic coefficients for an oscillating airfoil with hinged flap for a Mach number of 0.7 NACA Tech Note No. 2213, October 1950 (Previously issued as an Appendix to Chance Vought Aircraft Co. Report No. G.T.R. - 65, April 1948)
3	I.T. Minhinnick	Subsonic aerodynamic flutter derivatives for wings and control surfaces (compressible and incompressible flow) RAE Report Structures 87, July 1950 ARC 14,228

Wt.2078. CP185.K3 - Printed in Great Britain.

FIG. I & 2.

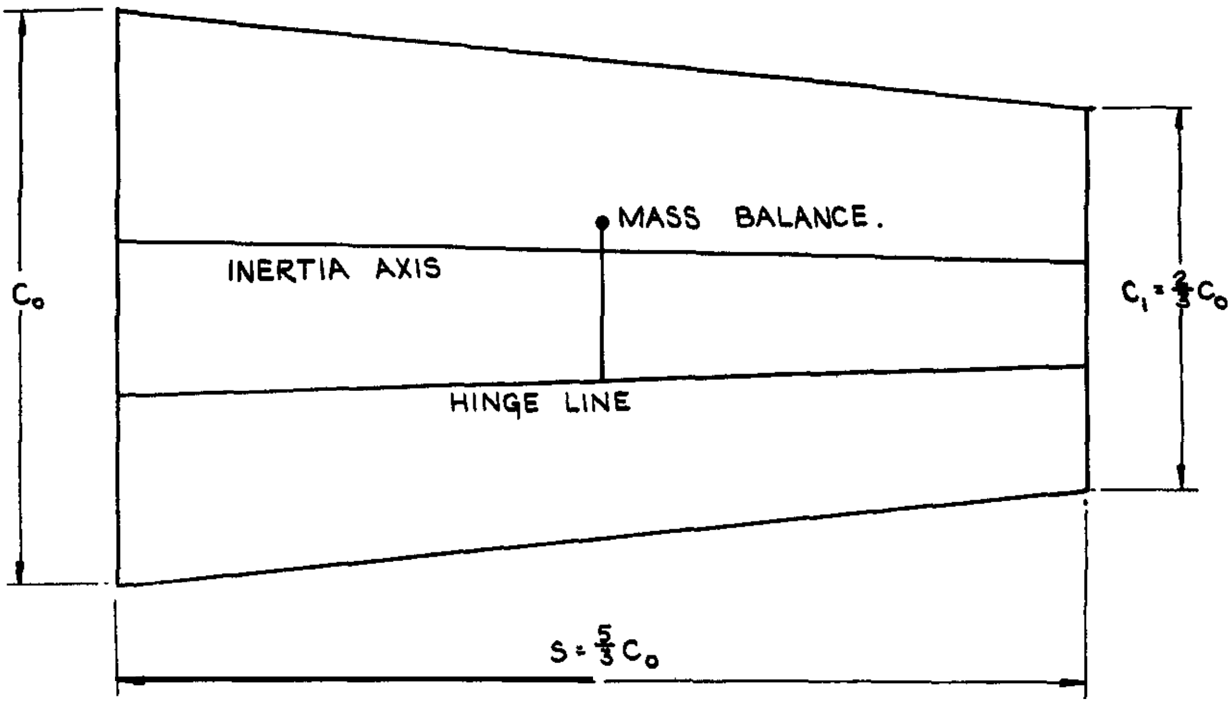
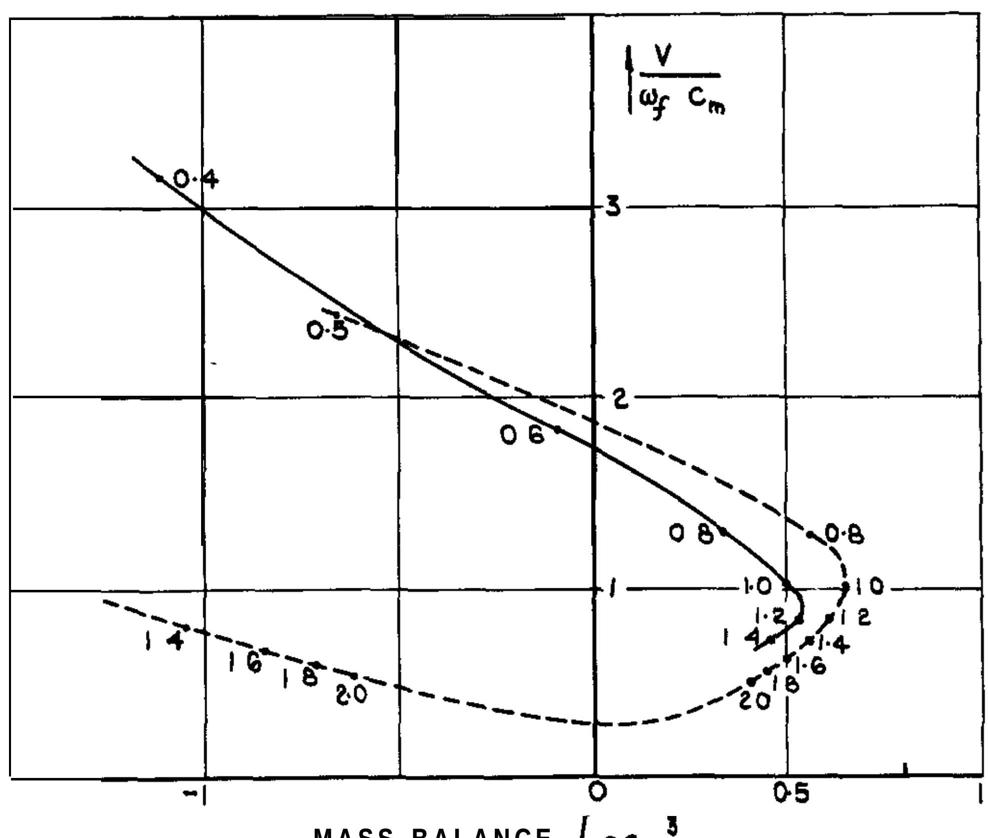


FIG. 1. THE TAILPLANE SYSTEM.



------- THE M = 0 CURVES ARE SHOWN BY BROKEN LINES.

——— THE M = 0·7 CURVES ARE SHOWN BY FULL LINES.

THE NUMBERS ON THE CURVES ARE THE VALUES OF THE FREQUENCY PARAMETER.

THE STATIC MA53 BALANCE IS 0·80 $\rho c_0{}^3$ AND IS MARKED ⊥

FIG. 2. MODE -A. TAILPLANE VERTICAL TRANSLATION. STICK FREE.

FIG. 3 & 4.

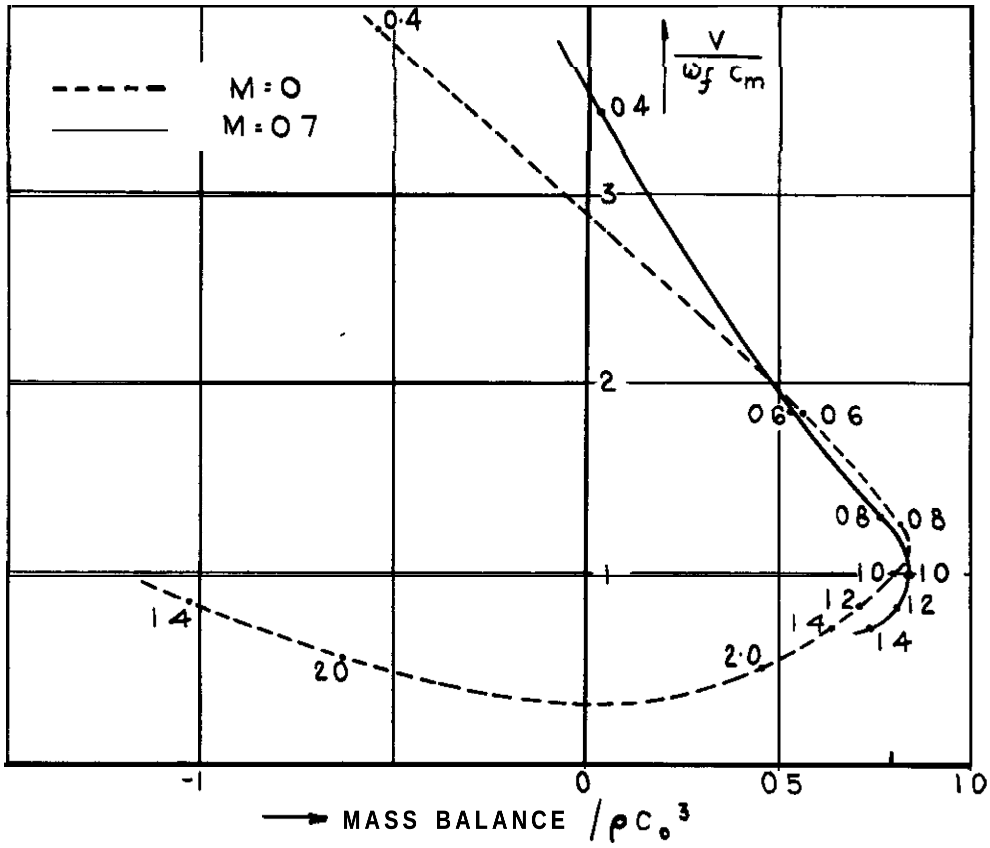
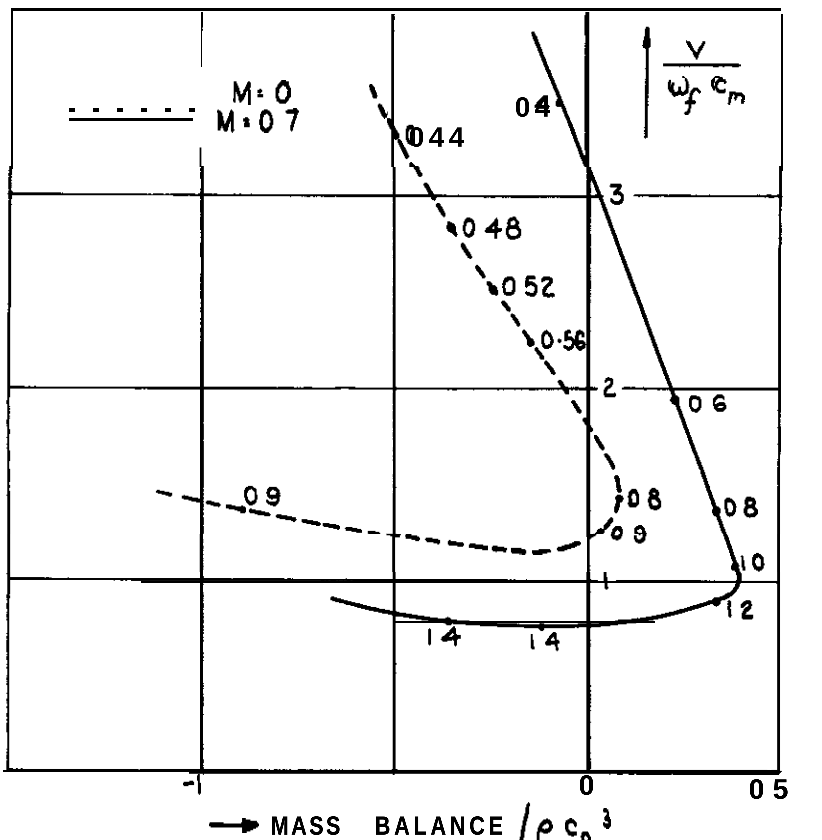


FIG. 3. MODE B. TAILPLANE PITCH AND VERTICAL TRANSLATION. STICK FREE.



THE STATIC MASS BALANCE IS 0 80 ρc_0^3

FIG. 4. MODE B. TAILPLANE PITCH AND VERTICAL TRANSLATION. STICK FIXED. ELEVATOR INERTIA DOUBLED.

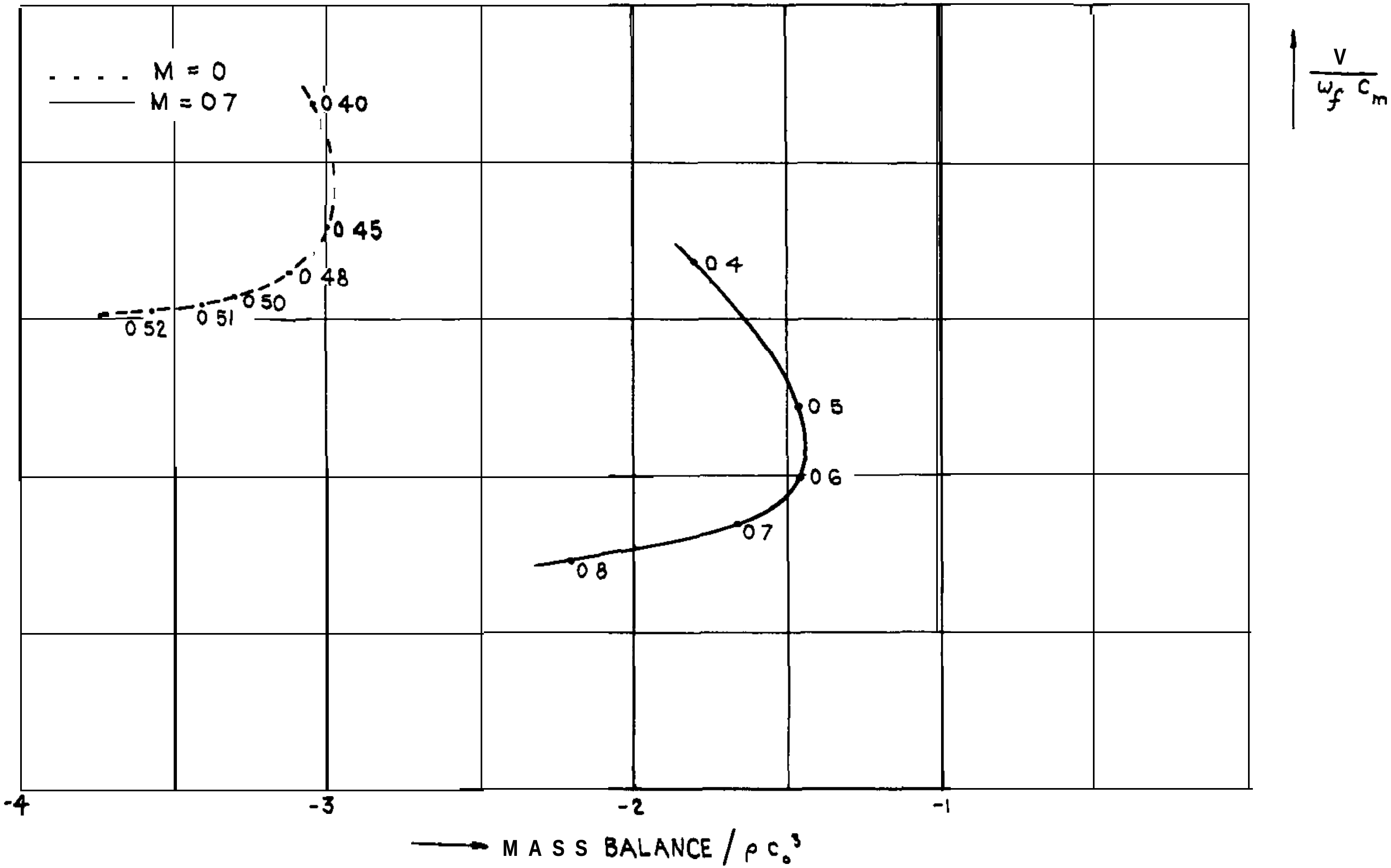
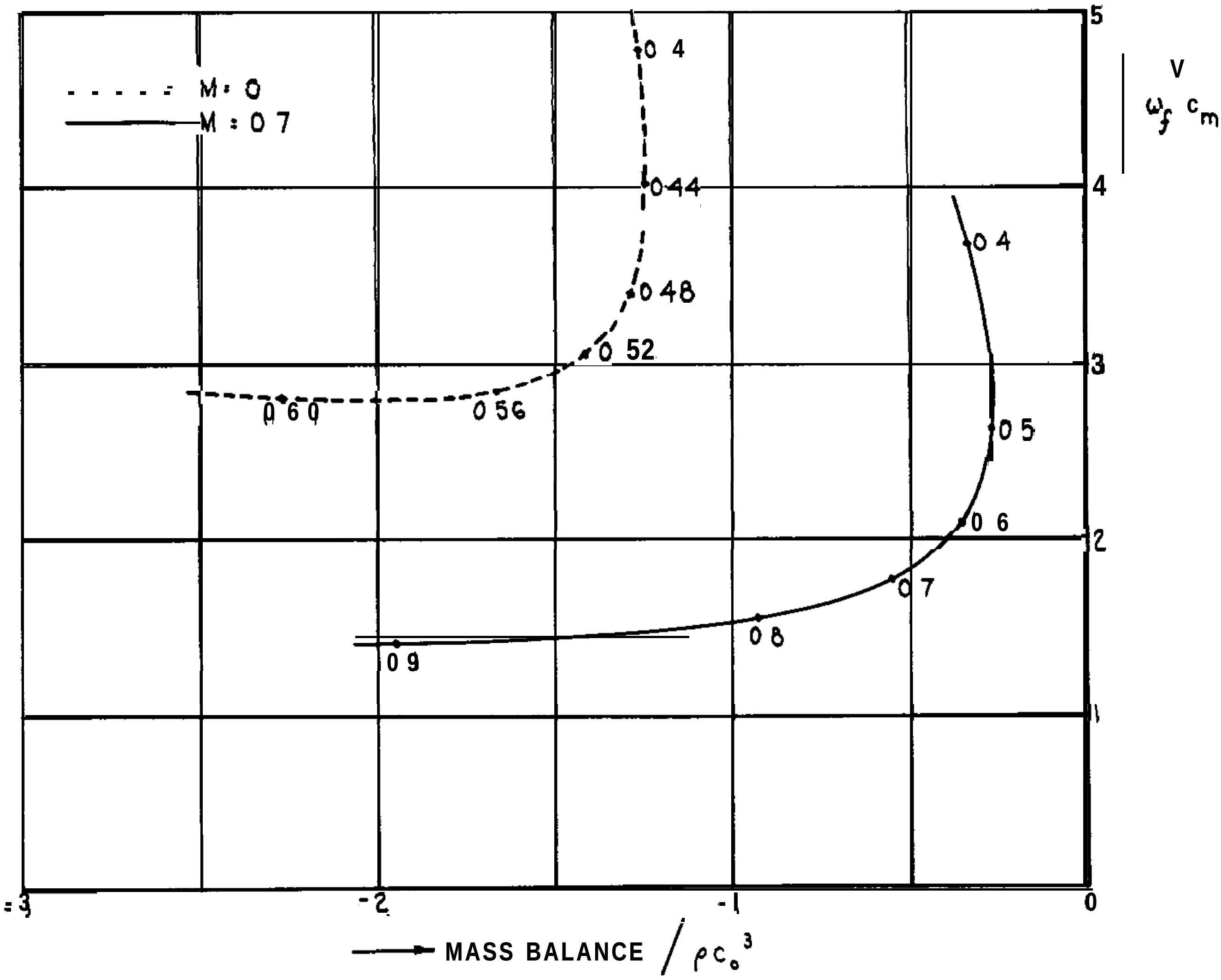


FIG.5. MODE A. TAILPLANE VERTICAL TRANSLATION. STICK FIXED.

FIG. 5.

FIG. 6.



THE STATIC MASS BALANCE IS 0 80 ρc_o^3

FIG.6. MODE B. TAILPLANE PITCH AND VERTICAL TRANSLATION. STICK FIXED.

PUBLISHED BY HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, LONDON, W C 2. 423 Oxford Street, LONDON, W.1
PO Box 569, LONDON, S.E 1
13a Castle street, EDINBURGH, 2 1 St. Andrew's Crescent, CARDIFF
39 King street, MANCHESTER, 2 Tower Lane. BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3 80 Chichester Street. BELFAST
or from any Bookseller

1954

Price 1s. 6d. net
PRINTED IN GREAT BRITAIN

S.O. Code No. U-9007-85

C.P. No. 185