C.P. No. 534 C.P. No. 534

MINISTRY OF AVIATION

AERONAUTICAL RESEARCH COUNCIL

CURRENT PAPERS

Measurements of Pitching Oscillation Derivatives at Subsonic and Transonic Speeds for a Cropped Delta Wing of Aspect Ratio 1.8

(Interim Report)

By

C. J. W. Miles, J. B. Bratt, B.A., B.Sc.,
and
K. B. Bridgeman of the Aerodynamics Division, N.P.L.

LONDON: HER MAJESTY'S STATIONERY OFFICE

1961

Price 3s. 6d. net

C.P. No.534

Measurements of Pitching Oscillation Derivatives at Subsonic and Transonic Speeds for a Cropped Delta Wing of Aspect Ratio 1.8 (Interim Report)

- By -
C. J. W. Miles, J. B. Bratt, B.A., B.Sc., and
K. B. Bridgman of the Aerodynamics Division, N.P.L.

5th February, 1960

SUMMARY

Measurements of the direct and indirect derivatives for pitching oscillations on a cropped delta wing of aspect ratio 1.8 have been made at subsonic and transonic speeds.

The effects of frequency parameter, amplitude of oscillation and mean incidence have been investigated. Tests were also made to determine the effects on the measurements of a root fence.

Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

1. Introduction

The measurements described in this report form part of a general programme of derivative tests made in the N.P.L. $9\frac{1}{2}$ in. high-speed tunnel on a half-wing model of a cropped delta wing of aspect ratio 1.8 with a trailing-edge flap. Measurements of the direct hinge moment derivatives have already been completed and are given in an earlier report[1]. For the present tests the flap was rigidly clamped to the wing and measurements of oscillatory pitching moment and lift were obtained for pitching oscillations about two axis positions, in order to give sufficient information for deducing plunging motion derivatives.

A Mach number range from 0.4 to 1.12 was covered in the tests, in general at amplitudes of oscillation of both 1° abd 2°. The direct derivatives m_α and $m_{\dot\alpha}$ were measured at two frequencies of approximately 25 c/s and 100 c/s and at mean incidences ranging from 0° to 10°. The indirect derivatives ℓ_α and $\ell_{\dot\alpha}$ were obtained only for the lowest frequency (25 c/s) and zero mean incidence at an amplitude of 2°.

A preliminary series of tests was made in which m_α and $m_{\dot\alpha}$ were measured with a fence in the form of a thin metal plate fixed at the root of the model to reduce effects of flow through the narrow gap between the root and the tunnel wall. The fence also covered holes in the tunnel wall for connections between model and apparatus. Fences of different size and shape were tested in order to give some guidance on the design of a fence for the main body of the tests.

2./

Previously issued as A.R.C.21,662.

2. Technique of Measurement

The apparatus used in these tests employed an electrically self-excited system, and is described in detail in Ref.2.

2.1 Direct derivatives m_α, $m_{\dot\alpha}$

For measurements of m_α and $m_{\dot\alpha}$ the apparatus inner frame was clamped to the earthed structure. The stiffness derivative coefficient m_α was measured by observing the change of frequency of the oscillating system on running the tunnel whilst the damping derivative coefficient $m_{\dot\alpha}$ was obtained as the change in useful electrical power required to maintain constant amplitude. A more detailed description of the measurements involved is given in Ref.2.

Some cases were encountered where m_α and consequently the change in frequency of the system was very small and tended to be masked by the effects due to changes in temperature. In these cases the sequence of measurements was designed to minimise temperature effects.

2.2 Indirect derivatives ℓ_α, $\ell_{\dot\alpha}$

For the measurement of ℓ_α and $\ell_{\dot\alpha}$ the inner frame was supported by the force units and observations of the oscillatory lift forces appearing at these units were made. Reduction of the observations to the coefficients ℓ_α and $\ell_{\dot\alpha}$ involved a dynamic calibration of the system in which a known oscillatory lift force was simulated by a mass attached to the oscillating model by means of a light Tufnol clamp. Two spanwise positions for the mass were used and in each case tests were made with the mass both forward of the L.E., and behind the T.E. The average value of 'measured force'/'calculated force' for all loading positions and both axes of oscillation was 1.05. The dynamic calibration also gave a value for the total phase shift through the measuring system, which amounted to 0.2° and involved a correction to $\ell_{\dot\alpha}$ of the order of 10% in the worst case.

Drifts of the force unit outputs due to temperature changes proved at first to be troublesome. A fair degree of temperature stabilisation was achieved by circulating water at constant temperature through small tanks of simple construction attached to the bases of the force units. The residual drifts, whilst allowing the oscillatory lift forces to be measured, proved to be too large for the measurement of static forces.

Considerable difficulty was at first experienced in measuring ℓ_α and $\ell_{\dot\alpha}$ due to the presence of relatively high-frequency noise signals superimposed on the lift signal when the tunnel was running. In many cases the noise swamped the lift signal and lead to cut-off in amplifier circuits and transformer effects in the dynamometer wattmeter used for measuring the vector components. The difficulty was finally overcome by the use of a suitable filter and auxiliary phase-shifter, a simple technique being developed for adjusting the latter to compensate for the phase shift introduced by the filter.

3. Notation

The complex pitching moment and lift relating to a pitching oscillation are expressed in the following form:-

$$\mathcal{M} = \rho V^2 S\bar{c}(m_\alpha + j\omega m_{\dot\alpha})\alpha$$

$$L = \rho V^2 S\,(\ell_\alpha + j\omega \ell_{\dot\alpha})\alpha$$

where the symbols are defined below

$\mathcal{M}$/

$\mathcal{M}$, pitching moment (positive nose up)

L lift (positive up)

c_o root chord

$\bar{c}$ mean chord

f frequency of oscillation

M Mach number

S area of wing

V wind speed

x distance forward of trailing edge

α pitching displacement (positive nose up)

α_o amplitude of oscillation

ρ air density (free stream)

ω frequency parameter ($= 2\pi f\bar{c}/V$)

$\left.\begin{array}{l} m_\alpha \\ m_{\dot\alpha} \\ \ell_\alpha \\ \ell_{\dot\alpha} \end{array}\right\}$ non-dimensional derivative coefficients as defined in Ref.3

4. Experimental Results

No tunnel corrections have been applied to any of the experimental results given in this paper.

The variation of the frequency parameter ω with Mach number for the two frequencies of the tests is shown in Fig.14.

4.1 Tests with various root fences

The five fences used in the tests are illustrated in Fig.2. All show the same characteristics of increasing width rearwards, the reason for this being the presence of a lug extending from the flap through a hole in the tunnel wall. The modifications in No.3 and No.4 were introduced to increase the overlap on the hole in the tunnel wall accommodating the tongue of the model for the respective axis positions.

The effects of the various fences on $-m_\alpha$ and $-m_{\dot\alpha}$ are shown in Figs.10(a), 10(b), 11(a) and 11(b), the tests being made at the highest frequency of the range. It seems that all the fences are more or less equally effective up to $M = 1.0$, with one exception shown in Fig.11(b). This, however, is likely to be a sensitive case since $-m_\alpha$ is very small. Above $M = 1.0$ fluctuations in the curves tend to appear, and some attempt was made to correlate these with shock wave patterns, but without success. Finally the smallest fence (No.1) was selected as being the least likely to produce undesirable effects at transonic speeds.

4.2 Measurements of m_α, $m_{\dot\alpha}$ at zero mean incidence

Curves of $-m_\alpha$ and $-m_{\dot\alpha}$ against Mach number for zero mean incidence are shown in Figs.4(a), 4(b), 5(a) and 5(b). For both axes of oscillation $-m_{\dot\alpha}$ rises at a steadily increasing rate with Mach number up to a peak value at about $M = 1.0$. For still higher values of M, $-m_{\dot\alpha}$ falls rapidly in the case of the rearmost axis position, but for the forward axis the curve shows only a small dip. The stiffness derivative $-m_\alpha$ shows very little change with Mach number up to $M = 0.9$. At higher values of M the changes become more rapid.

A large frequency effect can be seen on $-m_\alpha$ for the forward axis (Fig.5(a)). The similar effect in Fig.5(b) is actually a very small shift of the curve if plotted on the same scale as Fig.5(a), and corresponds to a change in a very small quantity. A similar trend with frequency is observable in the case of $-m_{\dot\alpha}$ for the forward axis position (Fig.4(a)).

Comparisons of results with and without fence are given in Figs.6 to 9. In general the effect of the fence is to produce a numerical increase below $M = 1.0$.

Tests were made on a dummy fence with the model removed. The forces measured on this fence were negligible.

4.3 Effect of mean incidence on m_α, $m_{\dot\alpha}$

Values of $-m_\alpha$ and $-m_{\dot\alpha}$ plotted against mean incidence for three Mach numbers generally are shown in Figs.12(a), 12(b), 13(a) and 13(b). For the rearward axis of oscillation $-m_{\dot\alpha}$ shows a large and sharp peak value at the higher Mach numbers for a mean incidence of 7.5 to 8.0 degrees. An attempt was made to correlate this result with the surface flow on the wing for static conditions using the oil flow technique. The starting position of the L.E. vortex is plotted against incidence in Fig.15, and for the two higher Mach numbers shows a delayed movement with increasing incidence at 7.0° to 8.0°.

4.4 Effects of transition

The major part of the experiment was carried out with free transition and laminar boundary layer, but a few measurements of m_α and $m_{\dot\alpha}$ were made with a turbulent boundary layer, transition being fixed by means of a strip of carborundum powder at the wing L.E. The effect of making the boundary layer turbulent was small and is shown in Figs.16(a), 16(b).

4.5 Measurements of ℓ_α, $\ell_{\dot\alpha}$

Curves of ℓ_α and $\ell_{\dot\alpha}$ for zero mean incidence plotted against Mach number are shown in Figs.17(a), 17(b), 18(a) and 18(b). Over the whole Mach number range ℓ_α shows a slight increase whilst $\ell_{\dot\alpha}$ shows a small decrease at the lower Mach numbers with a sudden, small increase at about $M = 0.9$.

5. Comparisons with Theory

Subsonic theoretical values of the derivative coefficients relating to a pitching oscillation have been obtained by Garner[4]. The subsonic curves for $-m_{\dot\alpha}$, shown in Figs.4(a) and 4(b) are in good agreement with experiment for the lowest frequency in the region of $M = 0.9$, but show a steeper rise with Mach number. In the cases of $-m_\alpha$ and ℓ_α (Figs.5(a), 5(b), 18(a) and 18(b)) the theoretical values are somewhat greater numerically than the experimental values, but $\ell_{\dot\alpha}$ shows an opposite trend below $M = 0.85$ (Figs.17(a) and 17(b)).

The/

The supersonic theory due to Watson[5] shows in general unsatisfactory agreement with experiment either in magnitude or trend.

6. Conclusions

(1) The use of a root fence appears to be of some importance, and in general increases the numerical value of the derivative at Mach numbers below $M = 1.0$.

(2) The effect of frequency on m_α and $m_{\dot\alpha}$ is quite marked except in the case of $m_{\dot\alpha}$ for the rearmost axis position.

(3) Incidence effects are most marked in the case of $-m_{\dot\alpha}$ for the rearmost axis where a pronounced peak appears at a mean incidence of approximately 8.0°. This is correlated with a discontinuity in the movement of the L.E. vortex with change in incidence, for the static condition.

(4) Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

References

No.	Author(s)	Title, etc.
1	J. B. Bratt, C. J. W. Miles and R. F. Johnson	Measurements of the direct hinge moment derivatives at subsonic and transonic speeds for a cropped delta wing with oscillating flap. R. & M.3163. May, 1957.
2	J. B. Bratt	A note on derivative apparatus for the N.P.L. 9½ in. High Speed Tunnel. A.R.C. C.P.269. January, 1956.
3	I. T. Minhinnick	Tables of functions for evaluation of wing and control surface flutter derivatives for incompressible flow. A.R.C.13,730. July, 1950.
4	H. C. Garner	Application of Multhopp's lifting-surface theory to the lift, pitching moment and hinge moment on a slowly pitching cropped delta wing with oscillating flap. (To be written).
5	J. Watson	Calculation of derivatives for a cropped delta wing with subsonic leading edges oscillating in a supersonic air stream. A.R.C. R. & M.3060. 1958.

FIG. 1.

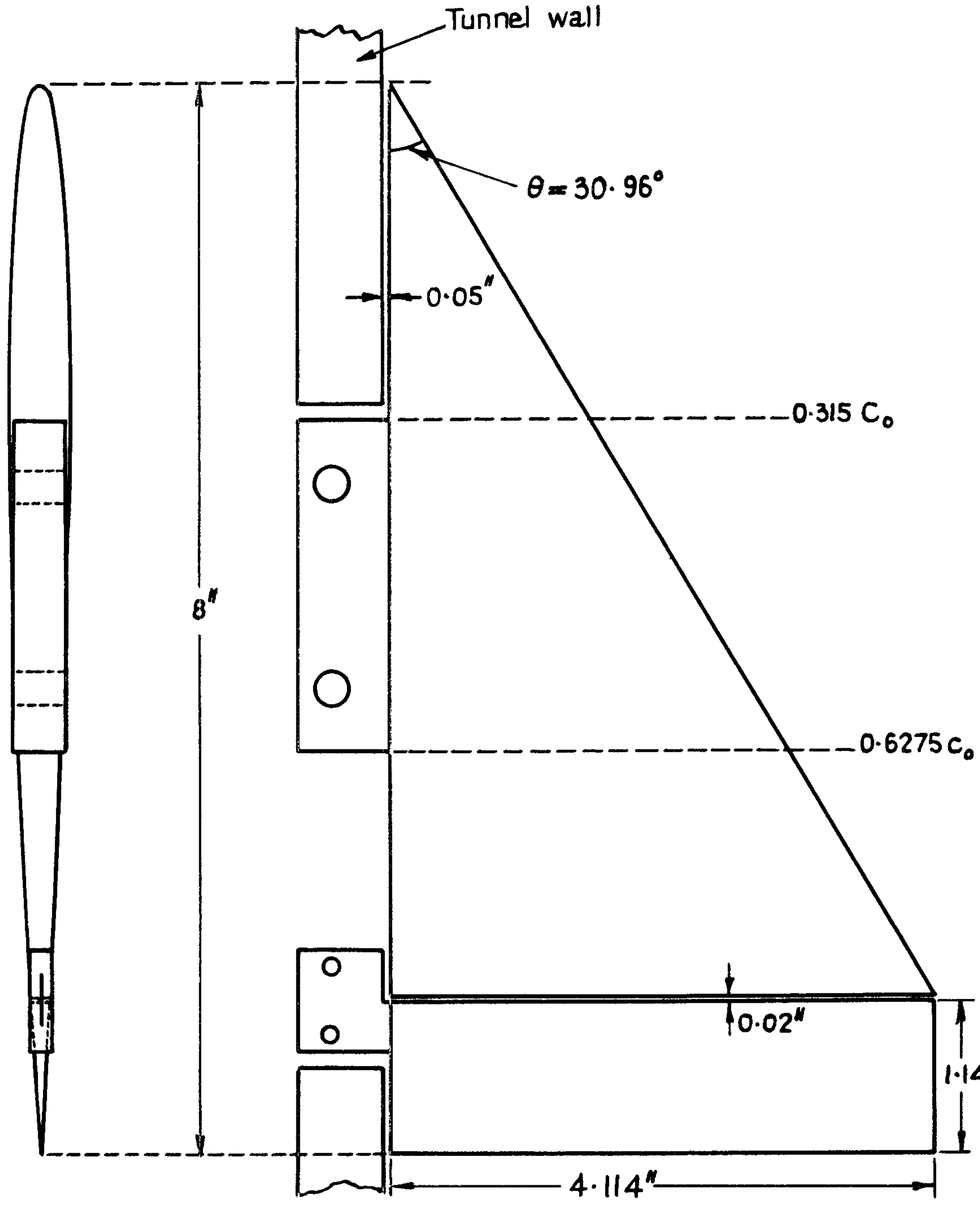
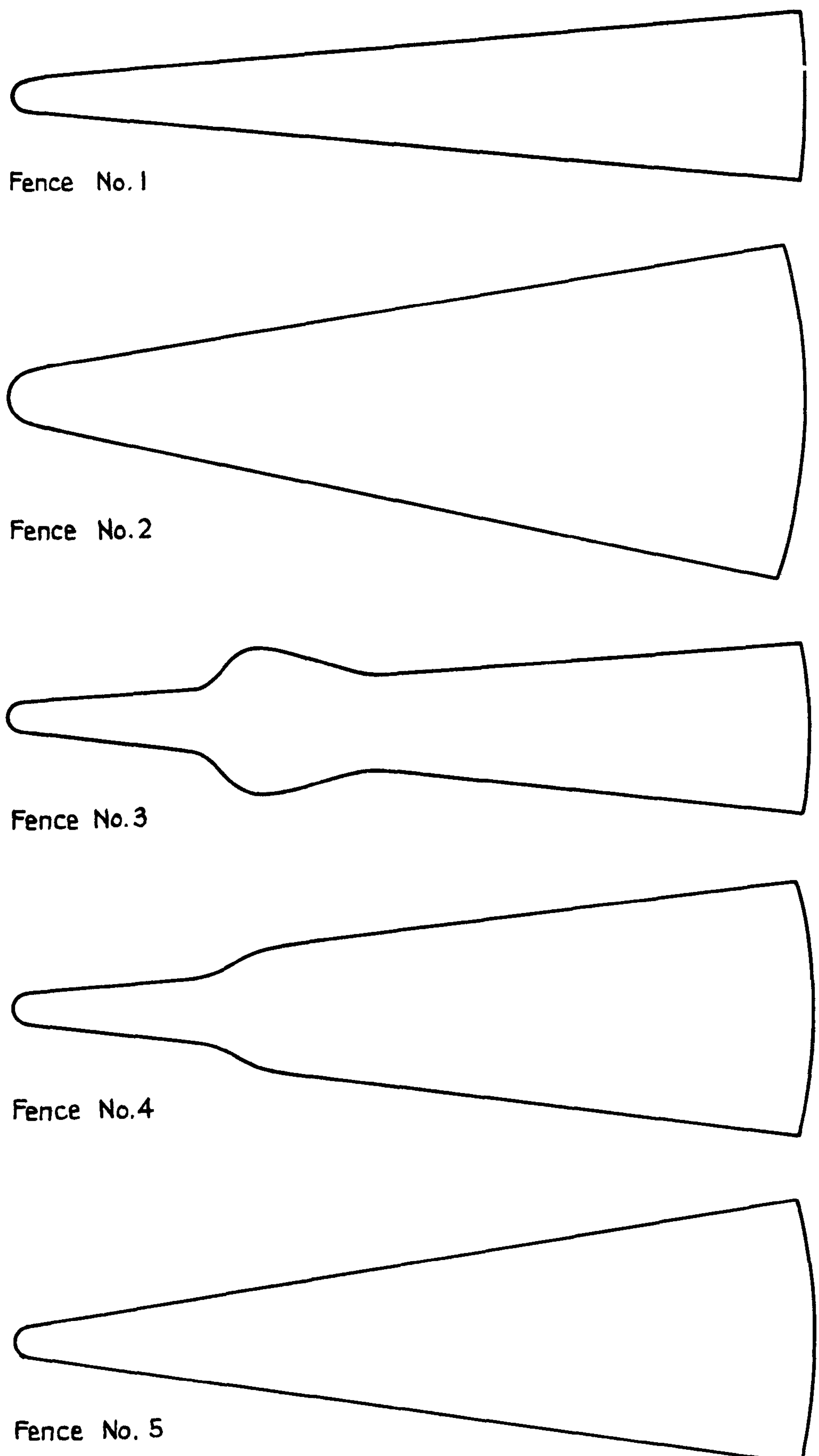


Diagram of model

FIG. 2



Scale 2/3 (approx)

Fence profiles

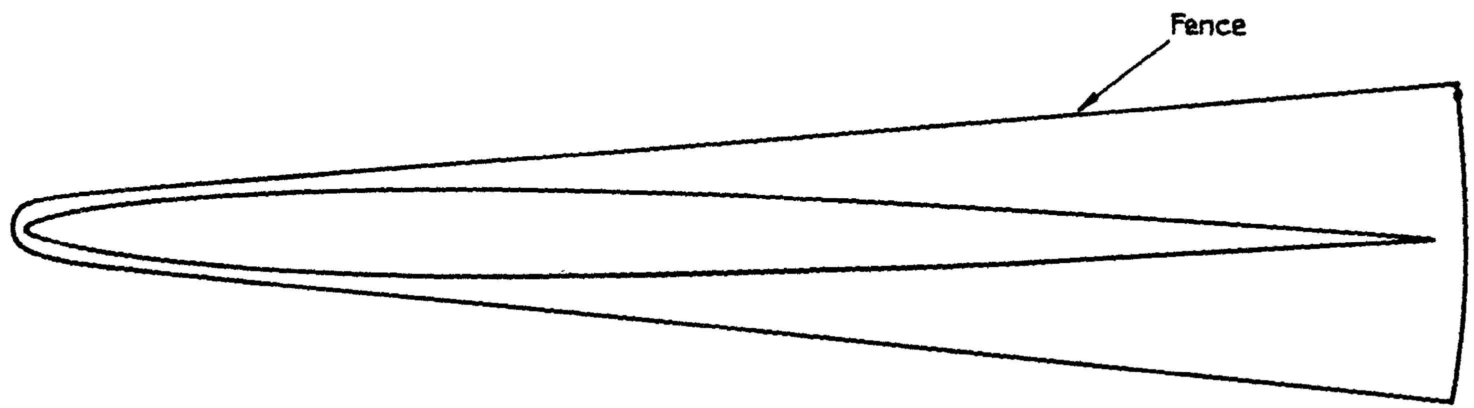
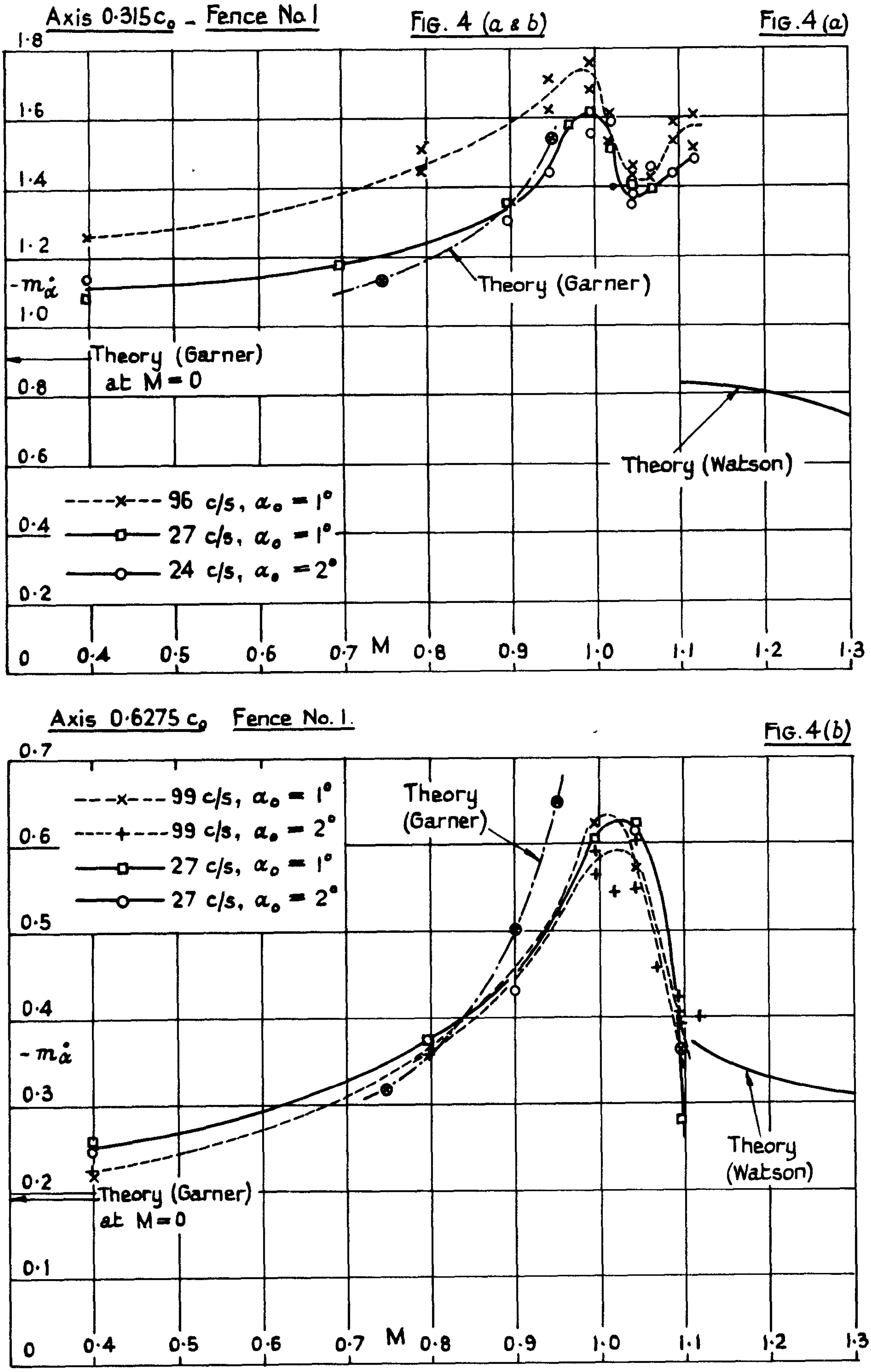


Fig. 3

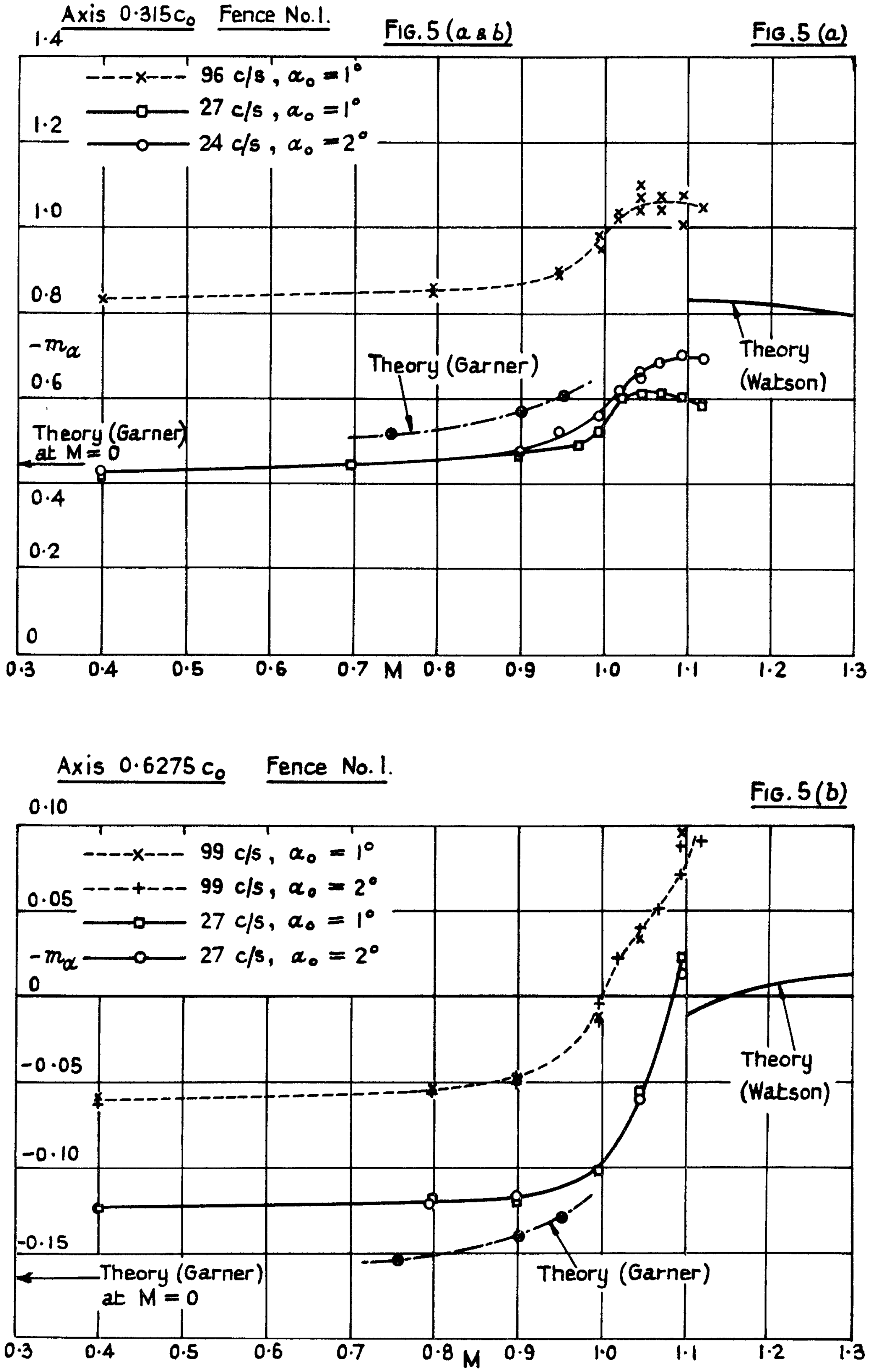
Fence No. 1 with root profile

Full scale



Comparison of $-m_{\dot{\alpha}}$ with theory.

FIG. 5 (a & b)



Comparison of $-m_\alpha$ with theory.

FIG. 6 (a & b)

FIG. 6 (a)

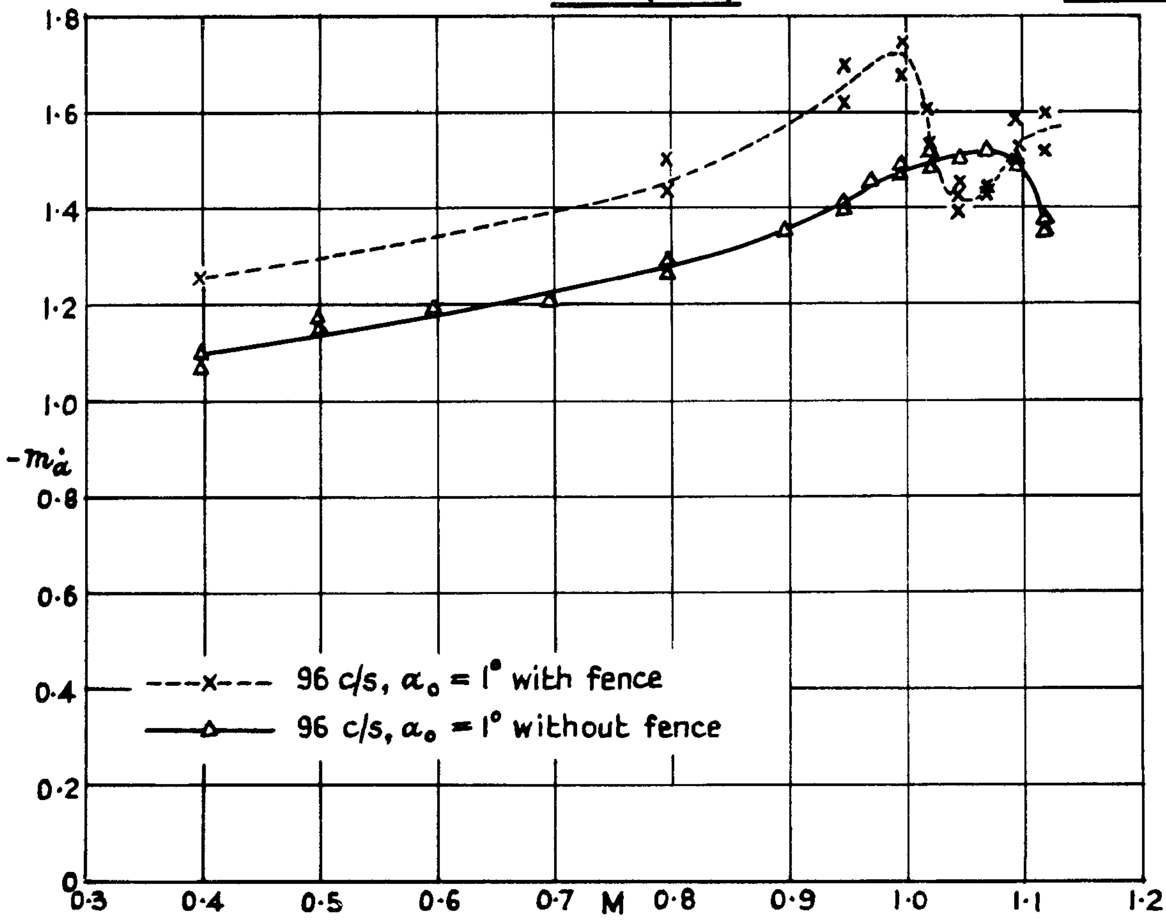
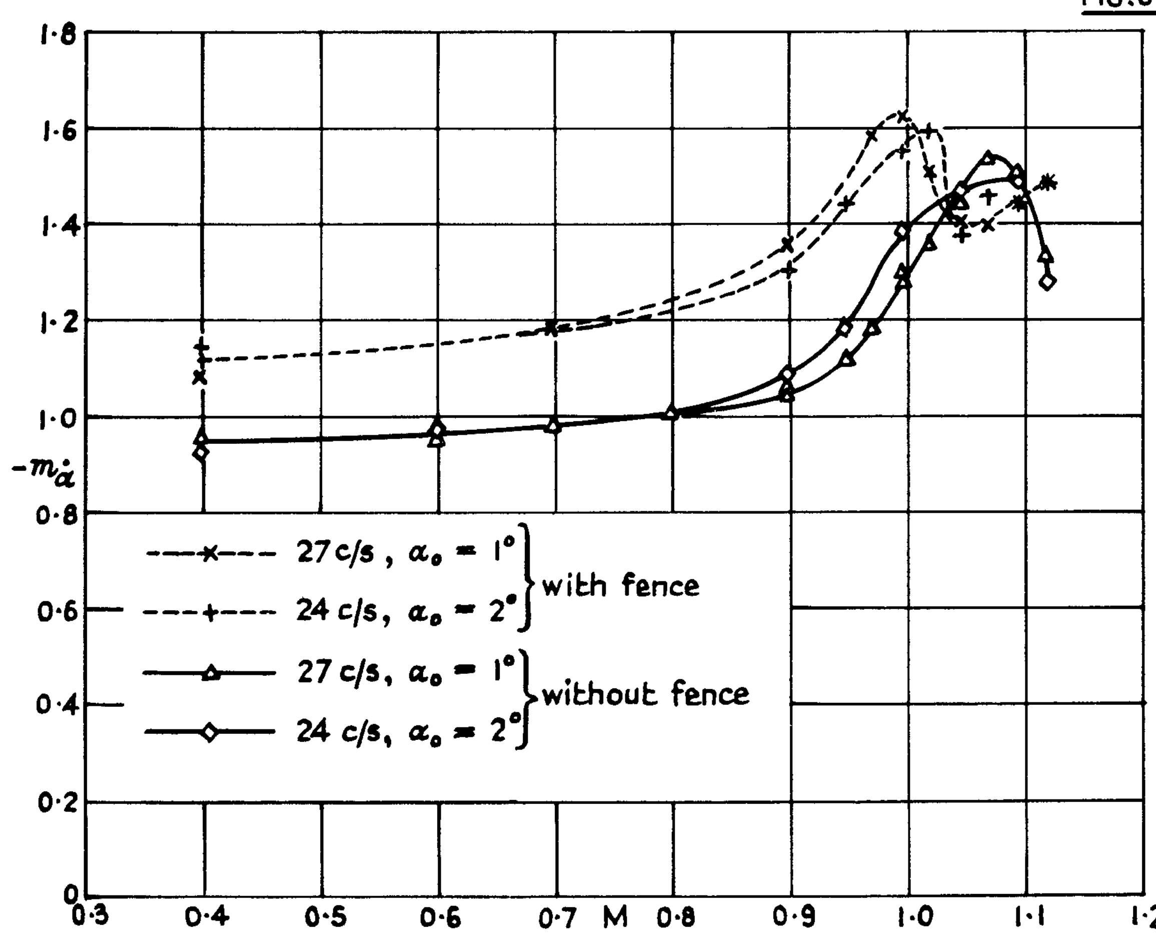


FIG. 6 (b)



Effect of fence No. 1 on $-m_{\dot{\alpha}}$ for the $0{\cdot}315\, c_0$ axis

Fig. 7 (a & b)

Fig. 7(a)

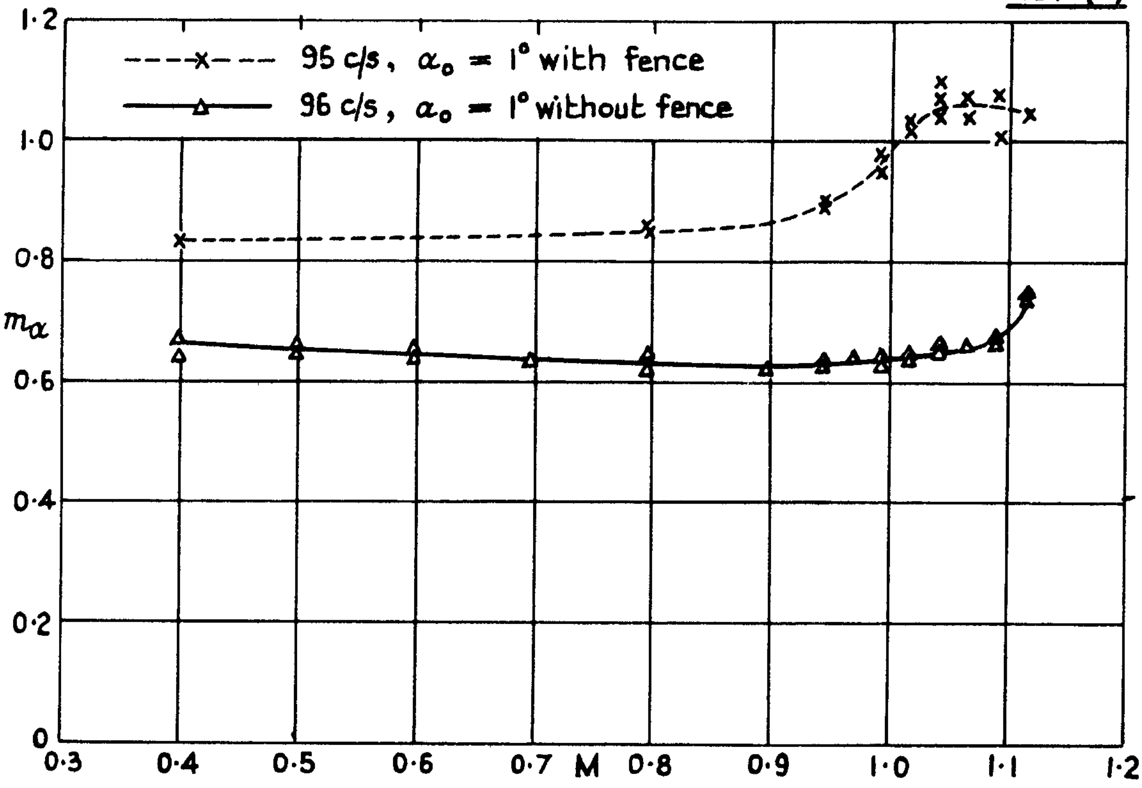
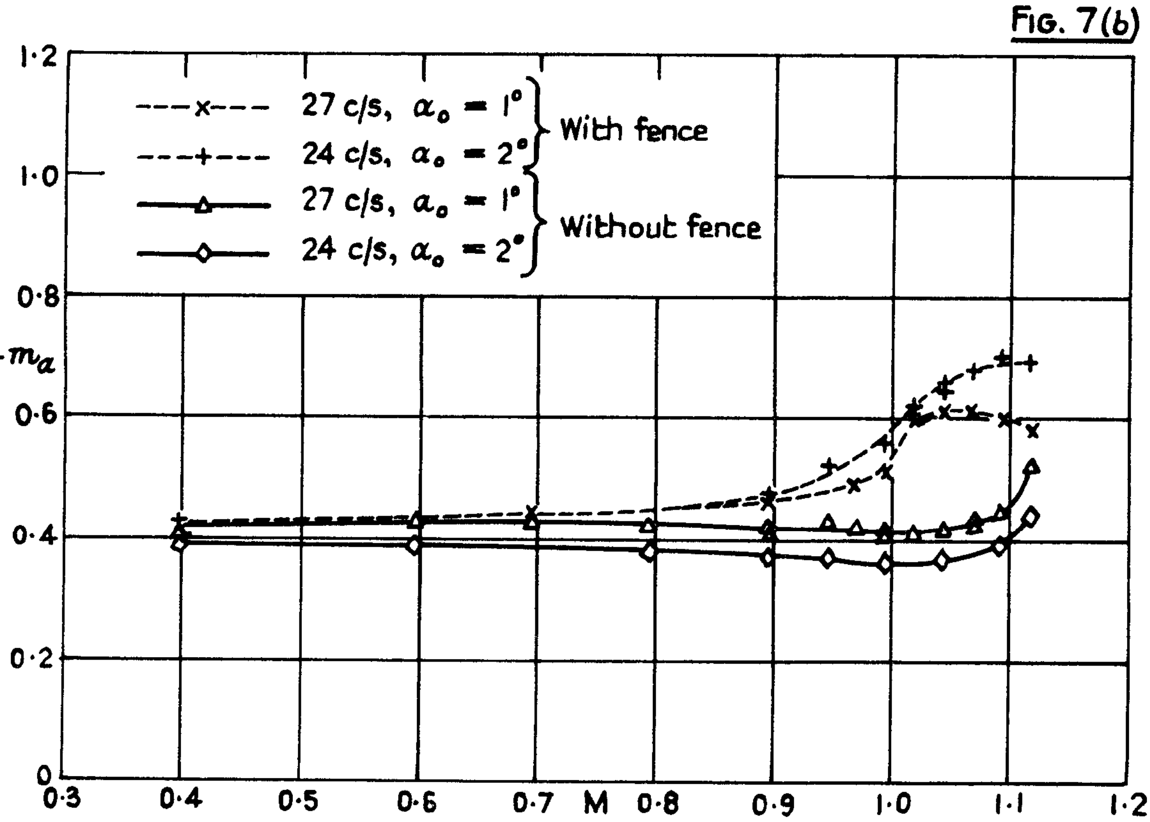


Fig. 7(b)



Effect of fence No. 1 on $-m_\alpha$ for the $0{\cdot}315\,c_0$ axis.

FIG. 8 (a & b)

FIG. 8 (a)

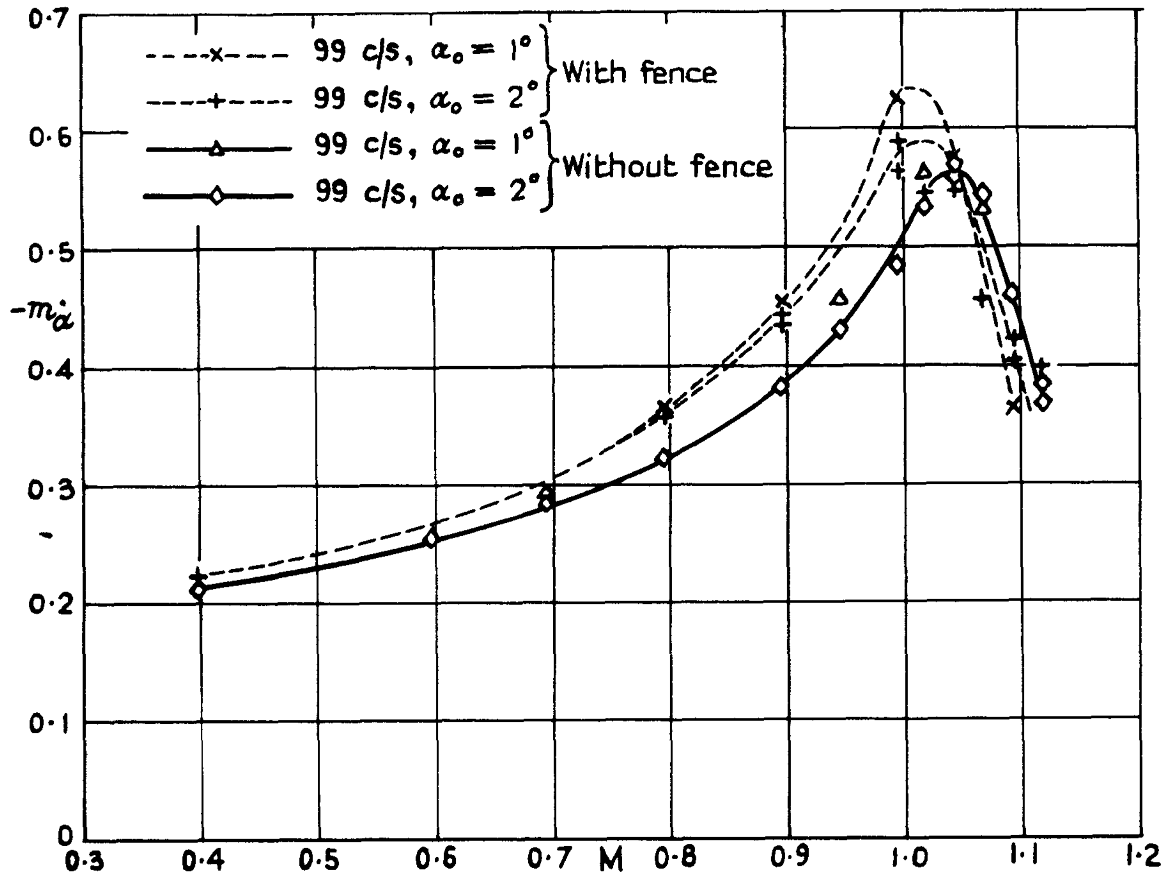
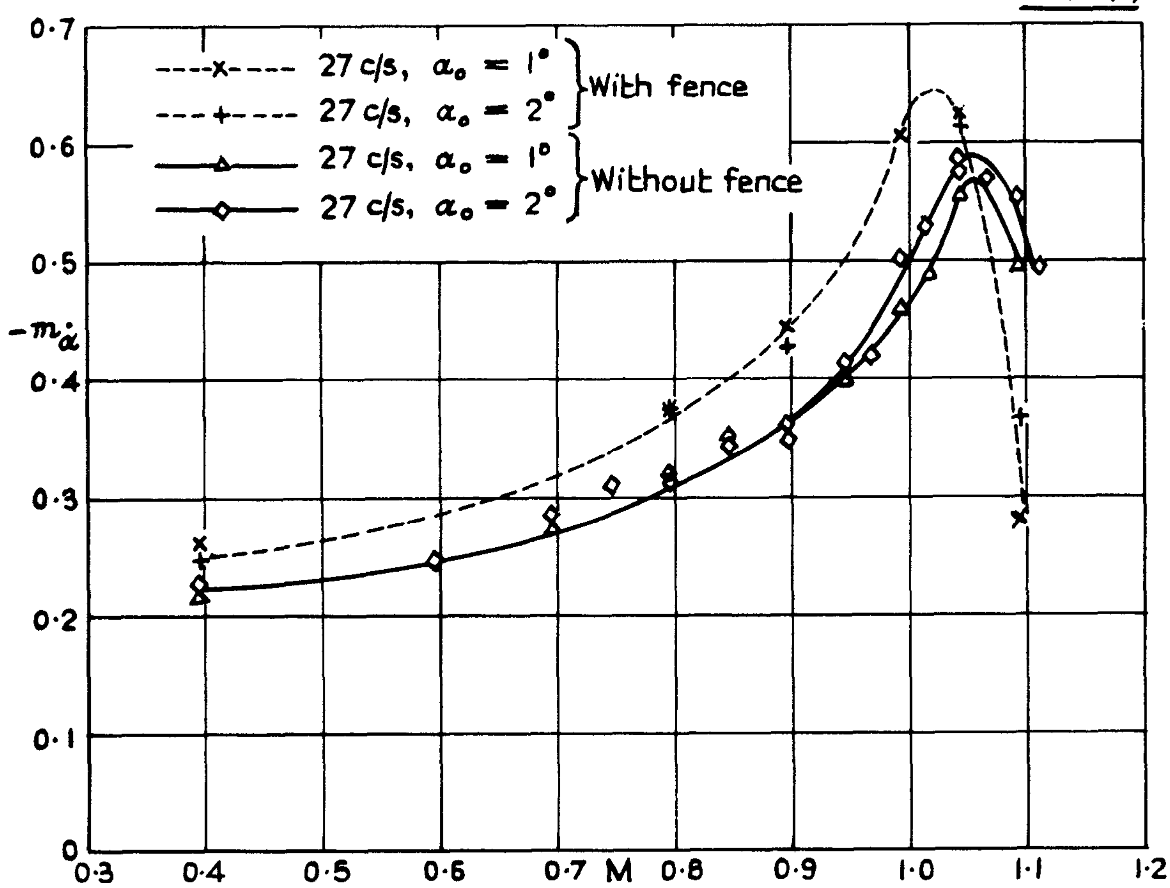


FIG. 8 (b)



Effect of fence No.1 on $-m_{\dot{\alpha}}$ for the 0·6275 c_o axis.

FIG. 9 (a & b)

FIG. 9 (a)

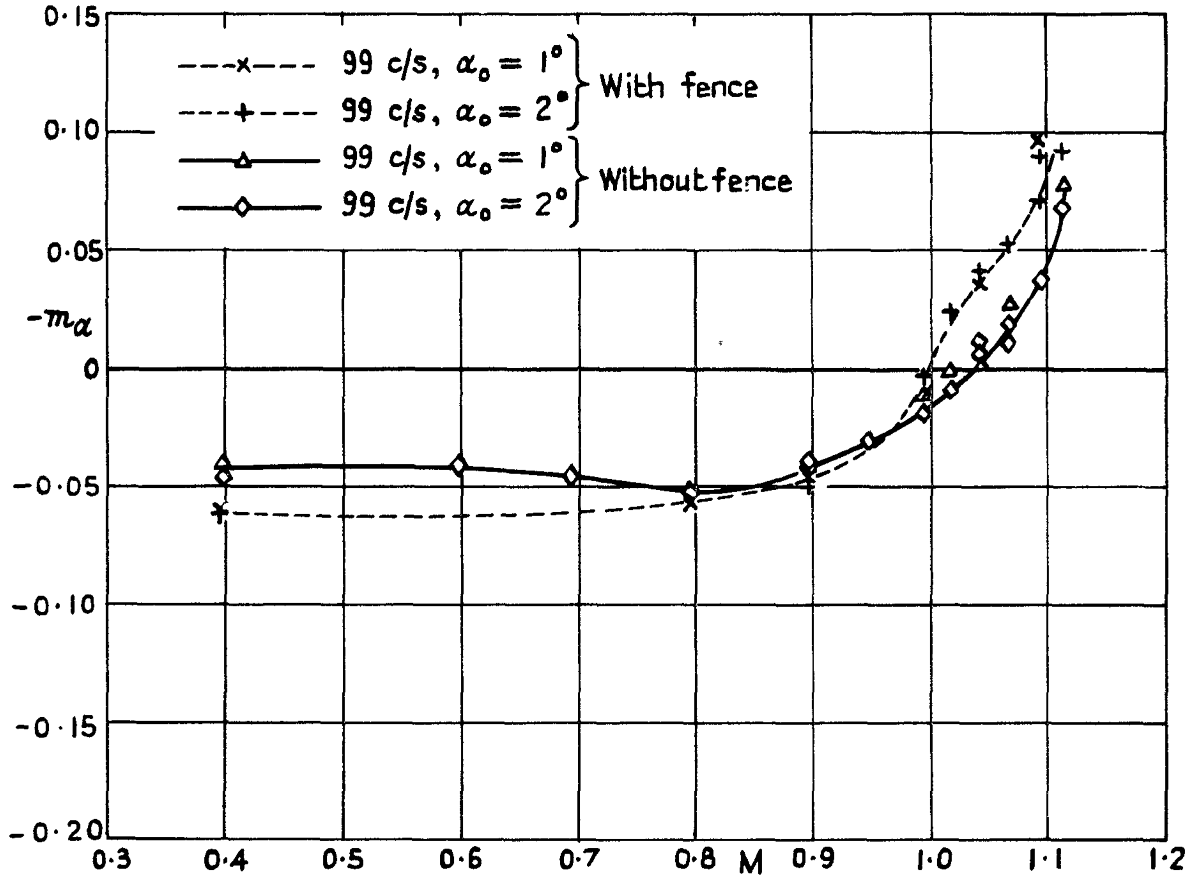
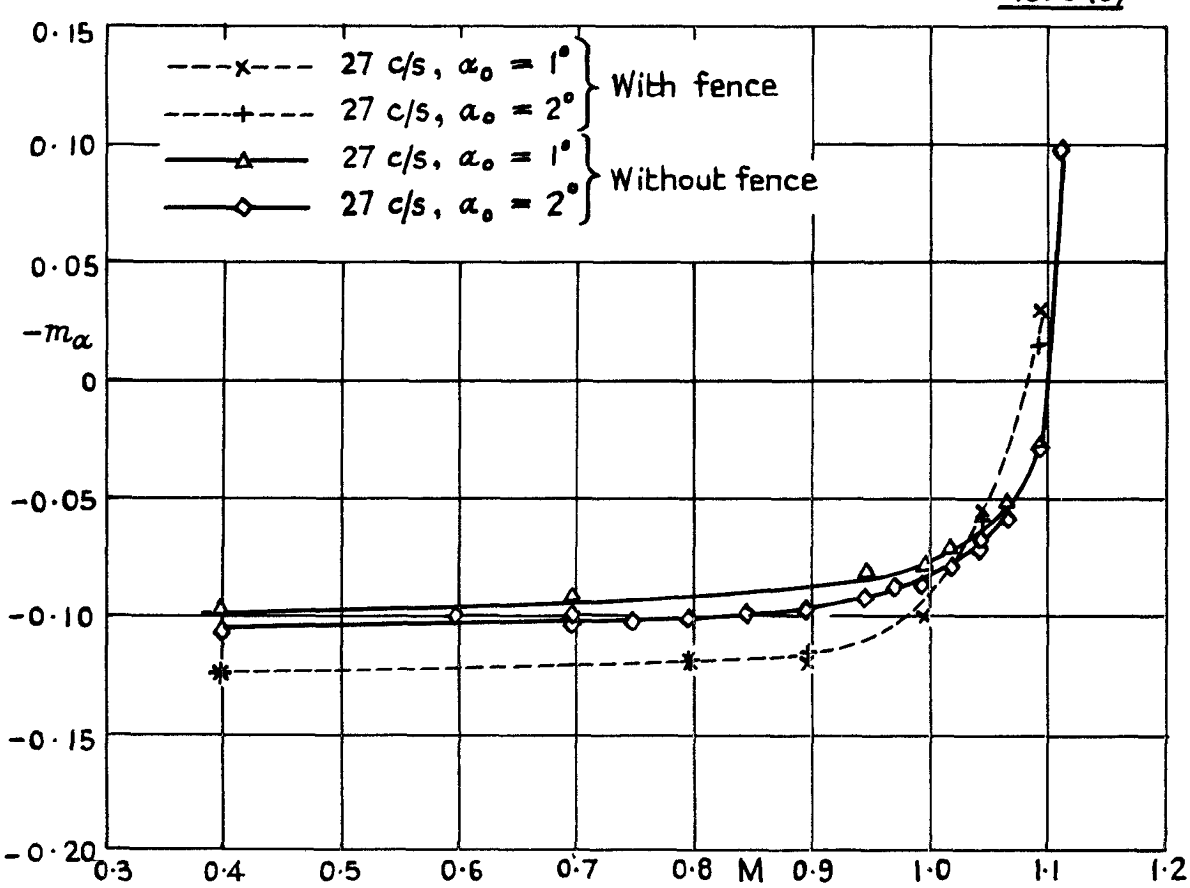


FIG. 9 (b)



Effect of fence No. 1 on $-m_\alpha$ for the 0·6275 c_0 axis.

FIG. 10(a)

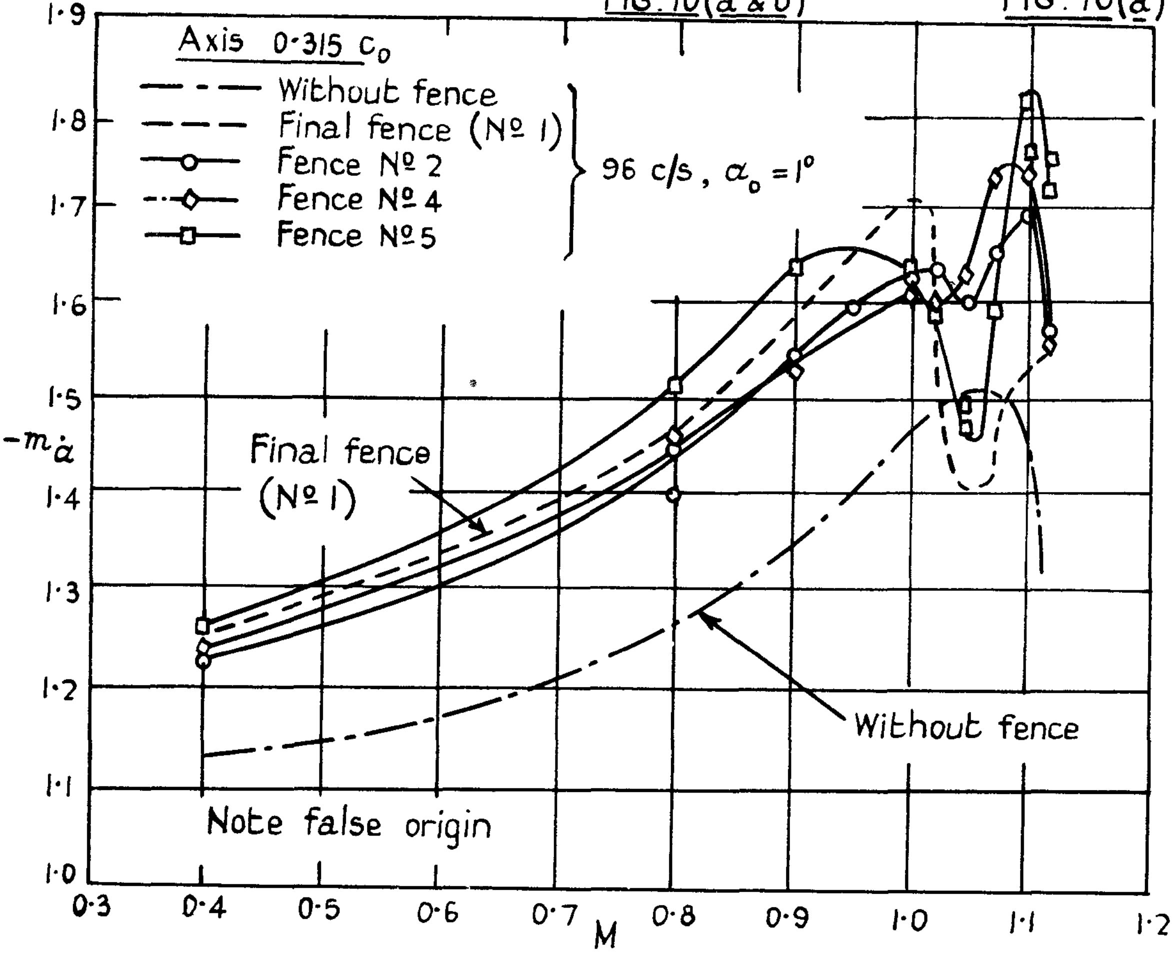
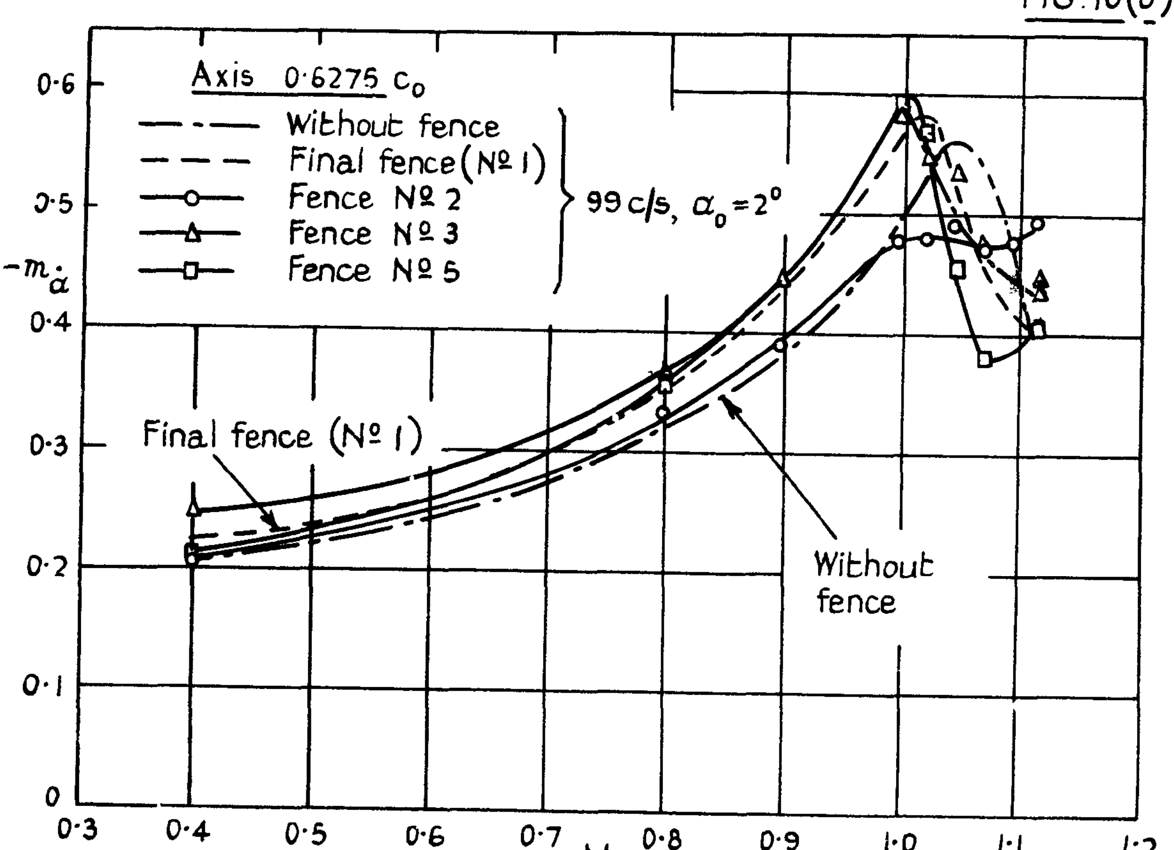


FIG. 10(b)



Effect of various fences on $-m_{\dot{\alpha}}$

FIG. 11 (a & b)

FIG. 11(a)

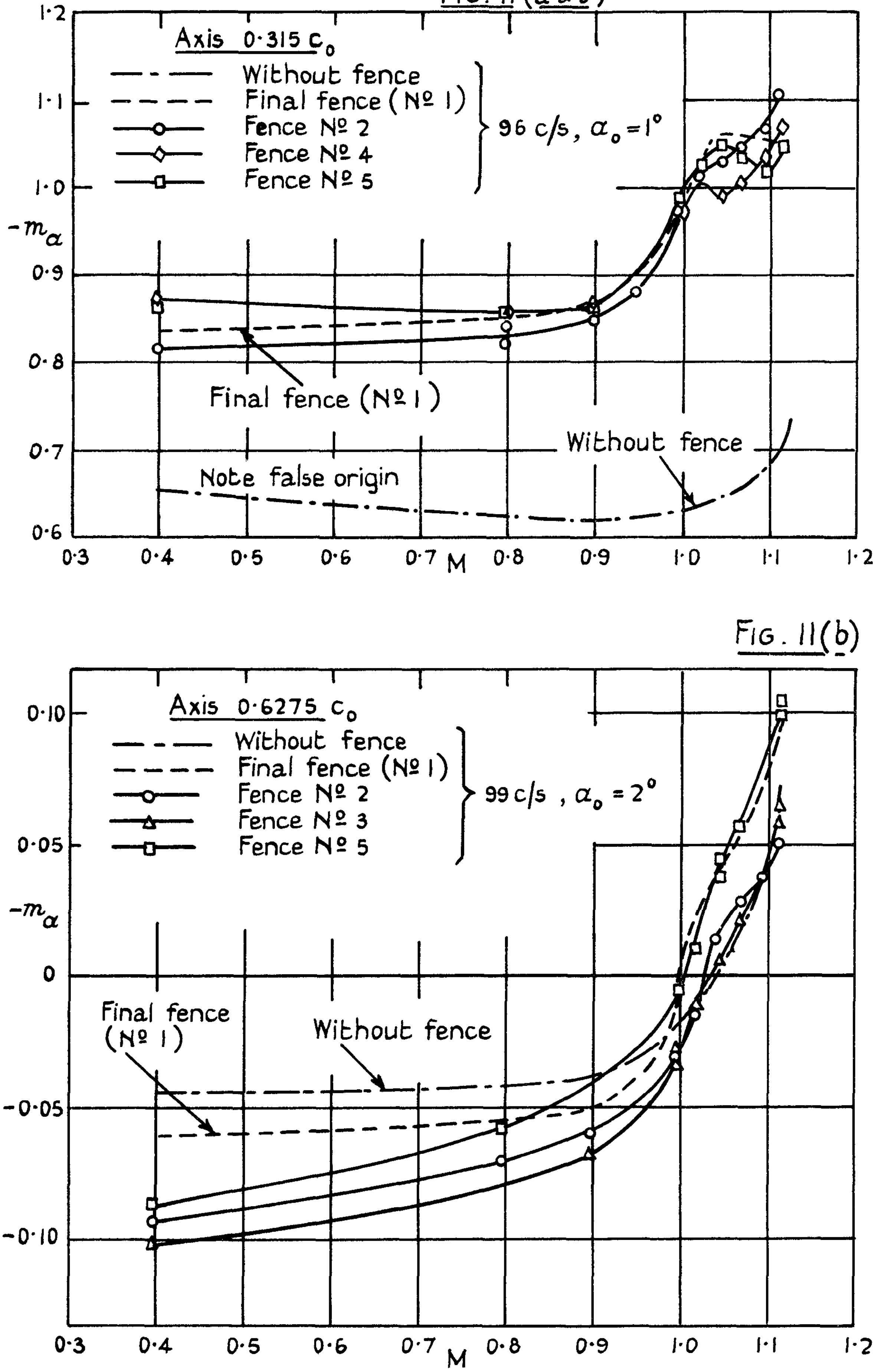
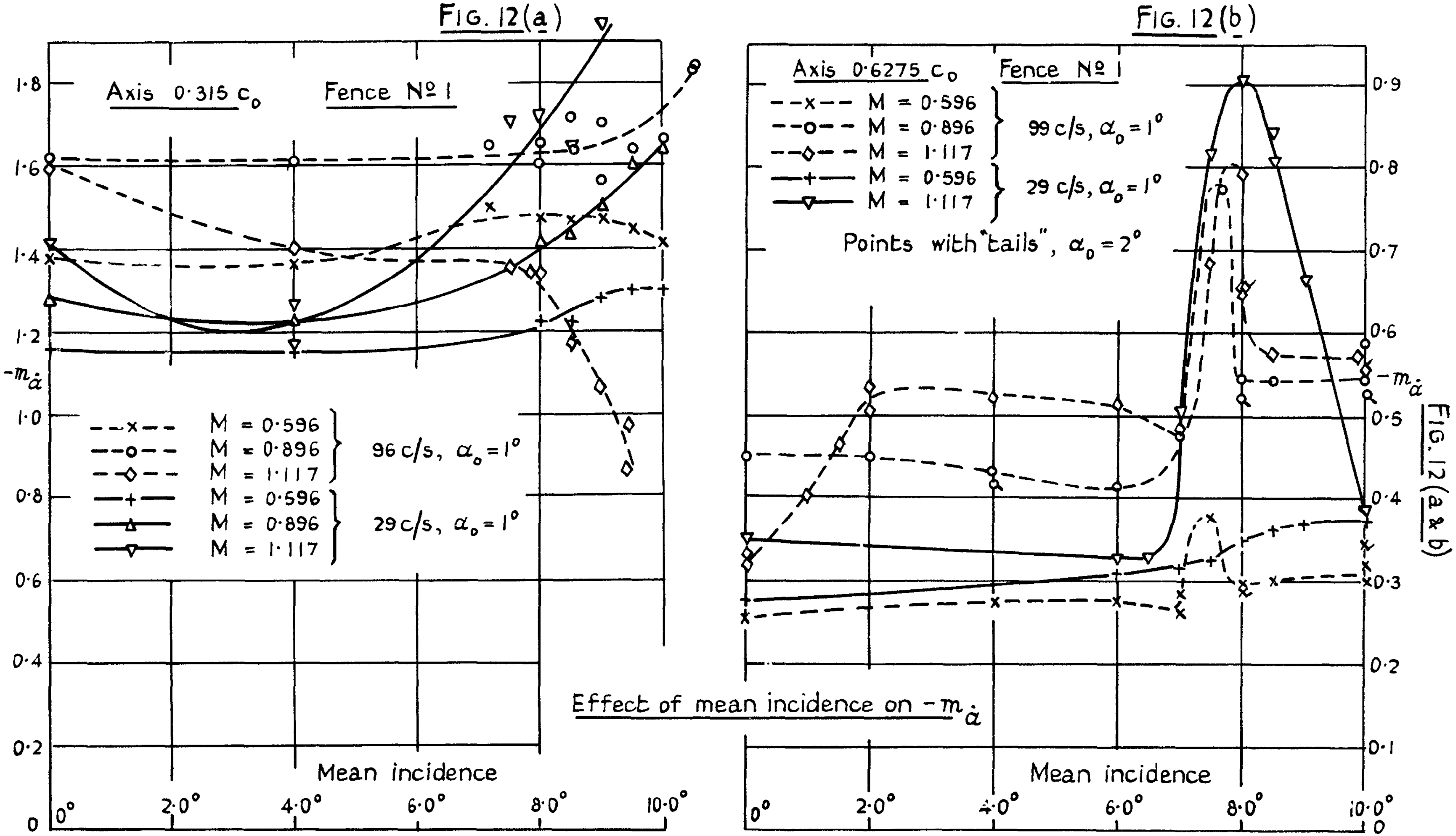
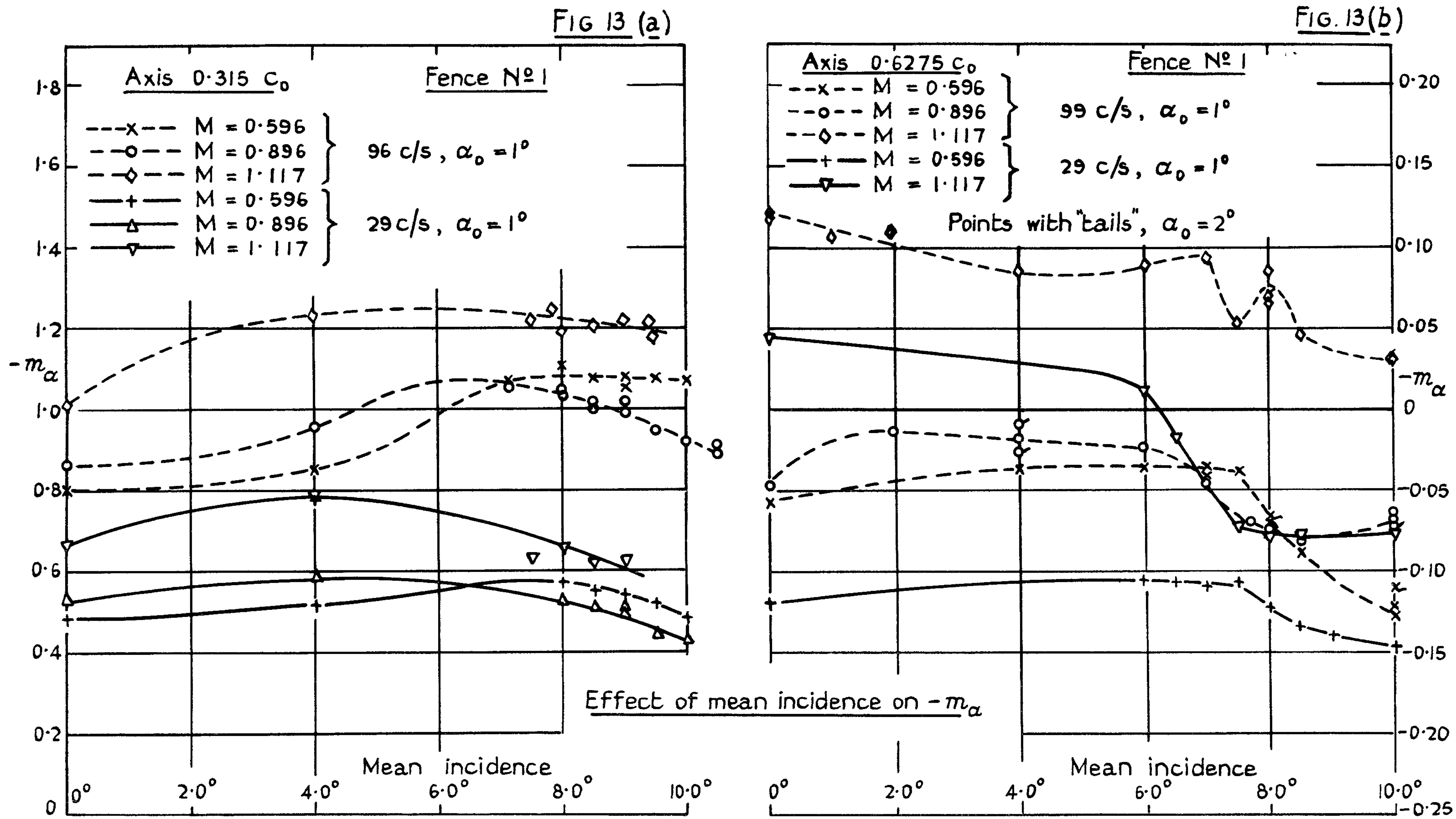


FIG. 11(b)

Effect of various fences on $-m_\alpha$.



Effect of mean incidence on $-m_{\dot{\alpha}}$

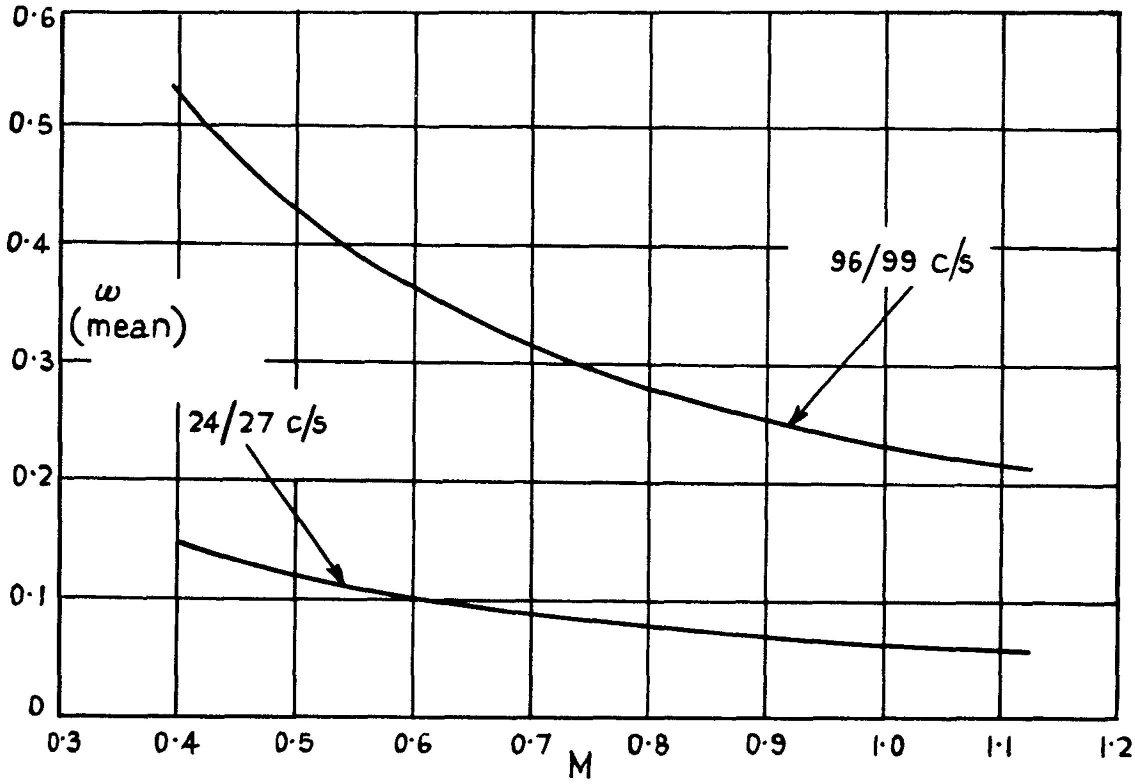


Effect of mean incidence on $-m_\alpha$

FIG. 13 (a & b)

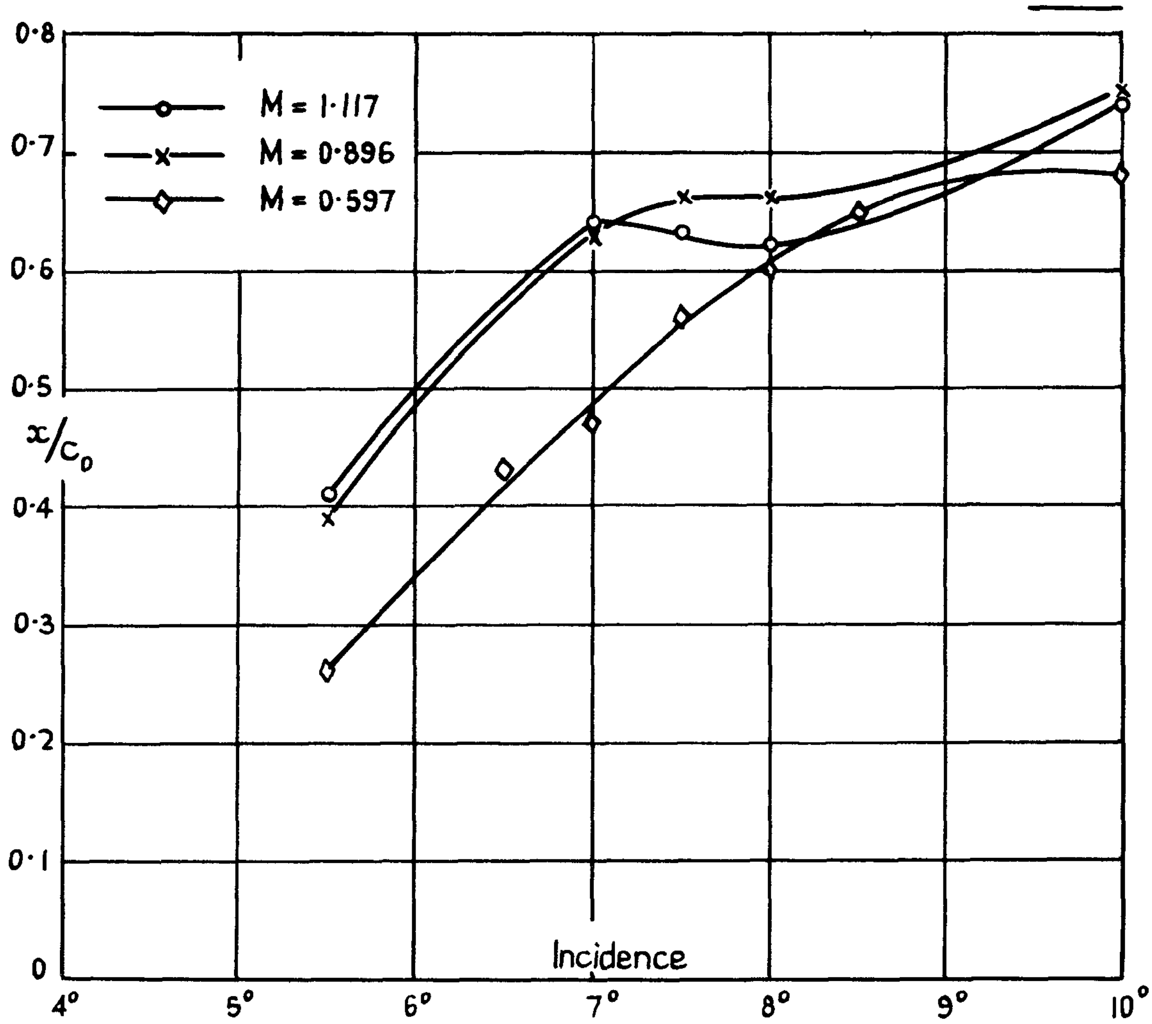
FIGS. 14 & 15

FIG. 14.



Variation of ω with Mach number.

FIG. 15.



Variation of vortex starting position with incidence.

FIG. 16 (a & b)

FIG. 16 (a)

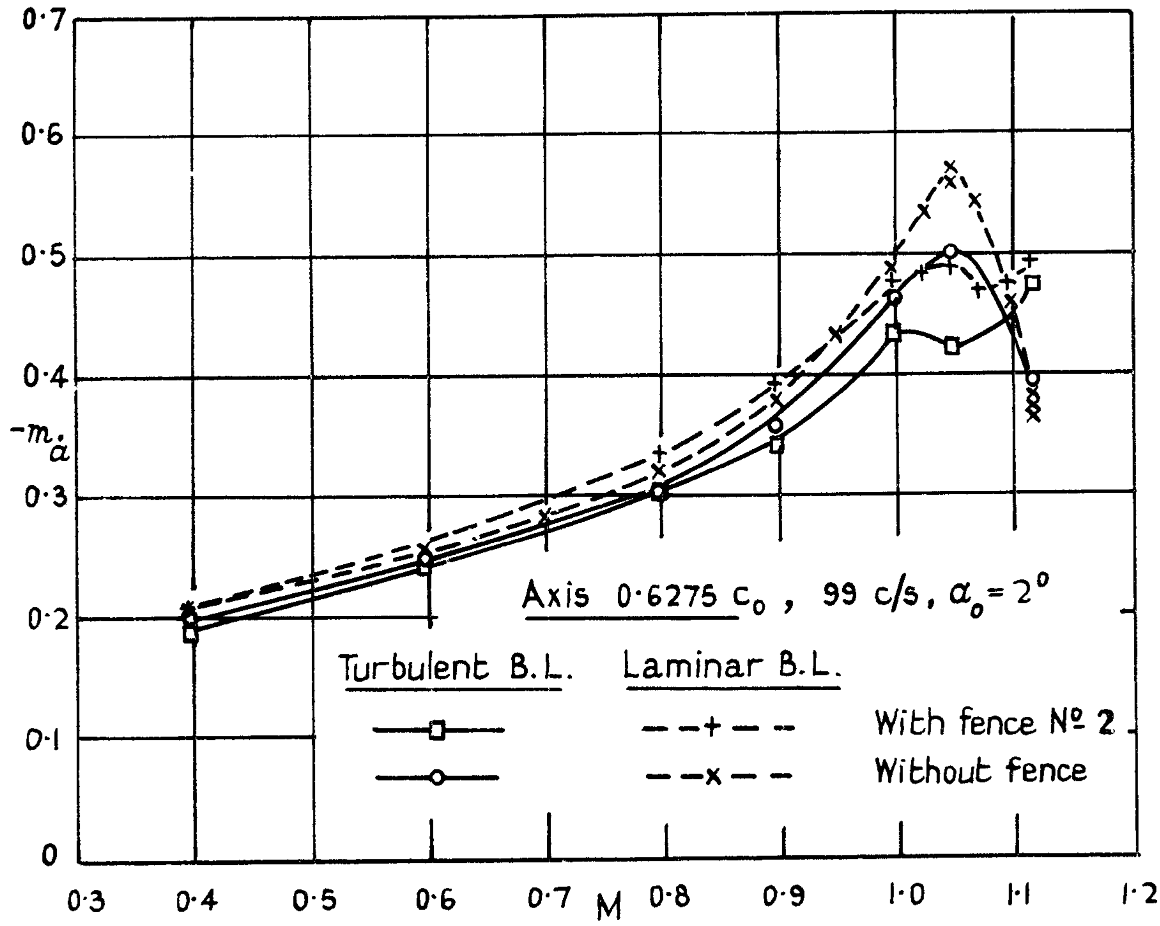
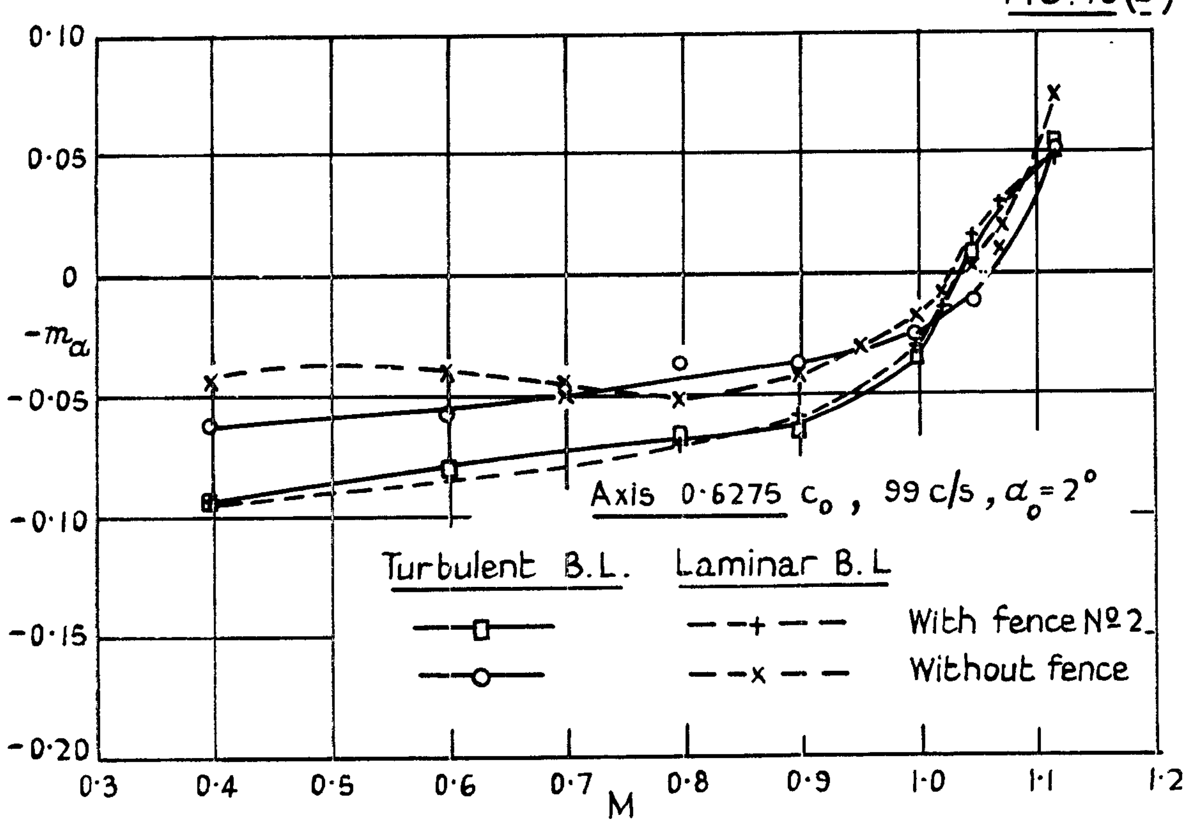


FIG. 16 (b)



Effect of turbulent B.L. on $-m_{\dot{\alpha}}$ and $-m_\alpha$.

FIG. 17(a & b)

FIG. 17(a)

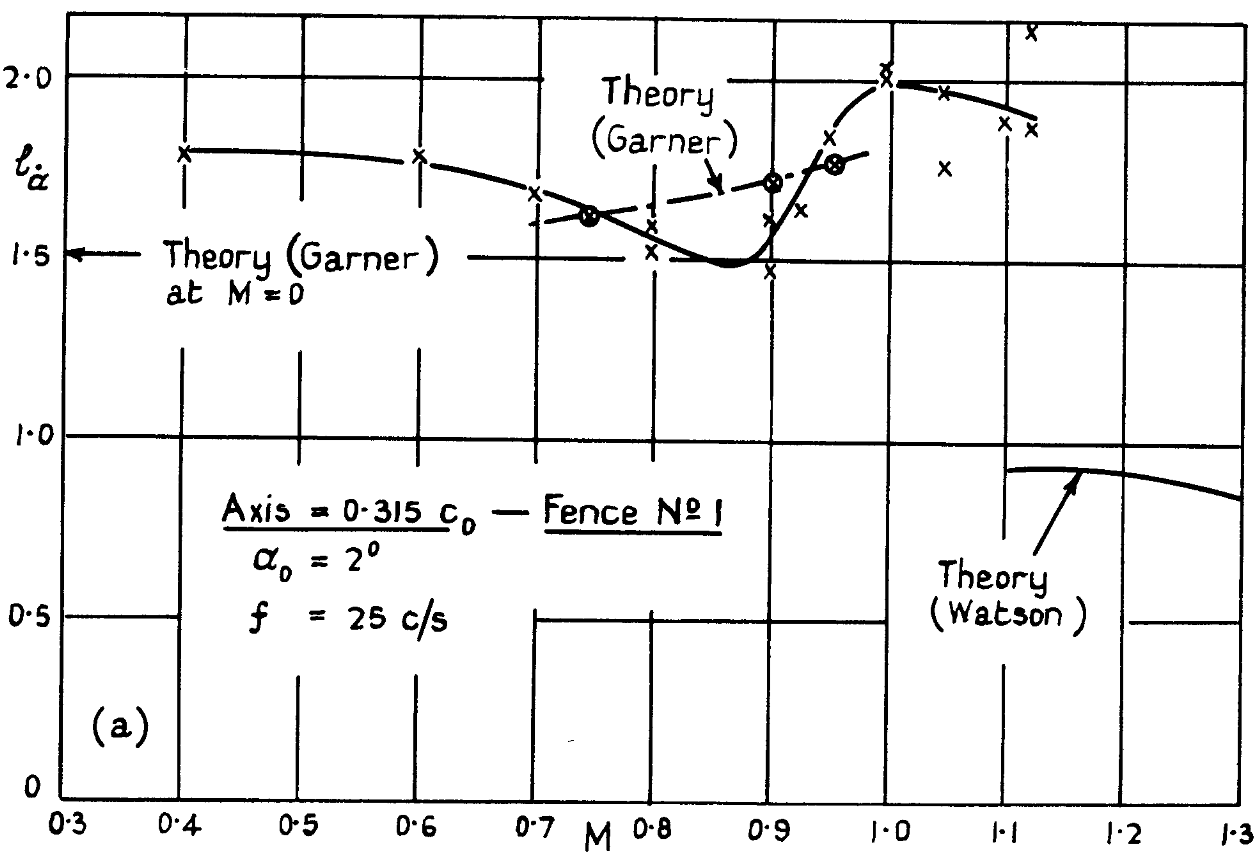
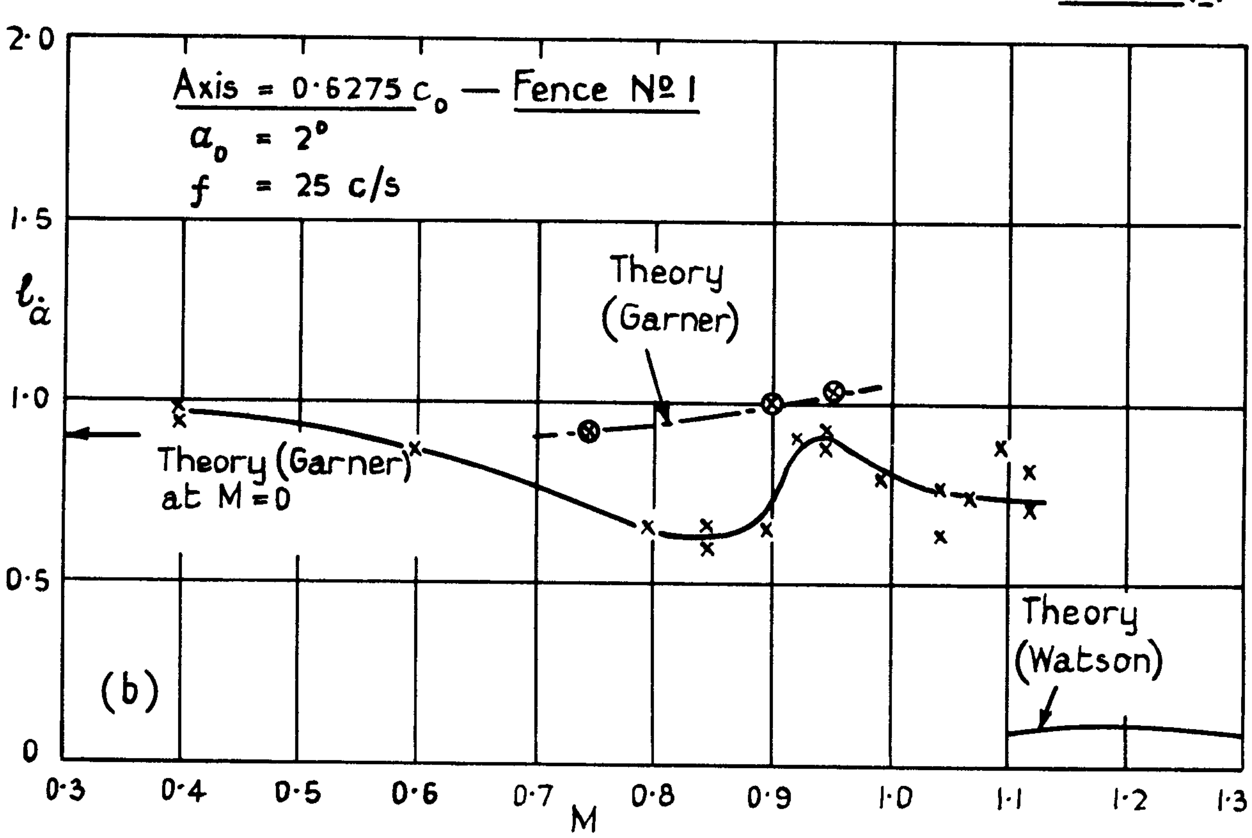


FIG. 17(b)



Comparison of $\ell_{\dot\alpha}$ with theory.

FIG. 18 (a & b)

FIG. 18 (a)

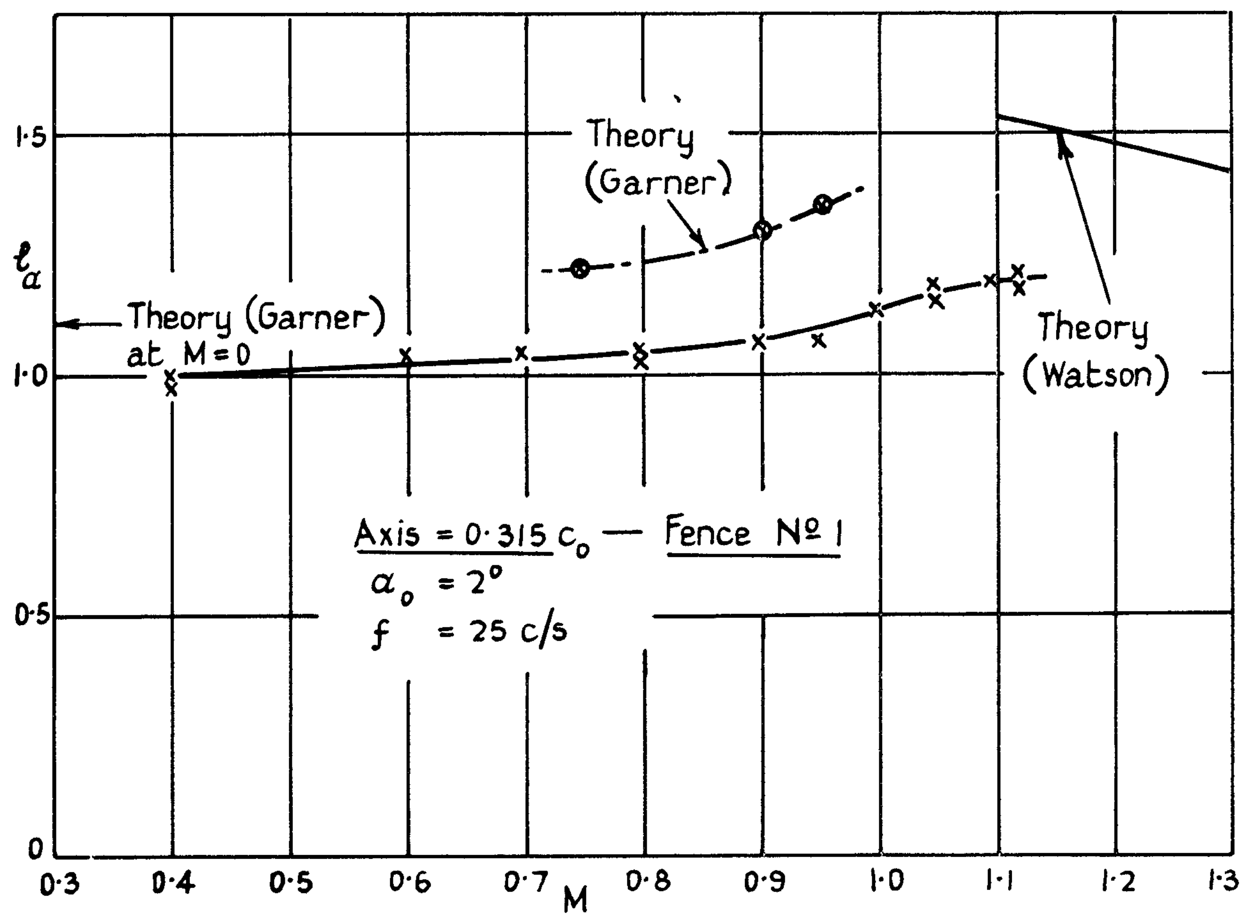
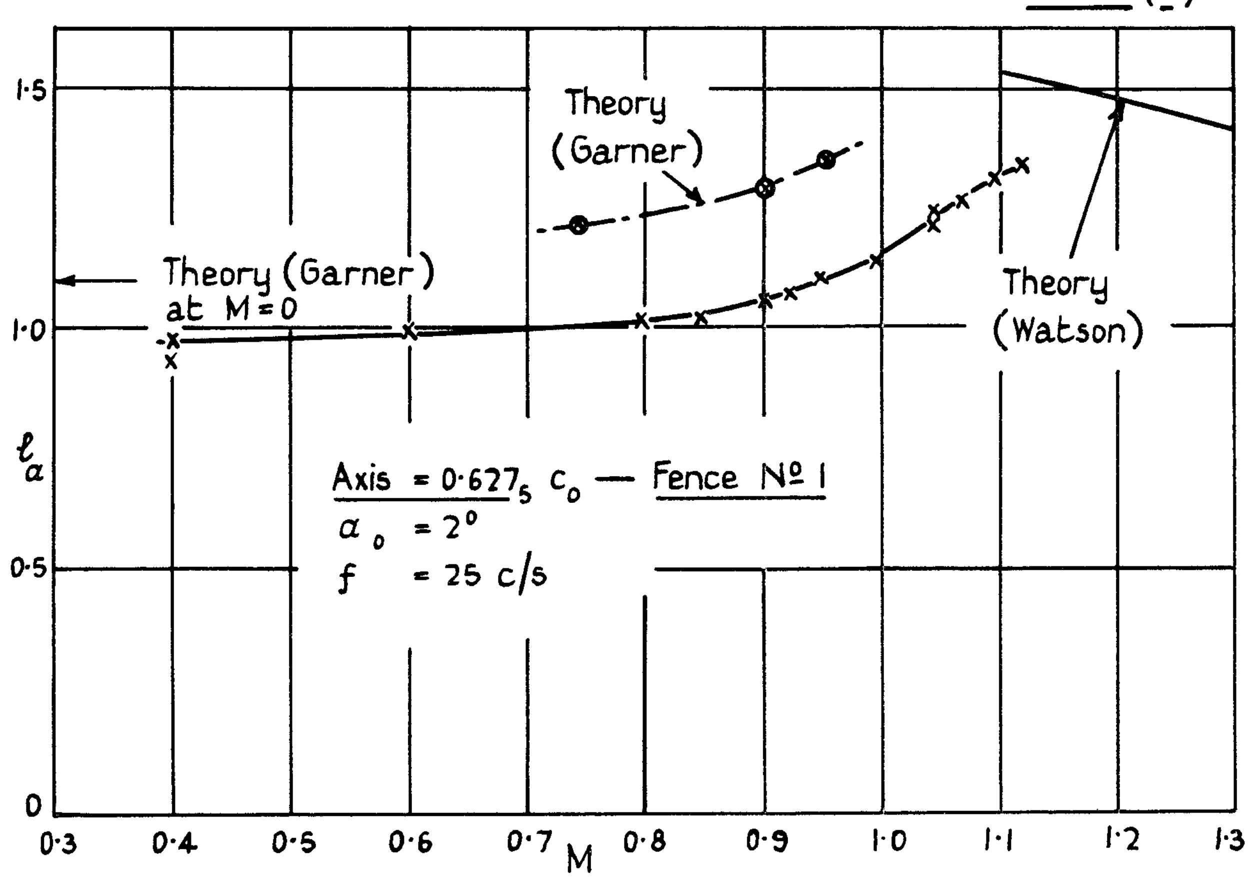


FIG. 18 (b)



Comparison of l_α with theory.

DS87973/1/Wt60 K4 3/61CL

C.P. No. 534

Miles, C. J. W., Bratt, J. B. and Bridgman, K. B. Nat. Phys. Lab.

MEASUREMENTS OF PITCHING OSCILLATION DERIVATIVES AT SUBSONIC AND TRANSONIC SPEEDS FOR A CROPPED DELTA WING OF ASPECT RATIO 1.8. (INTERIM REPORT)

Measurements of the direct and indirect derivatives for pitching oscillations on a cropped delta wing of aspect ratio 1.8 have been made at subsonic and transonic speeds.

The effects of frequency parameter, amplitude of oscillation and mean incidence have been investigated. Tests were also made to determine the effects on the measurements of a root fence.

Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

C.P. No. 534

Miles, C. J. W., Bratt, J. B. and Bridgman, K. B. Nat. Phys. Lab.

MEASUREMENTS OF PITCHING OSCILLATION DERIVATIVES AT SUBSONIC AND TRANSONIC SPEEDS FOR A CROPPED DELTA WING OF ASPECT RATIO 1.8. (INTERIM REPORT)

Measurements of the direct and indirect derivatives for pitching oscillations on a cropped delta wing of aspect ratio 1.8 have been made at subsonic and transonic speeds.

The effects of frequency parameter, amplitude of oscillation and mean incidence have been investigated. Tests were also made to determine the effects on the measurements of a root fence.

Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

C.P. No. 534

Miles, C. J. W., Bratt, J. B. and Bridgman, K. B. Nat. Phys. Lab.

MEASUREMENTS OF PITCHING OSCILLATION DERIVATIVES AT SUBSONIC AND TRANSONIC SPEEDS FOR A CROPPED DELTA WING OF ASPECT RATIO 1.8. (INTERIM REPORT)

Measurements of the direct and indirect derivatives for pitching oscillations on a cropped delta wing of aspect ratio 1.8 have been made at subsonic and transonic speeds.

The effects of frequency parameter, amplitude of oscillation and mean incidence have been investigated. Tests were also made to determine the effects on the measurements of a root fence.

Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

C.P. No. 534

Miles, C. J. W., Bratt, J. B. and Bridgman, K. B. Nat. Phys. Lab.

MEASUREMENTS OF PITCHING OSCILLATION DERIVATIVES AT SUBSONIC AND TRANSONIC SPEEDS FOR A CROPPED DELTA WING OF ASPECT RATIO 1.8. (INTERIM REPORT)

Measurements of the direct and indirect derivatives for pitching oscillations on a cropped delta wing of aspect ratio 1.8 have been made at subsonic and transonic speeds.

The effects of frequency parameter, amplitude of oscillation and mean incidence have been investigated. Tests were also made to determine the effects on the measurements of a root fence.

Comparisons with subsonic theory are reasonably satisfactory but agreement with supersonic theory is poor.

Printed and published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
York House, Kingsway, London w.c.2
423 Oxford Street, London w.1
13A Castle Street, Edinburgh 2
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
50 Fairfax Street, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast 1
or through any bookseller

Printed in England

S.O. Code No. 23-9012-34

C.P. No. 534