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Wing Flow Measurements of the Damping in Pitch Derivative of a 45° Delta Wing-Body Combination and with a Tailplane in two positions

by

R. Rose, M.Sc.

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Wing flow measurements of the damping in pitch derivative of a 45° delta wing-body combination and with a tailplane in two positions

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SUMMARY

Measurements of the damping in pitch derivative of a 45° delta wing-body combination and with a tailplane in two positions were made at transonic speeds using the wing flow technique. In the tailless configuration, the typical fall of $-(m_q + m_{\dot{w}})$ occurs at approximately M = 0.92 and agrees well with the available flight and tunnel tests. In the tests with the tail on, the damping contribution of the tailplane has been found and compared with theoretical estimates based on exposed tail area. The agreement is reasonable at supersonic speeds but poor at subsonic and sonic speeds.

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1 Introduction

As part of a programme of systematic tests to investigate the variation of the damping in pitch derivative $(m_q + m_{\dot{w}})$ at transonic speeds, measurements using the wing flow technique were made during April, 1955, on a half model of a 45° delta wing-body-tailplane combination.

The model was tested with the tailplane at two alternative distances behind the wing, and without the tailplane to enable the damping contribution of the tailplane to be found. These test results were compared with some of the theoretical results of Ref.1.

2 Description of the model and tests

Figure 1 shows a G.A. of the model and Table I gives principal geometric data. As with other wing flow models the wing and tailplane were made of steel and the body of wood. The model was balanced so that its centre of gravity coincided with the axis of oscillation.

A single degree of freedom oscillation technique was used.

Tests were made between Mach numbers of 0.70 and 1.10 and the Reynolds number, based on mean chord attained during these tests, was 0.5×10^6 at a Mach number of 1.0. The scope of the tests is given in the following Table.

Model Configuration	Reduced frequency parameter range
A Wing alone	0.1027 - 0.0645 0.1239 - 0.0769
B Wing + tailplane (short arm)	0.0945 - 0.0600
C Wing + tailplane (long arm)	0.0893 - 0.0567 0.1091 - 0.0683

The notation A, B and C will be used in the note to describe the different model configurations. The small differences in reduced frequency parameter ranges for the various configurations were caused by the small differnces in model pitching moment of inertia. All tests were made at a mean incidence of zero degrees. An attempt was made to fix both wing surfaces by small spoilers at 5% chord but transition was free on the tailplane.

3 Results and discussions

Figures 2(a) and (b) show the variation of $m_q + m_{\dot{w}}$ with Mach number for the wing-body combination at ranges of reduced frequency parameter $\omega = 0.1027 - 0.0645$ and $\omega = 0.1229 - 0.0769$. In both reduced frequency parameter ranges $-(m_q + m_{\dot{w}})$ increases up to $M = 0.9$ and then falls rapidly to a small negative value at $M = 0.94$ before increasing again. These results are typical of those to be expected from a 45 degree delta wing.

Figure 3 shows the variation of $-(m_q + m_{\dot{w}})$ with Mach number for configuration B at a reduced frequency parameter range of $\omega = 0.0945$ to 0.0600.

The scatter at subsonic speeds is large and makes it difficult to define the curve accurately in this region. Figures 4(a) and 4(b) show results for configuration C at two reduced frequency parameter ranges of $\omega = 0.0893$ to 0.0567 and $\omega = 0.1091$ to 0.0683.

The results obtained from all these configurations at the lower ranges of reduced frequency parameters are shown in Figure 5 and those for the wing-body combination alone have been compared with other experimental and theoretical results. The comparisons available were (a) flight tests up to $M = 0.92$ on a 45° delta wing tailless aircraft, Ref.2, (aspect ratio 3.8, thickness chord ratio 0.10), (b) some subsonic wind tunnel tests on a 45° delta wing-body combination, Ref.3, (aspect ratio 4.0, thickness chord ratio 0.06), and (c) some theoretical results for a wing alone calculated by the methods of Ref.1. The subsonic and supersonic theories do not hold for Mach numbers close to unity and except for a sonic theory point no values are shown for Mach numbers between 0.9 and 1.1. The agreement of all experimental results is good and clearly shows an increase in damping up to $M = 0.9$ followed by a very sudden loss to zero damping at a slightly higher Mach number. The agreement with subsonic theory is good, but agreement with the sonic and supersonic theories is poor.

The probable reason for the poor agreement with the sonic theory is the low value of the reduced frequency parameter ω, the theory does not hold for very low ω because the logarithmic term in the approximate solution tends to make $(m_q + m_{\dot{w}})$ too positive. The disagreement with supersonic theory is surprising as agreement between tunnel tests, free flight, full scale and theory is usually good at supersonic speeds.

From the comparison of the results without tail and with the tail in two positions, the increase in the general level of damping at subsonic speeds is as expected. From the difference in damping between configurations A and B and A and C, the contribution of the tailplane to $(m_q + m_{\dot{w}})$ for the two tail positions has been estimated (Figure 6). For both tail positions, except for rather sudden variations at transonic speeds, the general level of the damping remains similar at all Mach numbers. The sudden variations at transonic speeds probably have no significance as (a) it is known that the "wing flow" technique can produce this type of variation due to the difference in local Mach number at the wing and tail, and (b) the overall values are changing rapidly due to the changes of the damping due to the wing. Some calculations were made using the simple low speed downwash delay theory (Ref.1) which gives the tailplane contribution as

$$\Delta m_{\dot{\vartheta}} = -\frac{1}{2}\left(\frac{S_T}{S}\right)\left(\frac{\ell}{\bar{\bar{c}}}\right)^2\left(\frac{d\,C_L}{d\,\alpha}\right)_T\left(1 + \frac{d\,\varepsilon}{d\,\alpha}\right)$$

Values of lift curve slope and downwash were taken from the low speed tunnel tests on a triangular wing of aspect ratio 4 (Ref.4). S_T was taken as the exposed tailplane area. The results of these calculations are shown in Figure 6 and give values much lower than the wing flow tests. The tailplane contribution at the sonic speed was calculated by the method of para.4.2, Ref.1 using theoretical derivatives for the tailplane. For the two tailplane positions tested the calculated values are $\Delta m_{\dot{\vartheta}} = -1.80$ and -2.18 for the short tail arm and long tail arms respectively. These values are larger than the wing flow results.

The reason for the disagreement is again probably due to the theory not holding for low reduced frequency parameter ω, the logarithmic term in the approximate solution in this case makes $\Delta m_{\dot{\vartheta}}$ more negative.

Probably the fairest comparison between the wing flow results and sonic theory is to take the wing-tail combination when the large effects of low ω tend to cancel out. The result of this calculation is shown in Figure 5 and is in much better agreement with the experimental results.

Para.4.3 of Ref.1 shows that the contribution of the tailplane to the damping at supersonic speeds, for other than extreme positions of the tailplane, is given by the simple downwash delay theory.

Some calculations, using the simple downwash delay theory, were made for both configurations at M = 1.2 and gave values in reasonable agreement with those obtained experimentally.

4 Conclusions

The wing flow technique has been used to measure the damping in pitch derivatives of a 45° delta wing body combination of thickness chord ratio 0.06. In addition the damping contribution of a tailplane of similar planform to the wing has been measured at two tail arms.

The results have shown that:-

(a) For the wing-body combination alone $-(m_q + m_{\dot{w}})$ increases up to M = 0.9 and then falls sharply to a small negative value at M = 0.94 before recovering by a Mach number of 1.0. Good agreement is shown with flight, wind tunnel tests and theory at subsonic speeds on wing-body combinations of similar planform, but agreement with theory is poor at M = 1 and above.

(b) The addition of the tailplane increases the damping for the two tail positions by about $\Delta m_{\dot{\vartheta}}$ = -0.845 and -1.042 at a Mach number of 0.7 and these values stay roughly constant throughout the Mach number range tested. A loss of damping still occurs at a Mach number of 0.94 which is approximately equal to the loss in wing-body case. The agreement with the theoretical estimated increase in damping due to tail, based on exposed tail area, is reasonable at supersonic speeds and poor at subsonic and sonic speeds.

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No.	Author	Title, etc.
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TABLE I

Geometric Data

Wing

Leading edge sweep	45°
Aspect ratio	4.0
Taper ratio	0
Section	R.A.E. 101
Thickness/chord ratio	0.06
Root chord	3.50 inches
Standard mean chord, $\bar{c}$	1.75 inches
Distance of axis of oscillation behind apex	1.75 inches
Aerodynamic mean chord, $\bar{\bar{c}}$	2.333 inches

Tailplane

Leading edge sweep	45°
Aspect ratio	4.0
Taper ratio	0
Section	R.A.E. 101
Thickness/chord ratio	0.06
Root chord	1.50 inches
Distance between axis of oscillation and mid-point of the tailplane root chord, $\bar{\bar{c}}$ 3.063 or	3.50 inches
Tailplane height above wing chord line	0 inches

NOTATION

$\omega = \frac{2\pi f\bar{\bar{c}}}{V}$, the reduced frequency parameter.

f = frequency of the oscillation.

V = true speed ft/sec.

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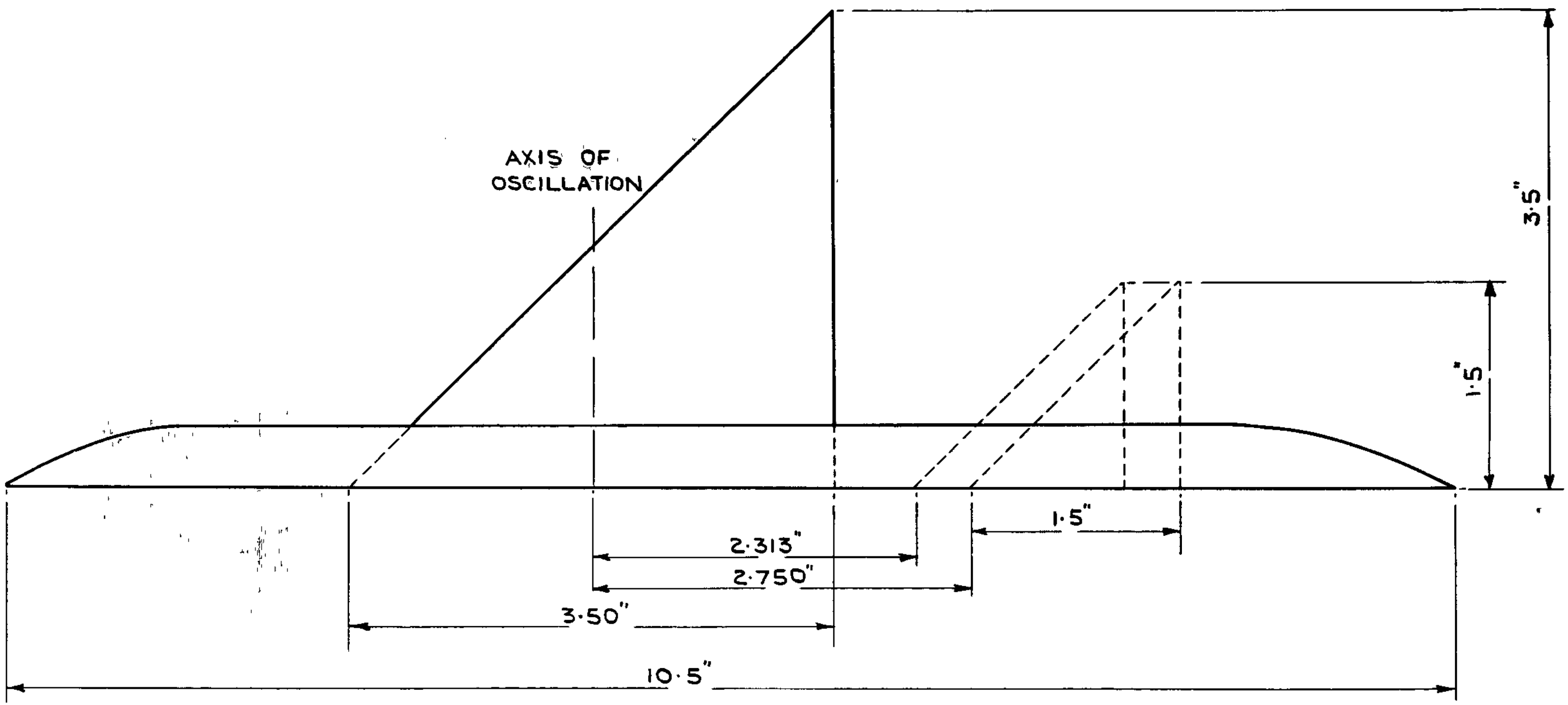
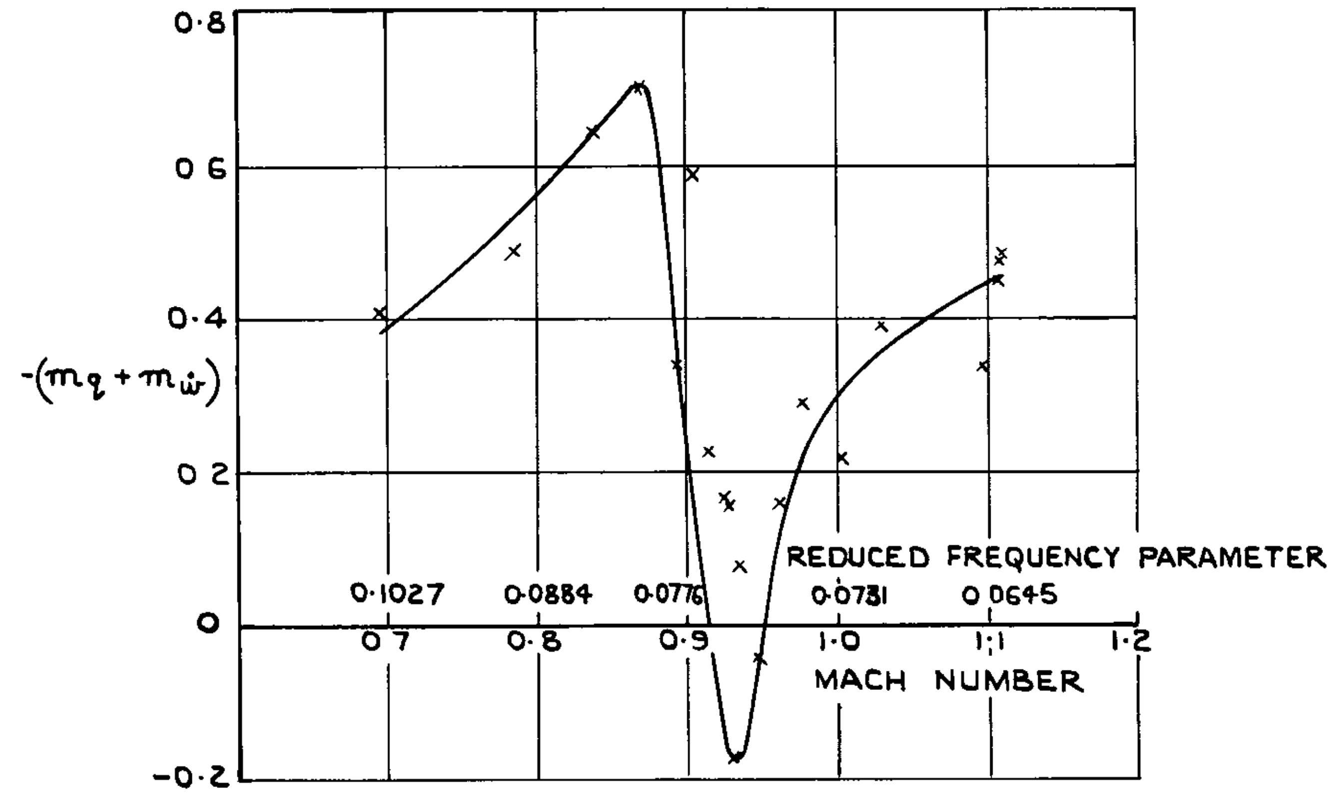
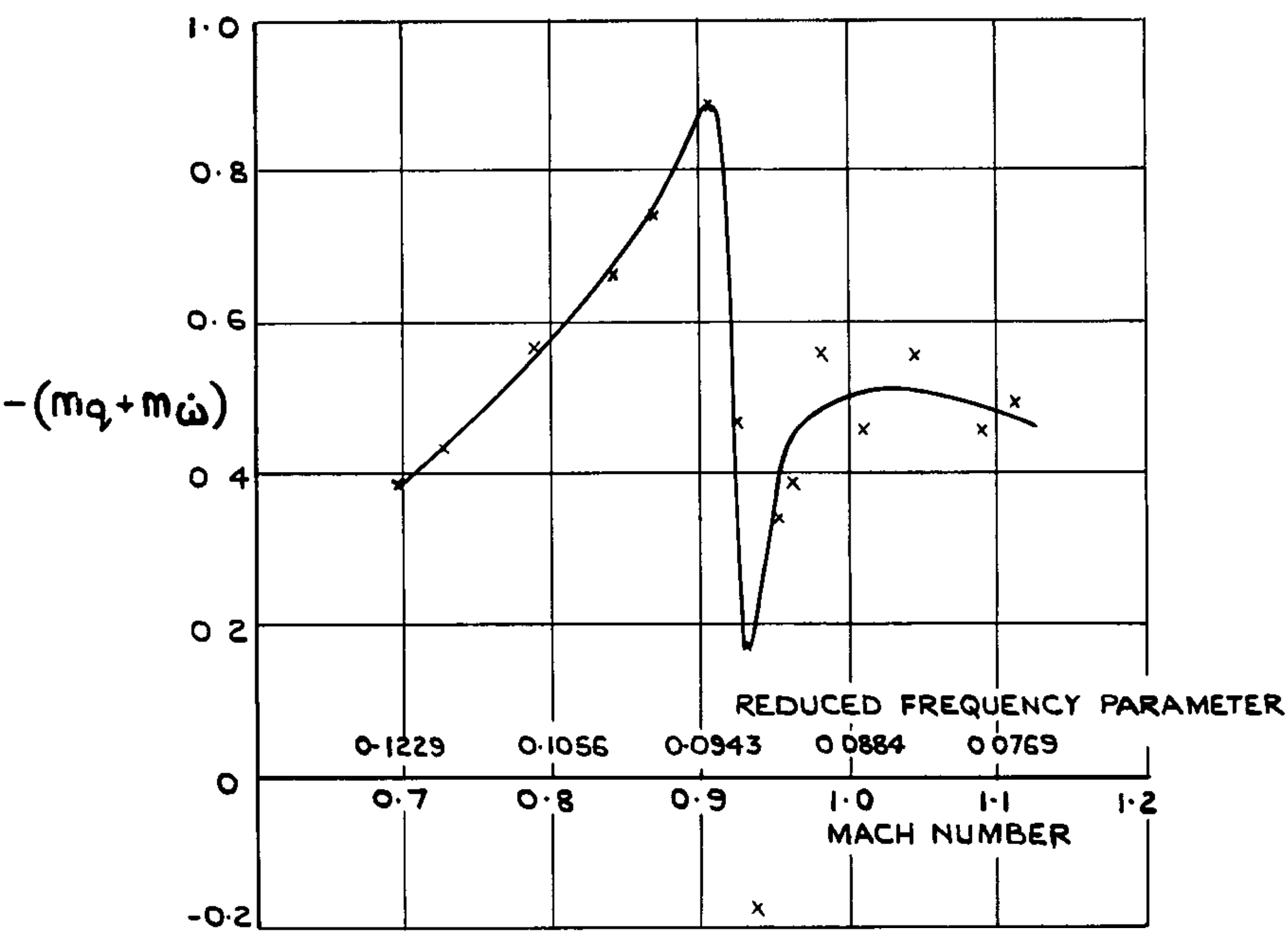


FIG. 1 . G.A. OF THE MODEL.



(a) VARIATION OF $-(m_q + m_{\dot{w}})$ WITH MACH NUMBER. CONFIGURATION A-WING BODY COMBINATION.



(b). VARIATION OF $-(m_q + m_{\dot{w}})$ WITH MACH NUMBER.

CONFIGURATION A - WING BODY COMBINATION.

FIG. 2 (a & b).

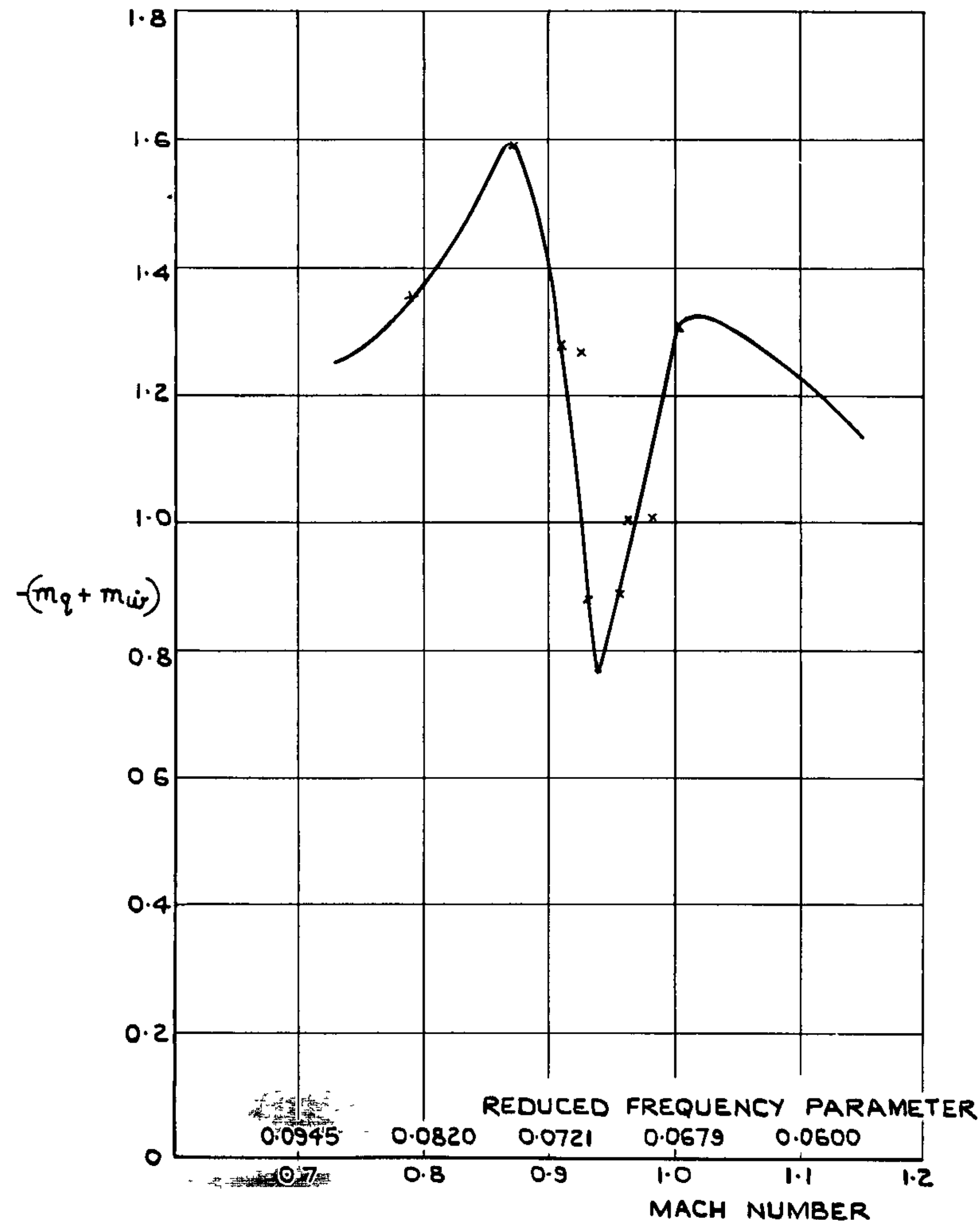
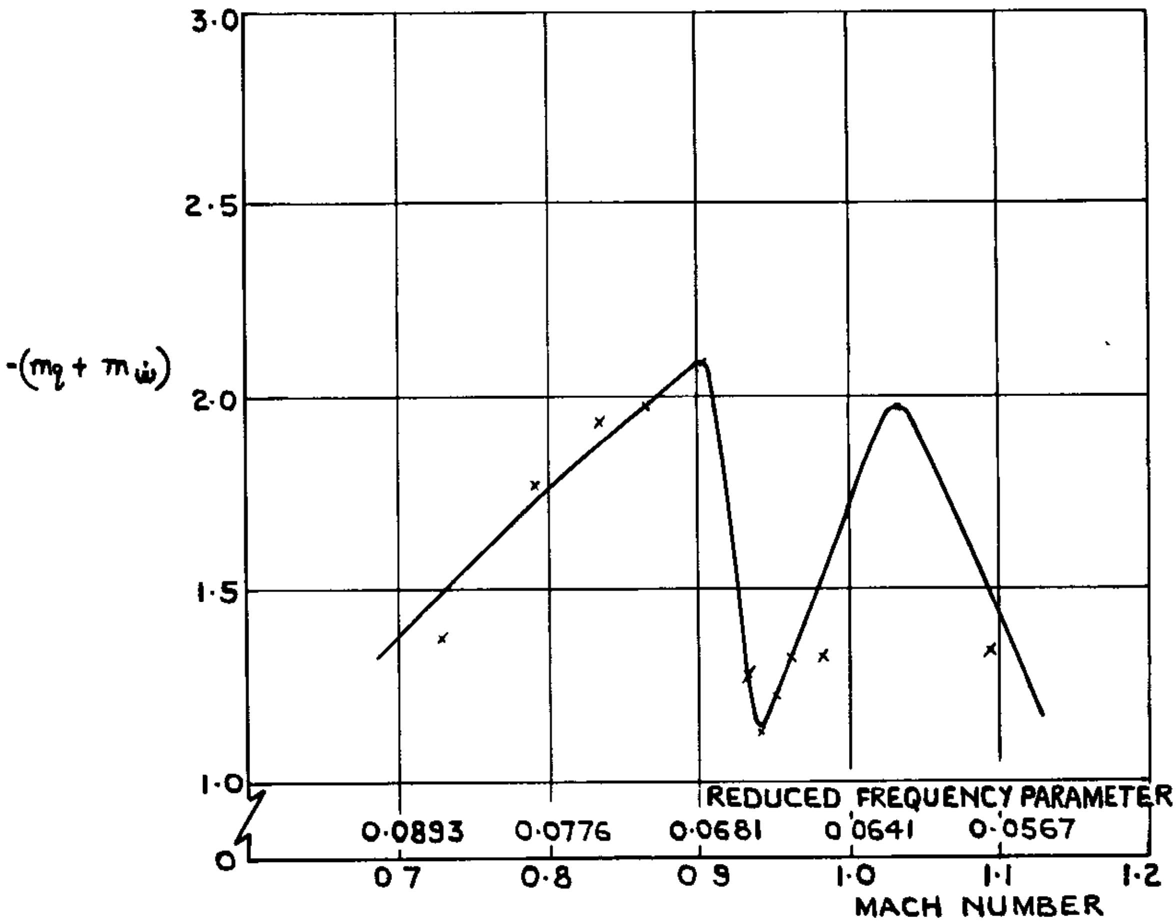
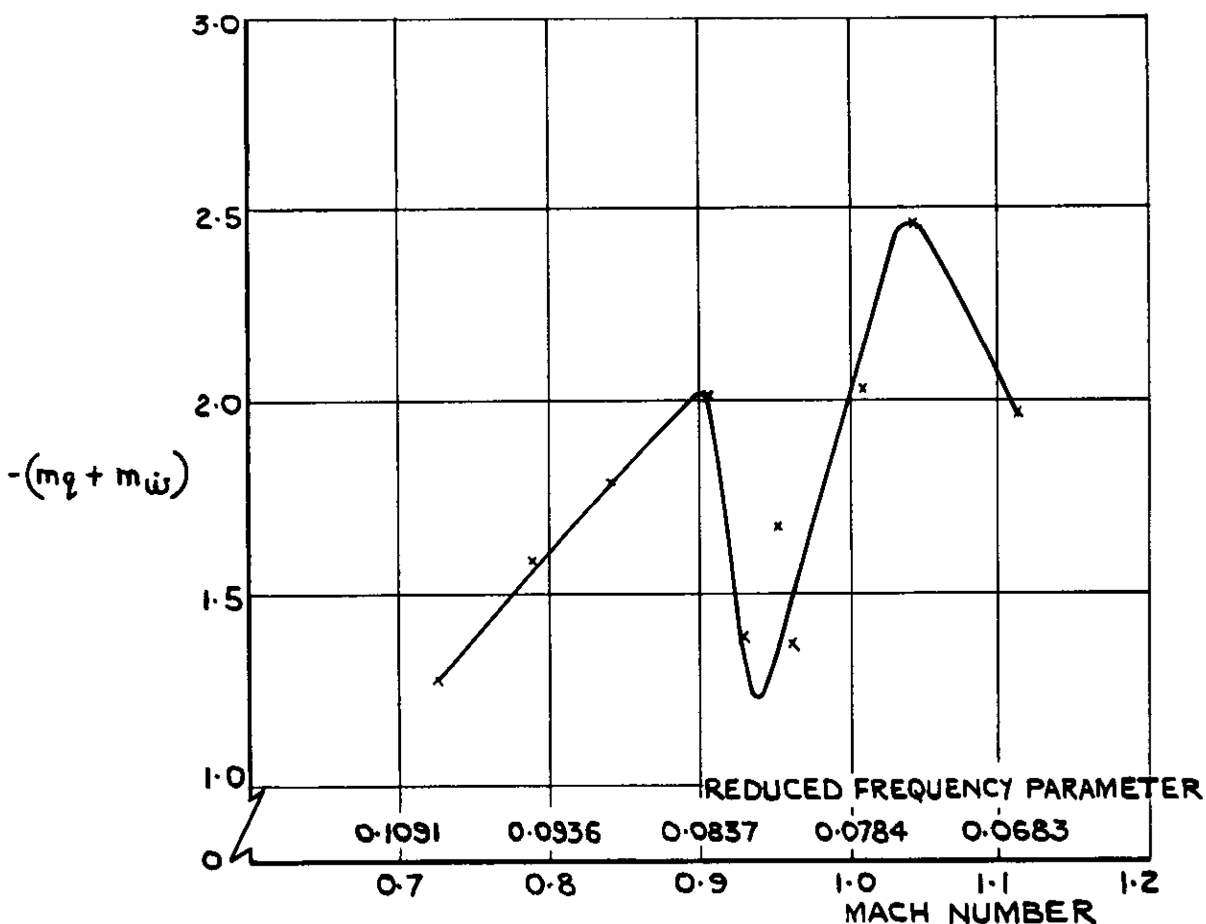


FIG. 3. VARIATION OF $-(m_q + m_{\dot{w}})$ WITH MACH NUMBER.
CONFIGURATION B – WING BODY + TAIL (SHORT ARM)



(a) VARIATION OF $-(m_q+m_{\dot{w}})$ WITH MACH NUMBER.
CONFIGURATION C WING BODY + TAIL (LONG ARM.)



(b) VARIATION OF $-(m_q+m_{\dot{w}})$ WITH MACH NUMBER.
CONFIGURATION C WING BODY + TAIL (LONG ARM.)

FIG. 4. (a & b)

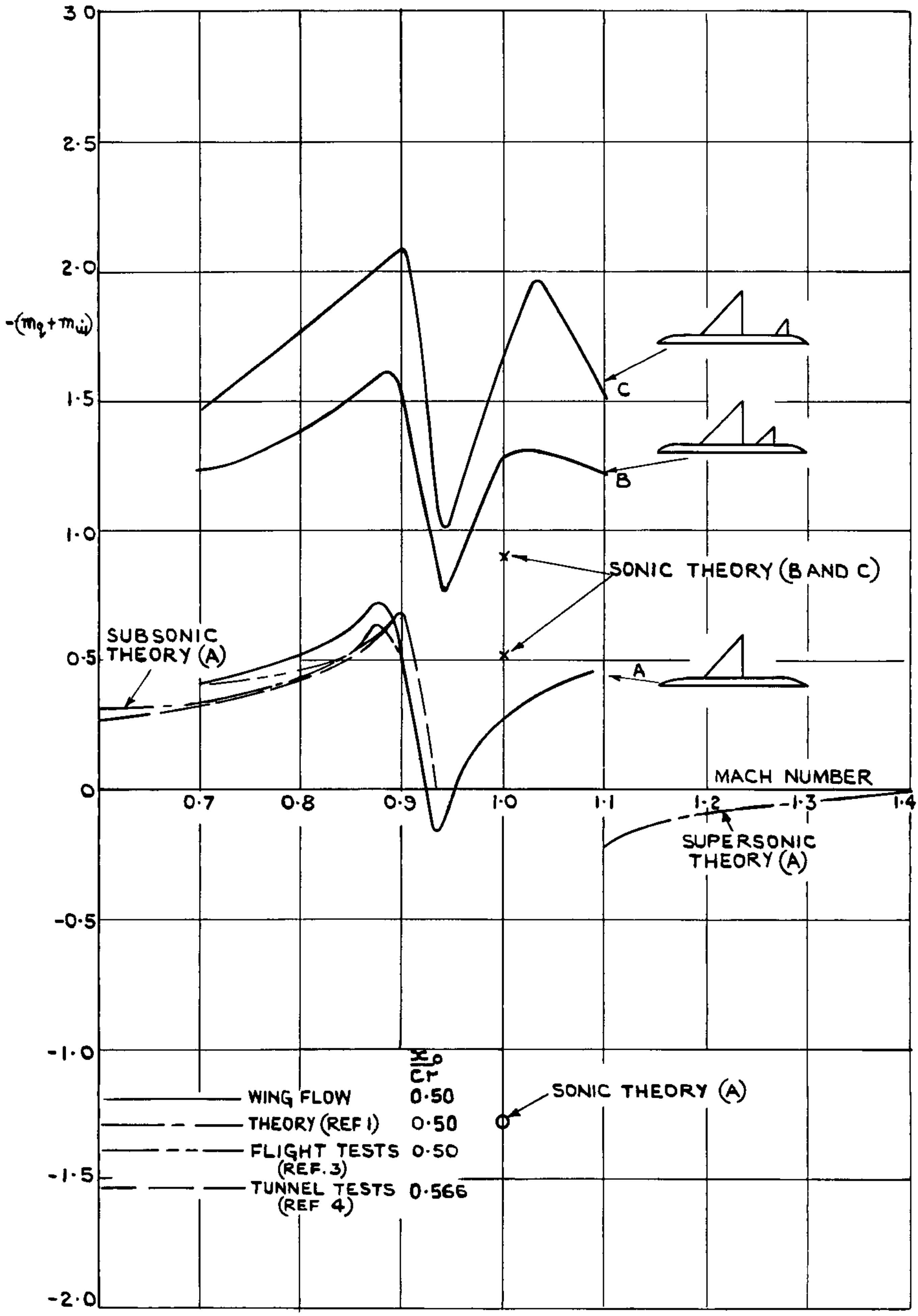


FIG. 5. COMPARISON OF $-(m_q + m_{\dot{w}})$ FOR THE THREE CONFIGURATIONS, A, B AND C.

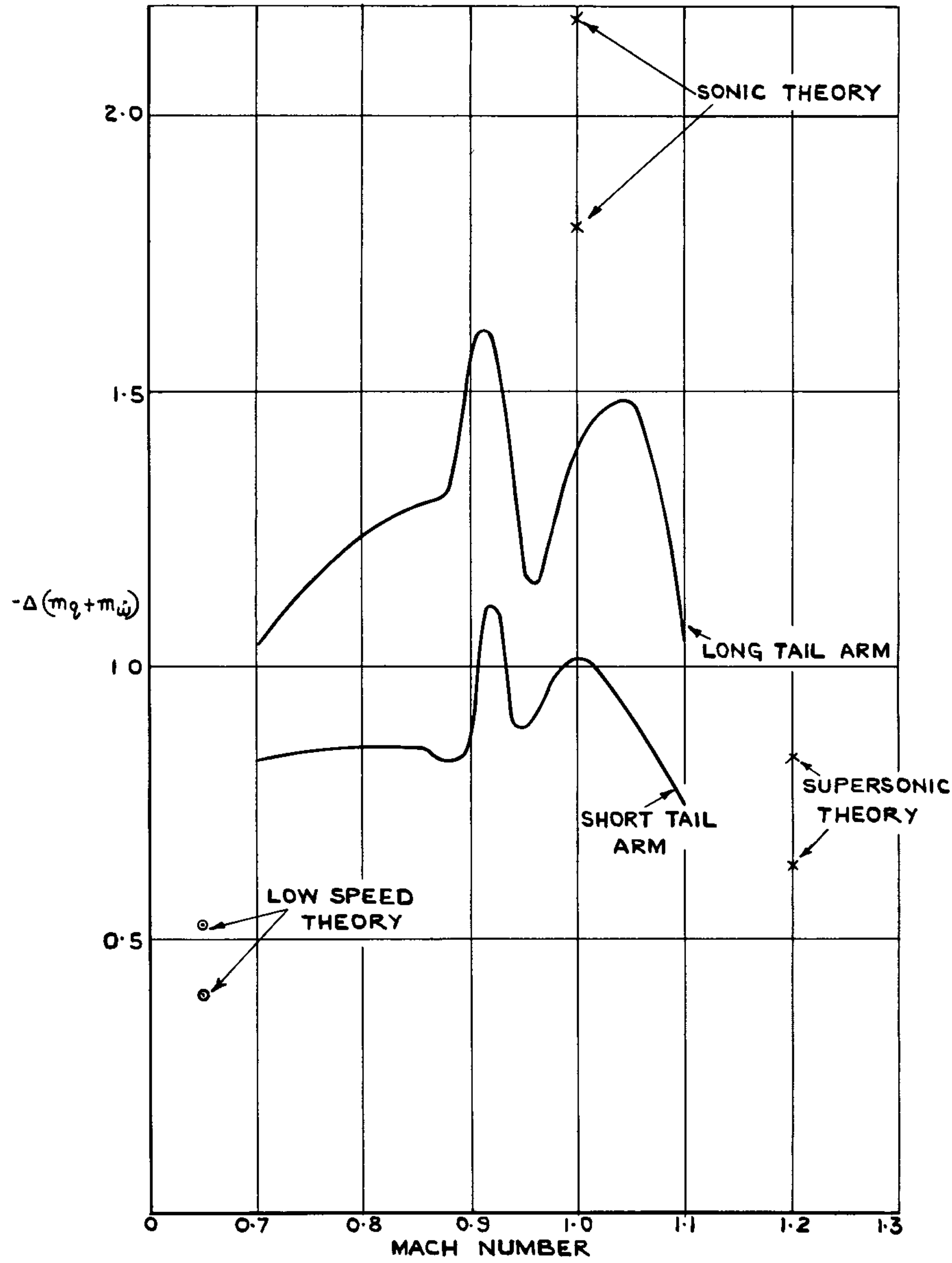


FIG.6. VARIATION OF THE TAILPLANE CONTRIBUTION TO $-(m_q + m_{\dot{w}})$ WITH MACH NUMBER.

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