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Tests to High Subsonic Speeds in the 10ft × 7ft Tunnel, of Several Wing-mounted Air-brakes on a Half-model of a Four-jet Bomber (Vickers Valiant)

By

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SUMMARY

Increments of lift, drag and pitching moment were measured for five air-brake configurations on a 1/20 scale half-model at a Reynolds number of 1.3×10^6 (on wing $\bar{c}$) over the Mach number range 0.4 to 0.9. These were required to help in selecting a suitable arrangement when buffetting was encountered in flight with the existing brakes.

At low Mach number, lower-surface brakes gave nose-down trim changes and positive lift increments, upper-surface brakes gave the opposite, while brakes on both surfaces gave increments in between, tending to be nearer those for upper-surface brakes.

At Mach numbers above 0.8, the lower-surface brake increments became unacceptably large (up to $\Delta C_m = -0.08$ and $\Delta C_L = 0.2$), while the upper-surface brake suffered a severe loss of effectiveness due to a shock-induced separation occurring on the wing ahead of the brake. This was reflected in the results for brakes on both surfaces which then tended to lie nearer to those for lower-surface brakes.

The drag increments were only roughly proportional to frontal area; for arrangements having brakes on the upper-surface, severe reductions of drag increment occurred at $M > 0.8$.

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4.2.1/

Replaces A.R.C.17,703.

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1. Introduction

During flight tests of the prototype Valiant (Vickers B9/48 four-jet bomber) buffetting of the tailplane was encountered when the air-brakes were opened. These brakes were mounted on both surfaces of the wing at about 60% local chord and extended from about 28% to 45% semi-span (Fig.2). Tests on several different arrangements of these brakes were done during comprehensive tests of a 1/20 scale model at the Ames Aeronautical Laboratory of the N.A.C.A.[1].

The buffetting was eliminated during flight tests by removal of the upper-surface brakes. This, however, as well as reducing the drag coefficient by a large amount, led to increased downloads on the tailplane at high subsonic speeds, through the large nose-down changes of trim associated with the use of lower-surface brakes only.

It was therefore required to test alternative air-brake arrangements to try to reduce the trim and lift changes accompanying their use, whilst obtaining sufficient drag. No reliable guide was available in the model tests for indicating whether the brakes would cause buffetting, but it was intended to mount the brakes about 8% semi-span further out on the wing than the original brakes to reduce the possibility of their wakes hitting the tailplane.

These tests were done in the 10 ft × 7 ft High Speed Wind Tunnel on a 1/20 scale half-model of the port wing and fuselage.

2. Experimental Details

2.1 Details of model (Figs. 1 and 2)

Leading dimensions of the model and air-brakes are given in Table 1. The "half-model" test technique was used, the model consisting of a port wing and half-body. When this model was designed (in 1948) it was thought that better results might be obtained from the half-model technique if the aircraft plane of symmetry were represented by the edge of the boundary layer on the tunnel floor rather than by the tunnel floor itself. The model was therefore designed for the plane of symmetry to be 3 in. above the tunnel floor. A parallel sided fairing, fixed to the turntable, having as section that of the body in the plane of symmetry, was provided to enclose (without touching) the stub by which the model was attached to the balance.

With/

With the exception of the wing trailing edge which was of "Tufnol", the model was made of teak throughout and finished with "Pheenoglaze". The fin, tailplane, cockpit canopy and jet pipes were not represented and the wing root leading edge intakes were smoothly faired over.

The air-brakes were of T-section, consisting of steel plates, brazed together at the desired angle and strengthened by means of triangular gussets brazed in on the down-wind side. The cross piece of the "T" was recessed into the wing surface and attached with six wood screws. Wooden filling pieces maintained the contour of the wing when the brakes were not being used.

2.2 Details of tests

The Reynolds number based on standard mean chord of the gross wing was 1.3×10^6 and transition was not fixed. The following configurations were tested over a Mach number range from 0.4 to 0.9:-

(a) Clean model
(b) Prototype brake on lower surface only (Air-brake 'B')
(c) Production brake on lower surface only (Air-brake 'C')
(d) Pathfinder brakes on both surfaces (Air-brake 'D')
(e) Pathfinder brake on upper surface only (Air-brake 'E')
(f) Combination of prototype brake on the lower surface and production brake on the upper surface (Air-brake 'F')

Normal force, drag and pitching moment were measured, with the pitching moment axis located at $0.25\bar{c}$.

3. Correction and Analysis of Results

The results were resolved into wind axes through the mean quarter-chord point and corrections due to $-0.1°$ sidewash and tunnel constraint of downwash were applied to the drag coefficients and angles of incidence. The corrected incidences are quoted relative to the aerofoil datum at the wing root.

Blockage corrections were applied using the method of Evans[2] and the fully corrected results were plotted against corrected Mach number at constant indicated incidence. Values of the coefficients could then be read off at the desired constant Mach numbers over the incidence range covered.

4. Discussion of Results

Paragraphs 4.1, 4.2 and 4.3 outline the main trends as shown by the Figures; para. 4.4 briefly discusses the results for the model without air-brakes and para. 4.5 discusses the flow phenomena involved when the brakes are installed.

No detailed comparison has been made with the results of Ref.1 because of the considerable differences in the conditions of test, e.g., engine air flow was represented, most tests were done with the tailplane in position and the angular settings of the air-brakes were varied without any particular setting being comparable with the present arrangements. However, qualitatively the results agree with the present results and support the observations made below on the effects of the various configurations.

4.1 Effects on lift coefficient

Fig.3 (a) and (b) shows the increments in lift coefficients due to the brakes plotted against Mach number, for constant incidences.

4.1.1 Air-brakes 'B' and 'C' (lower surface only)

The increments are not sensitive to incidence and rise steadily with Mach number so that the value at $M = 0.9$ is about twice that at $M = 0.4$. The 30% greater area of brake 'C' results in increments only about 0.01 - or about 10% - greater than those due to brake 'B' over practically the entire range of the tests. As one would expect from their similarity, there is very little difference in the variations with Mach number of the increments from the two brakes.

4.1.2 Air-brakes 'D' and 'F' (both surfaces)

When the upper-surface brake is added, it spoils the flow and hence reduces circulation. Thus the lift increments for these two flap arrangements are less than those for flaps 'B' and 'C'. At low Mach number the increments become increasingly negative as the incidence is increased but are not sensitive to Mach number at any given incidence. At high Mach number (> 0.8) the increments become positive, the change of sign occurring at a lower Mach number as the incidence is increased. At Mach numbers exceeding 0.85 and for positive angles of incidence the increments tend towards those for brakes 'B' and 'C', indicating a reduction in the spoiling effect of the upper-surface brake.

4.1.3 Air-brake 'E' (upper surface only)

At low Mach number (< 0.7) the increments are negative and are not sensitive to incidence but increase in magnitude with Mach number. Starting at Mach numbers around 0.8, the decrement decreases with increase of Mach number in a similar way to those of brakes 'D' and 'F'; the peak decrement occurs at decreasing Mach number with increasing incidence.

4.2 Effects on drag coefficient

Fig.4 (a), (b) and (c) shows the increments in drag coefficient due to the brakes plotted against Mach number for constant lift coefficients.

4.2.1 Air-brakes 'B' and 'C' (lower surface only)

For Mach numbers below 0.8 the drag coefficients are insensitive to Mach number and fall only slightly at the higher lift coefficients reached. Brake 'C' gives about 20% more drag than brake 'B' for its 30% greater area. At all positive lift coefficients the drag increments do not vary much with Mach number although the difference between them diminishes somewhat at the highest Mach numbers reached.

4.2.2 Air-brakes 'D' and 'F' (both surfaces)

Despite a difference of some 25% in the projected frontal areas of these two brake configurations they give very nearly the same drag increments under almost all conditions. At low Mach numbers the increments do not change with incidence and increase very slowly with Mach number. At high Mach numbers a considerable reduction of the increment occurs, being slightly more severe in the case of brake 'D' so that between $M = 0.8$ and $M = 0.9$ the increments have been reduced to about half their peak values.

4.2.3 Air-brake 'E' (upper surface only)

The drag increment curves for brake 'E' have the same shape as for brakes 'D' and 'F' but the absolute values are lower than those for brakes 'D' and 'F' due to the absence of the lower surface brake.

4.2.4/

4.2.4 Direct comparison of drag increments

The table below shows the frontal area (A) of each brake arrangement when projected on to a plane perpendicular to the aerofoil datum on the untwisted outboard section of the wing, the perforations being neglected. The area of each is expressed as a fraction of the area of brake 'B'. The total span of each brake is expressed as a fraction of the model semi-span. The drag increments (ΔC_D) are given as multiples of that due to brake 'B' and are given at two Mach numbers -0.4 and 0.75, the latter being approximately the cruising Mach number of the aircraft.

Table 2

Drag increments given by the various air-brake configurations

Zero lift

Brake type	Area ratio A/A_B			Increment ratio $\frac{\Delta C_D}{\Delta C_{D_B}}$		Span ratio
	U/S	L/S	Total	M = 0.4	M = 0.75	
B	0	1.00	1.00	1.00	1.00	0.185
C	0	1.31	1.31	1.22	1.11	0.185
D	0.87_5	0.87_5	1.75	2.18	2.10	0.214
E	0.87_5	0	0.87_5	1.22	1.17	0.214
F	1.18	1.00	2.18	2.18	2.05	0.185

From the above table it is evident that for Mach numbers $\leqslant 0.75$:-

(i) Increasing the area of a lower-surface brake does not lead to a proportionate increase in drag increment.

(ii) For a given double-surface brake area, greater drag increments are to be expected from "finger" type air-brakes than "flap" type brakes. This is likely to be partly due to the fact that the "finger" type (brake 'D') cover a larger part of the span (see also (iii) below), but the different layout, in particular the larger angle, probably also contributes.

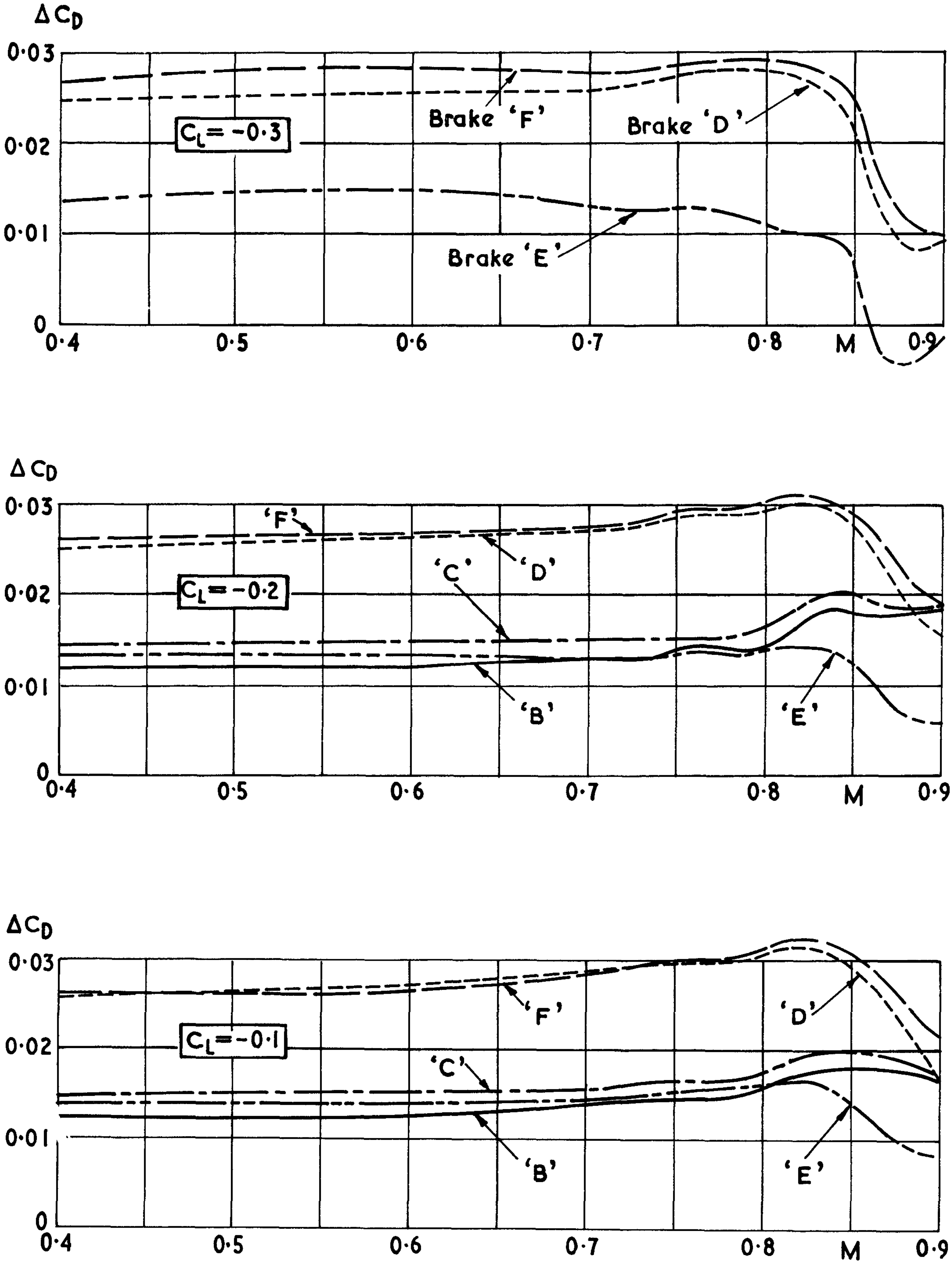
(iii) A single "finger" type brake (on the upper surface) gives a greater drag increment than a "flap" type brake (on the lower surface) even at $C_L = 0$. Again, this is probably due to a combination of the larger proportion of span affected and the different layout. At higher incidences the upper-surface brake gives a still larger increment (Fig.4 (b) and (c)) because the model incidence, and hence its drag, has to be increased to maintain constant lift, whereas the lower-surface brake requires a reduced model incidence and drag to maintain the same lift.

4.3 Effects on pitching moment coefficient

Fig.5 (a) and (b) shows the increments in pitching moment coefficient due to the various brakes plotted against Mach number at constant lift coefficient.

4.3.1/

FIG. 4 (a)



Drag increments, ΔC_D due to air-brakes, at constant lift coefficient.

H.S.W.T. tests on Valiant half-model

with brakes on both surfaces naturally lie somewhere between these two extremes, in respect of lift and pitching moment, with a tendency to be nearer to those for the upper-surface brake. This is probably because the upper-surface component has a greater spoiling effect on the extra circulation which the lower-surface component attempts to set up.

The rise in drag associated with the formation of shock waves starts at about $M = 0.8$ at $C_L = 0$ on the model without brakes (Fig.9) and the appearance of less regular changes of characteristics coincides with this. The increased circulation associated with the lower-surface brake would result in the shock wave occurring further aft on the upper surface; both this and the modification of the lower-surface pressure distribution by the build up of pressure in front of the brake would tend to increase the lift increment and the nose-down trim change. For the upper-surface brake, on the other hand, the pressure rise in front of it would tend to keep the shock further forward on the wing. Any shock-induced separation occurring would then immerse the brake and severely reduce its effects. This may be seen at $M = 0.9$ where all the increments for brake 'E' are very small. Arrangements having brakes on both the surfaces again lie in between the two extremes, but because of the violent loss of effectiveness of the upper-surface brake at $M > 0.8$, the increments now tend to lie closer to those for the lower-surface brake alone.

In the absence of any measurements of buffetting, it can only be said that besides creating a wake which could impinge on the tailplane, unless they were mounted far enough out along the span, upper-surface brakes seem intrinsically to be more likely to cause wing buffetting because they create drag and destroy lift by causing separations to occur on the upper surface where the pressure gradients are already adverse, whereas any tendency to separation due to the lower-surface brake is more likely to be suppressed by a favourable wing pressure distribution.

The result throughout the tests that the pitching moment increments were not sensitive to incidence changes indicates that opening the air-brakes caused only small changes of aerodynamic centre position. However, it is possible that it might change the rate of change of downwash at the tailplane and hence cause shifts of the neutral point; no indication of this could be obtained from the present tests, but the tests of Ref.1 indicated that movements of the neutral point also would be small.

5. Conclusions

If judged from the point of view of obtaining large drag increments (of the order of 0.03) with only small accompanying lift and trim changes, then of the air-brakes tested, those combining upper and lower-surface components are the most satisfactory. The remaining doubt about their usefulness at full scale lies in whether moving them out along the wing will reduce the buffetting on the tailplane. "Finger" type brakes are more effective than "flap" type brakes for a given area; this is likely to be partly due to the extra span they affect. Both types of brakes suffer a substantial loss of effectiveness at high Mach numbers when the upper-surface component is affected by the shock-induced separation on the wing ahead of it. This phenomenon has an even more serious effect on an arrangement with brakes on the upper surface only, when the increments due to the brake become very small at $M = 0.90$.

The lower-surface "flap" type air-brakes do not suffer any serious loss of effectiveness at any Mach number but give large increments of lift (up to $\Delta C_L = 0.2$) and nose-down trim change (up to $\Delta C_{m_0} = -0.08$) and would be unsatisfactory from this point of view, although it is thought that they would be unlikely to produce much buffetting.

References/

References

No.	Author(s)	Title, etc.
1	L. E. Boddy and H. F. Emerson	Wind-tunnel tests of an M-235 model at high subsonic Mach numbers. NACA RMSA9 J20; October, 1949. NACA/TIB/2142
2	J. Y. G. Evans	Corrections to velocity for wall constraint in any 10 × 7 rectangular subsonic wind tunnel. A.R.C. R. & M. 2662, April, 1949.

Table 1/

Table 1

Vickers B9/48 (Valiant) 1/20 scale half-model

Details of half-wing

	Model scale
Gross area (see Fig.2)	2.96 sq ft
Span	2.83 ft
Standard mean chord	1.04_5 ft
Aspect ratio of whole wing	5.42_5
Chord at model C_L	1.89 ft
Root chord (at 0.28 ft from model C_L)	1.77_5 ft
Root section	t/c max. 12.0% at 35% chord
Chord at 1.28 ft from model C_L	0.99_5 ft
Section at 1.28 ft from model C_L	t/c max. 11.0% at 45% chord
Chord 2.77 ft from model C_L	0.47 ft
Section at 2.77 ft from model C_L	t/c max. 9.0% at 35% chord
Wing/body angle	3.25 deg
Wing twist between root and 1.28 ft from model C_L (about root spar)	- 1 deg
Twist outboard of 1.28 ft from model C_L	0 deg
Sweepback of 0.5 chord line (mean between root and tip)	19.1 deg
Dihedral	0 deg

Axis of pitching moments is at 1.04_5 ft aft of L.E. root chord (at 0.28 ft from C_L)

Air-brake details

Air-brake	Wing surface	Projected frontal area* (per wing) sq in.	Overall span (per wing) as fraction of wing semi-span
B. Prototype	Lower	3.96	0.185
C. Production	Lower	5.18	0.185
D. Pathfinder	Both	6.92	0.214
E. Pathfinder	Upper	3.46	0.214
F. Prototype plus Production	Lower Upper	3.96 4.68 Total 8.64	0.185

*Brake areas projected onto a plane perpendicular to the aerofoil datum of the untwisted outboard section of the wing and neglecting the "perforations".

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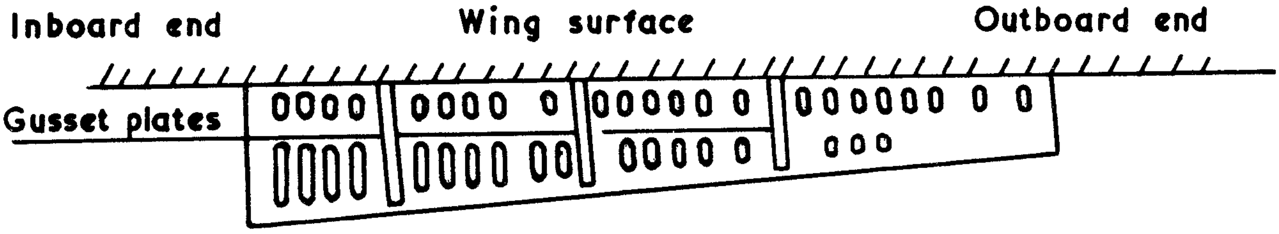
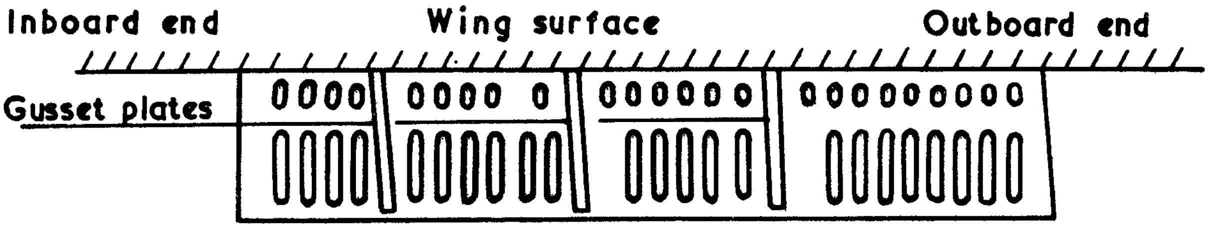
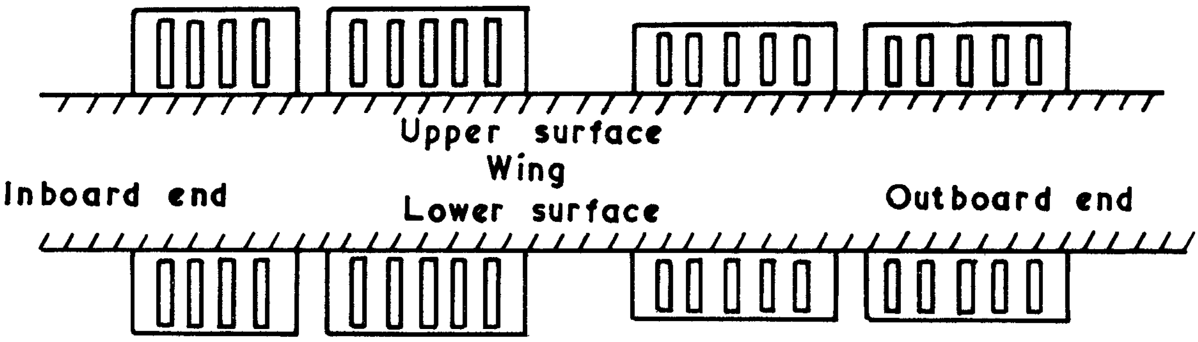
FIG. 1



Prototype air-brake (Brake 'B')

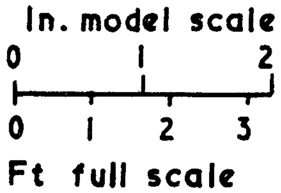


Production air-brake (Brake 'C')



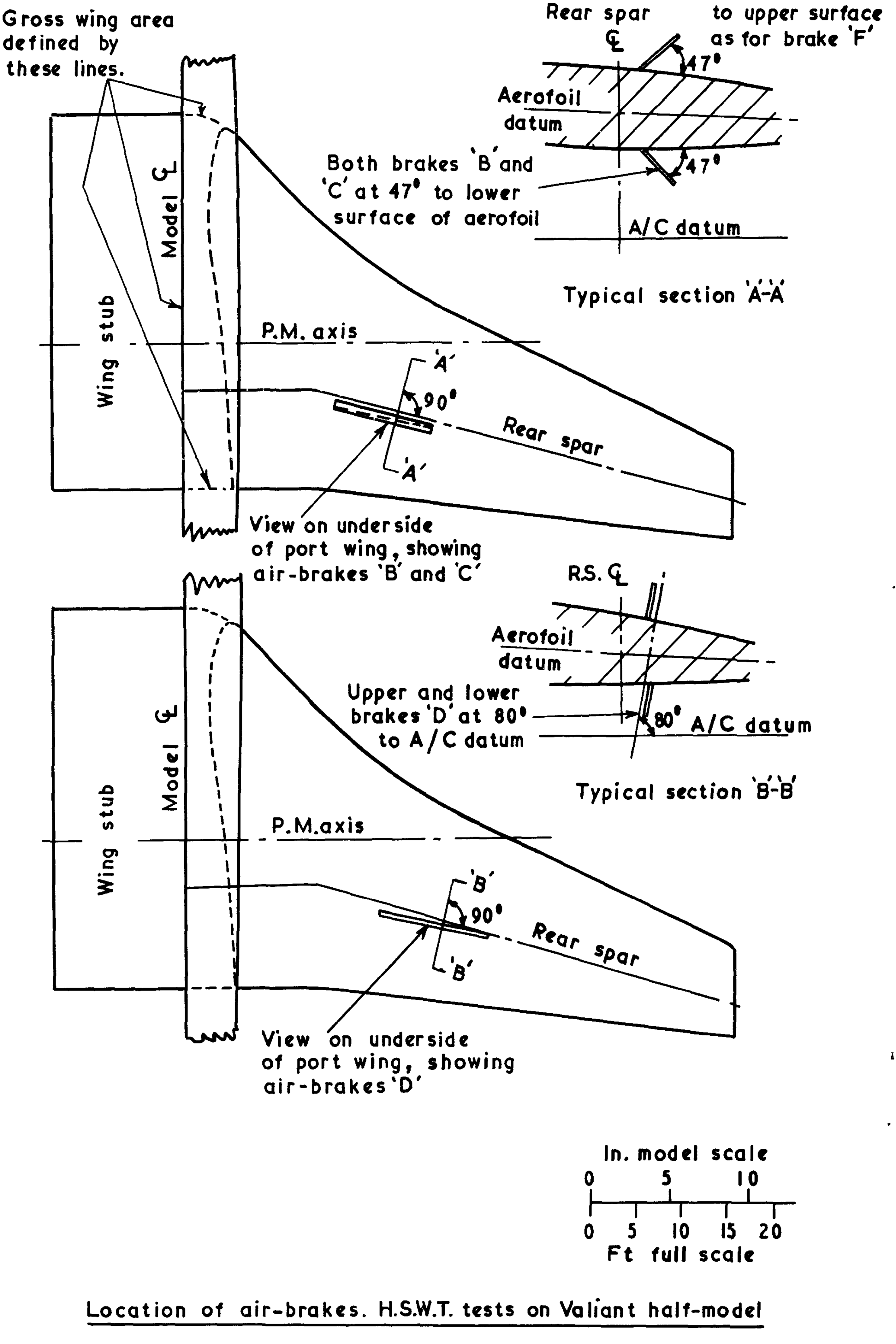
Pathfinder air-brake (Brake 'D')

Diagrams give true views of each brake plate



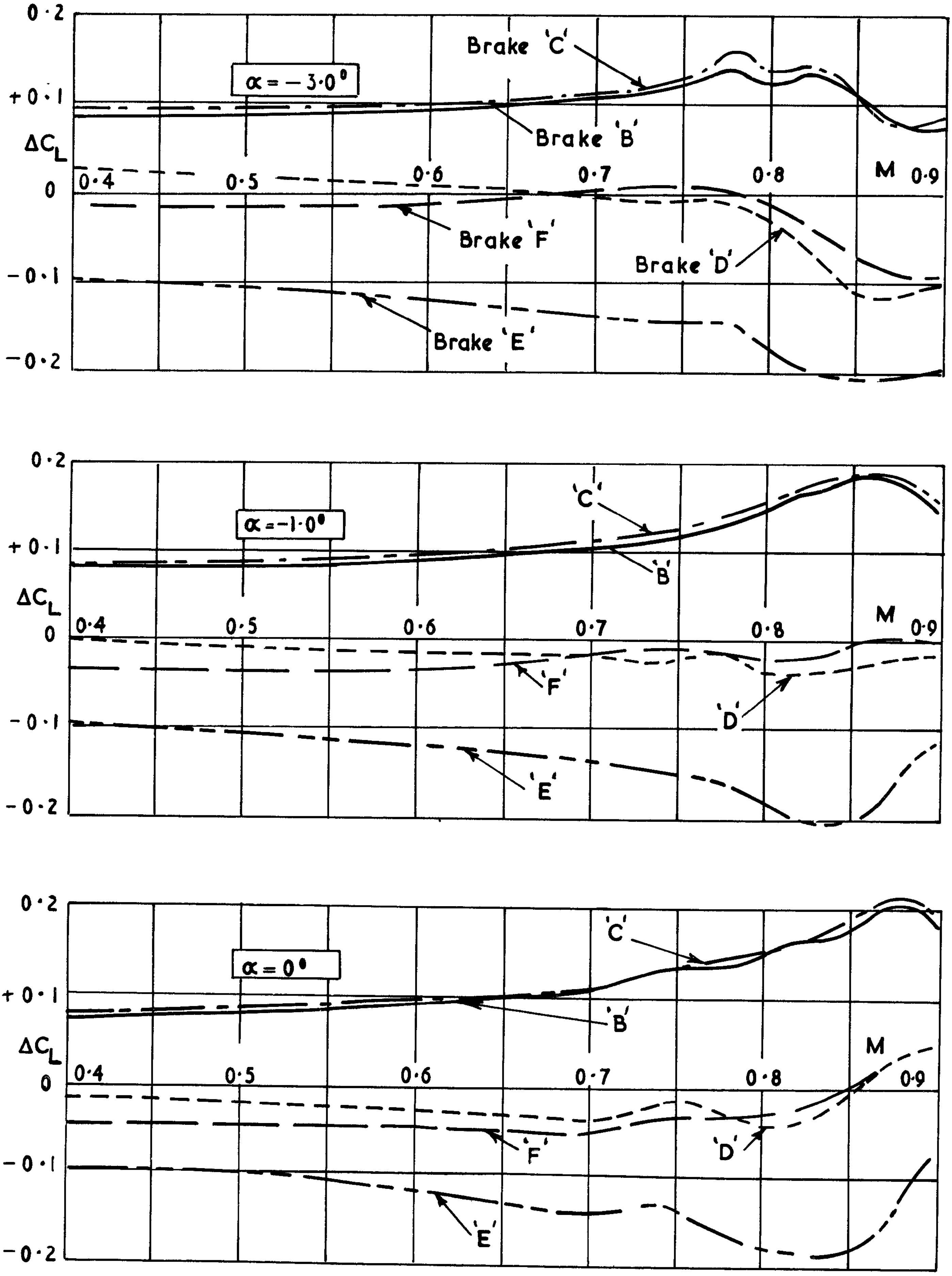
Details of air-brakes. H.S.W.T. tests on Valiant half-model.

FIG. 2



Location of air-brakes. H.S.W.T. tests on Valiant half-model

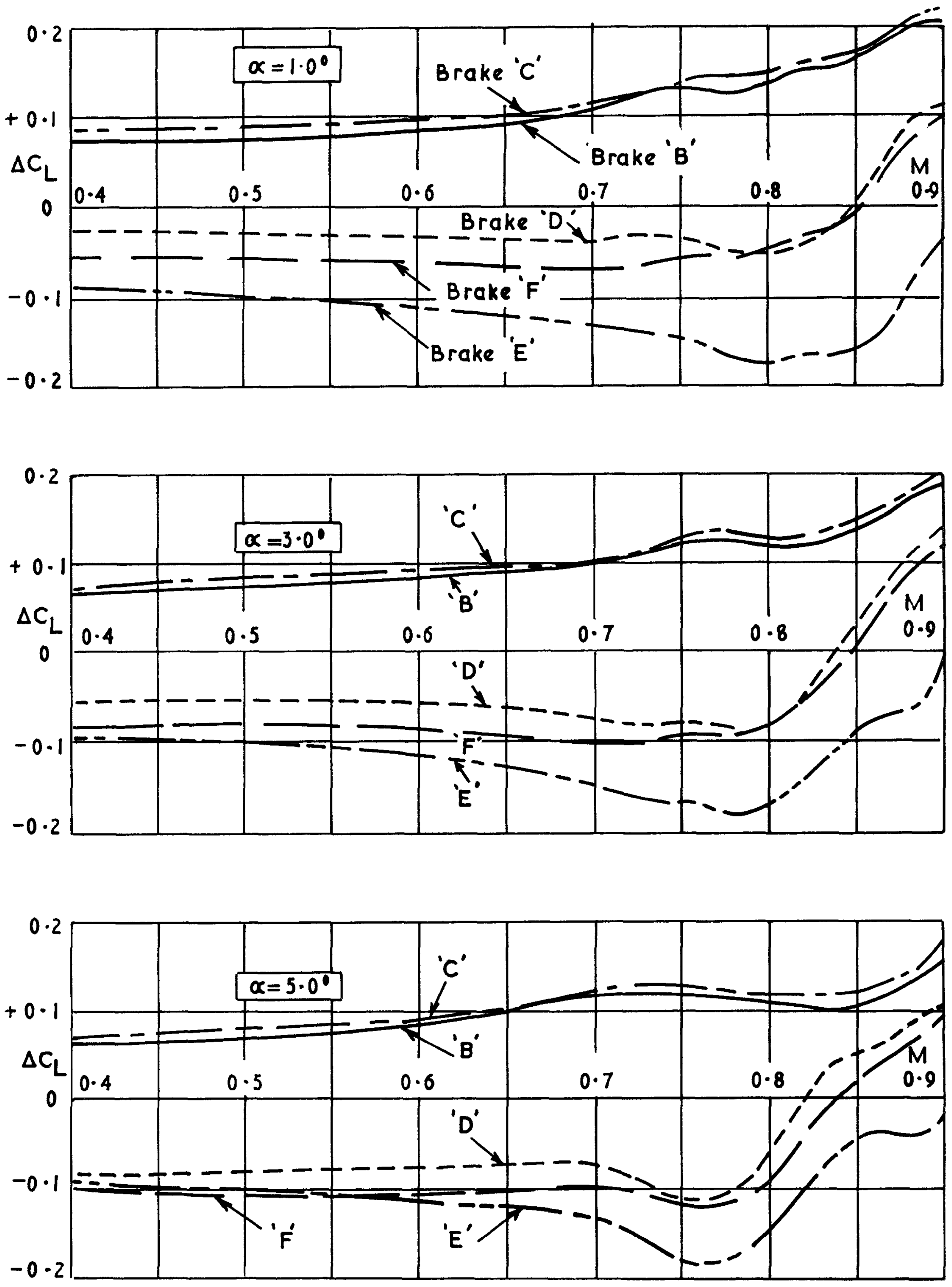
FIG. 3(a)



(a) Lift increments, ΔC_L, due to air-brakes, at constant incidence

H.S.W.T. tests on Valiant half-model

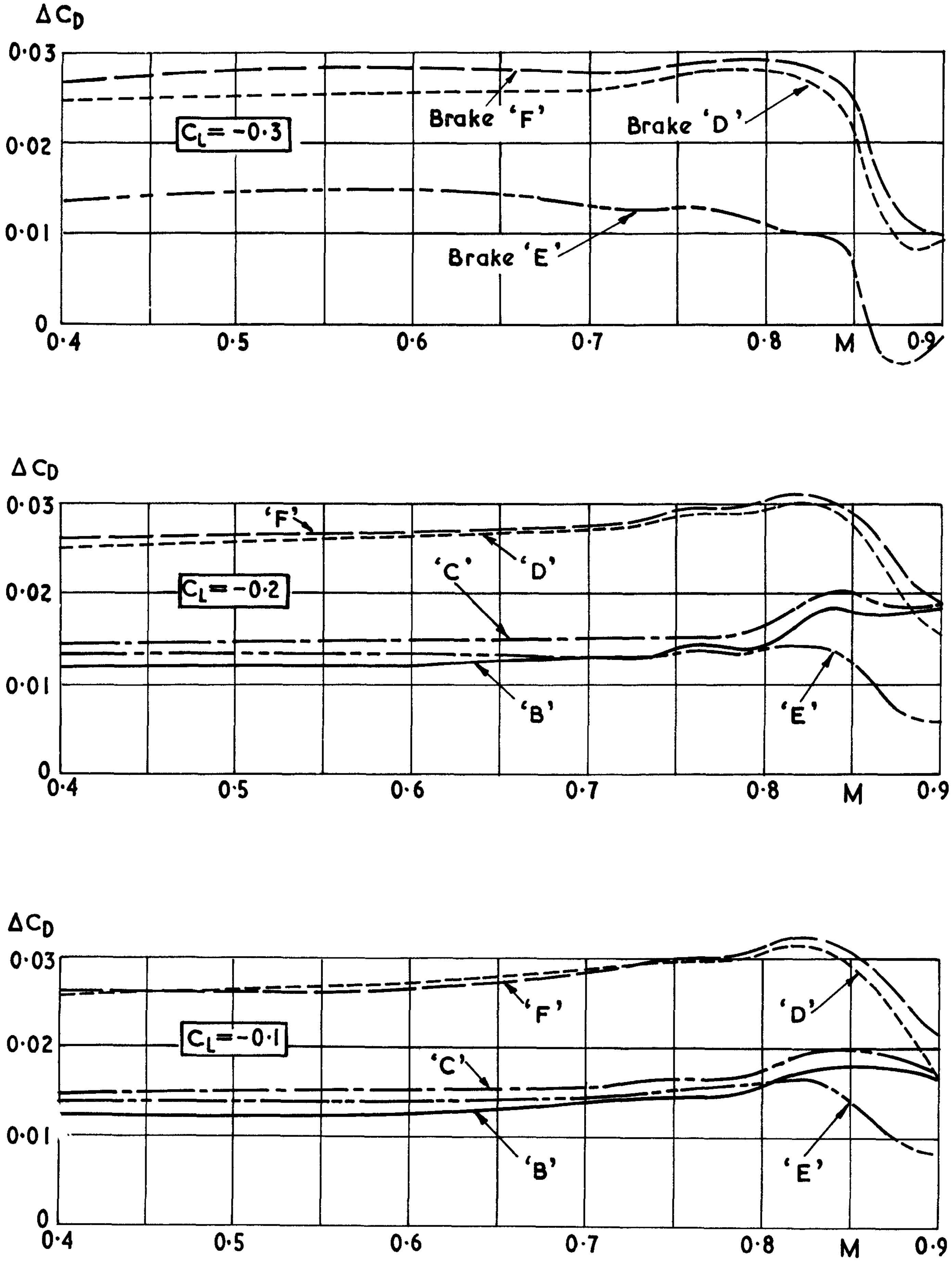
FIG. 3(b)



(b) Lift increments, ΔC_L, due to air-brakes, at constant incidence

H.S.W.T. tests on Valiant half-model.

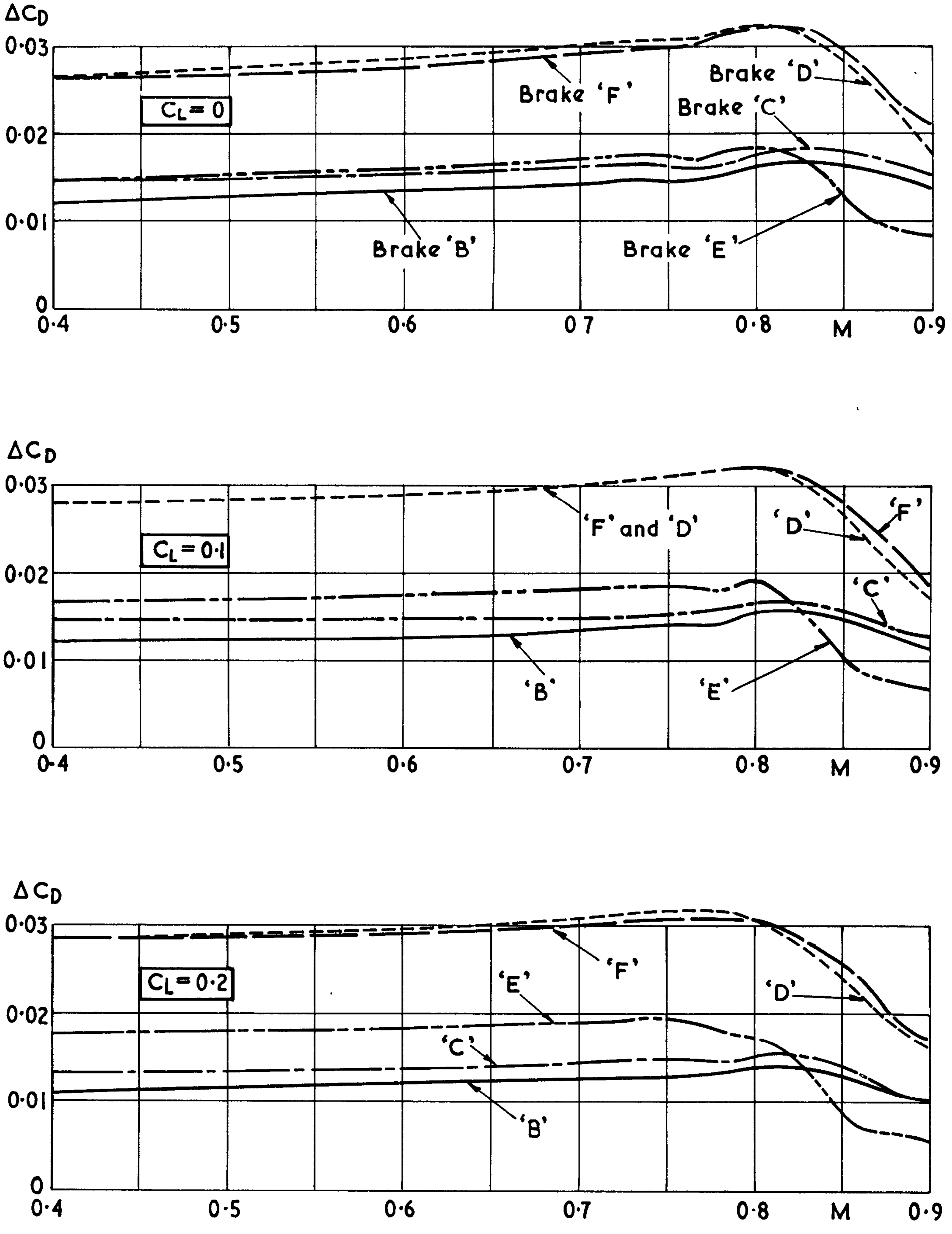
FIG. 4 (a)



Drag increments, ΔC_D due to air-brakes, at constant lift coefficient.

H.S.W.T. tests on Valiant half-model

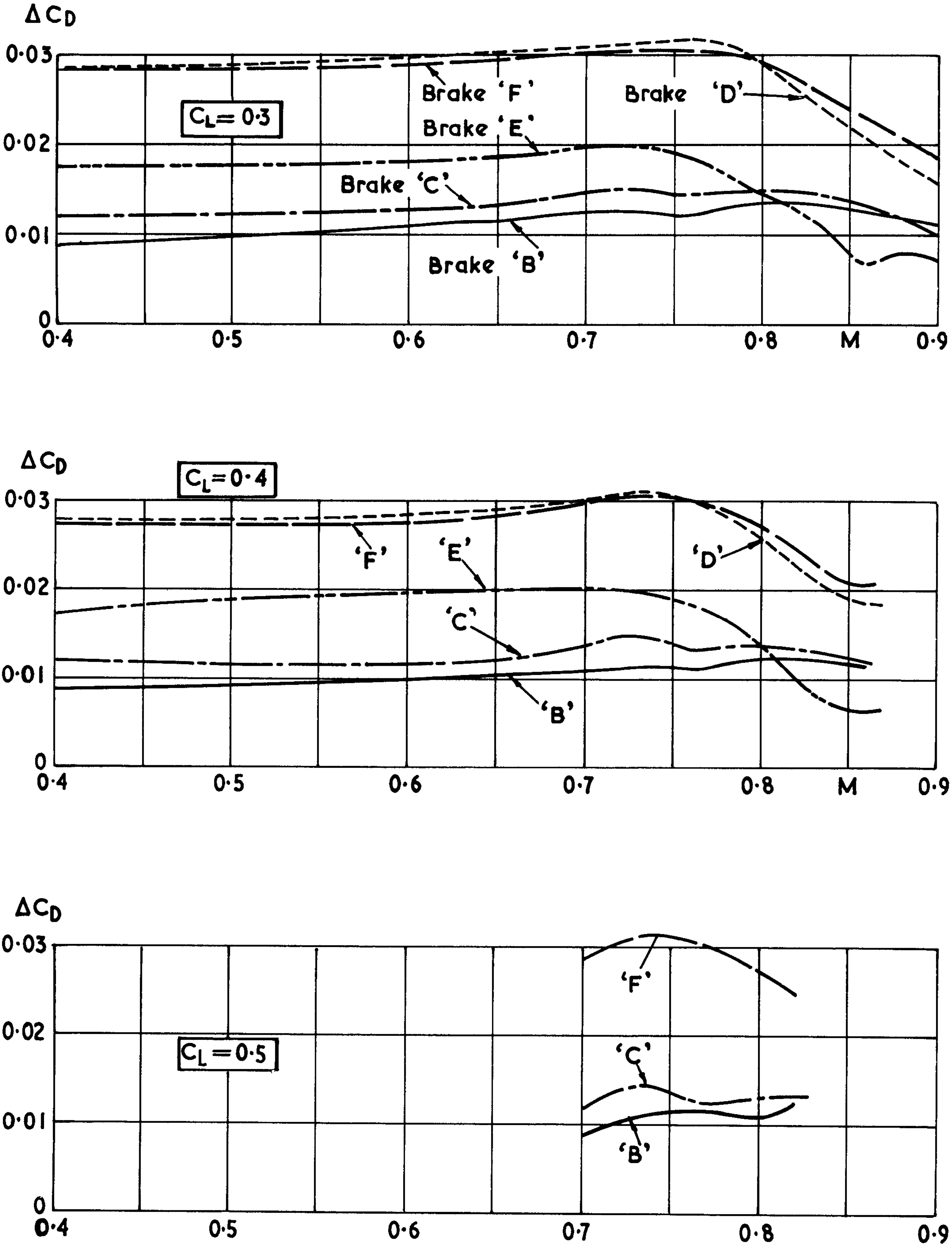
FIG. 4 (b)



Drag increments, ΔC_D, due to air-brakes, at constant lift coefficient

H.S.W.T. tests on Valiant half-model

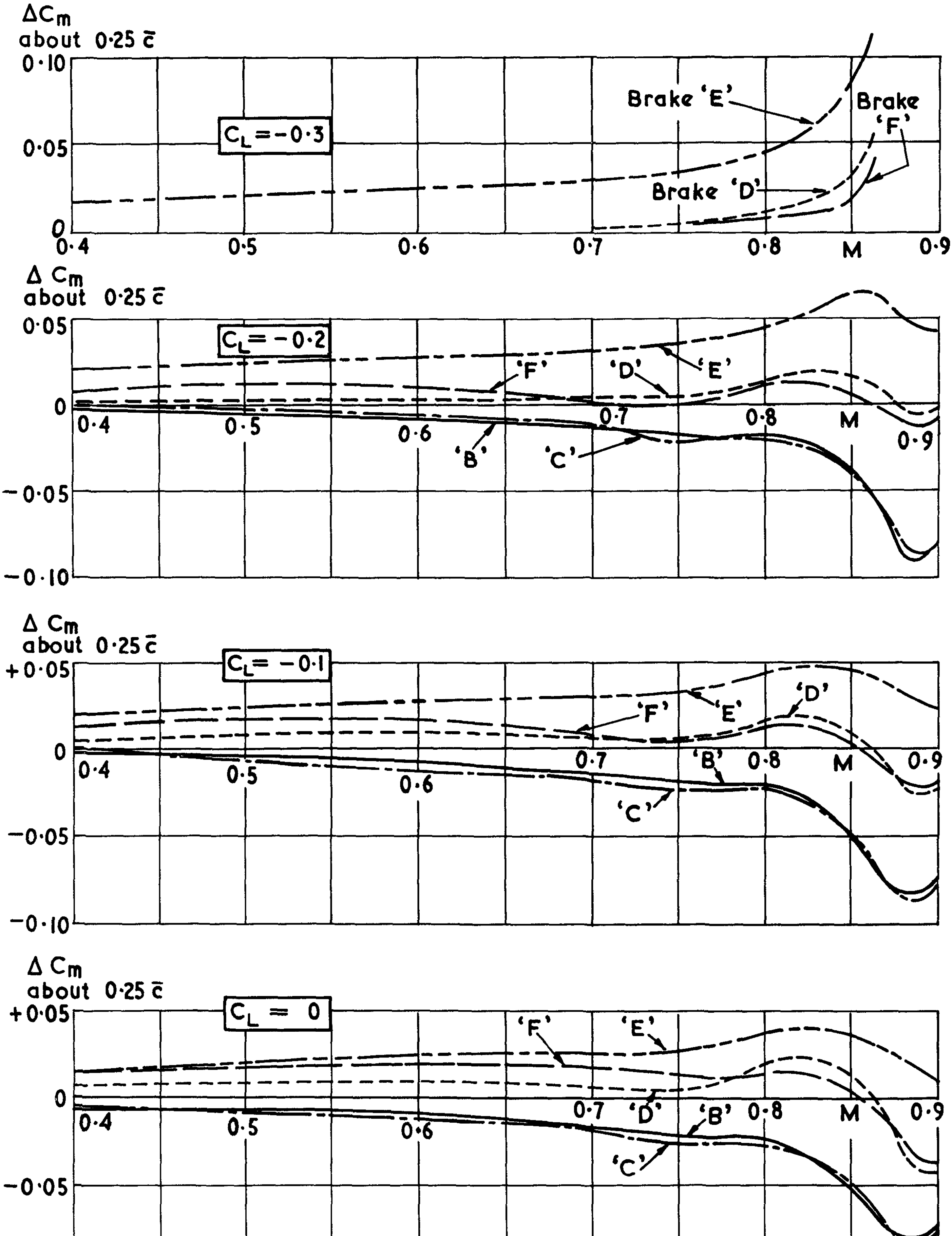
FIG. 4 (c)



Drag increments, ΔC_D, due to air-brakes, at constant lift coefficient.

H.S.W.T. tests on Valiant half-model

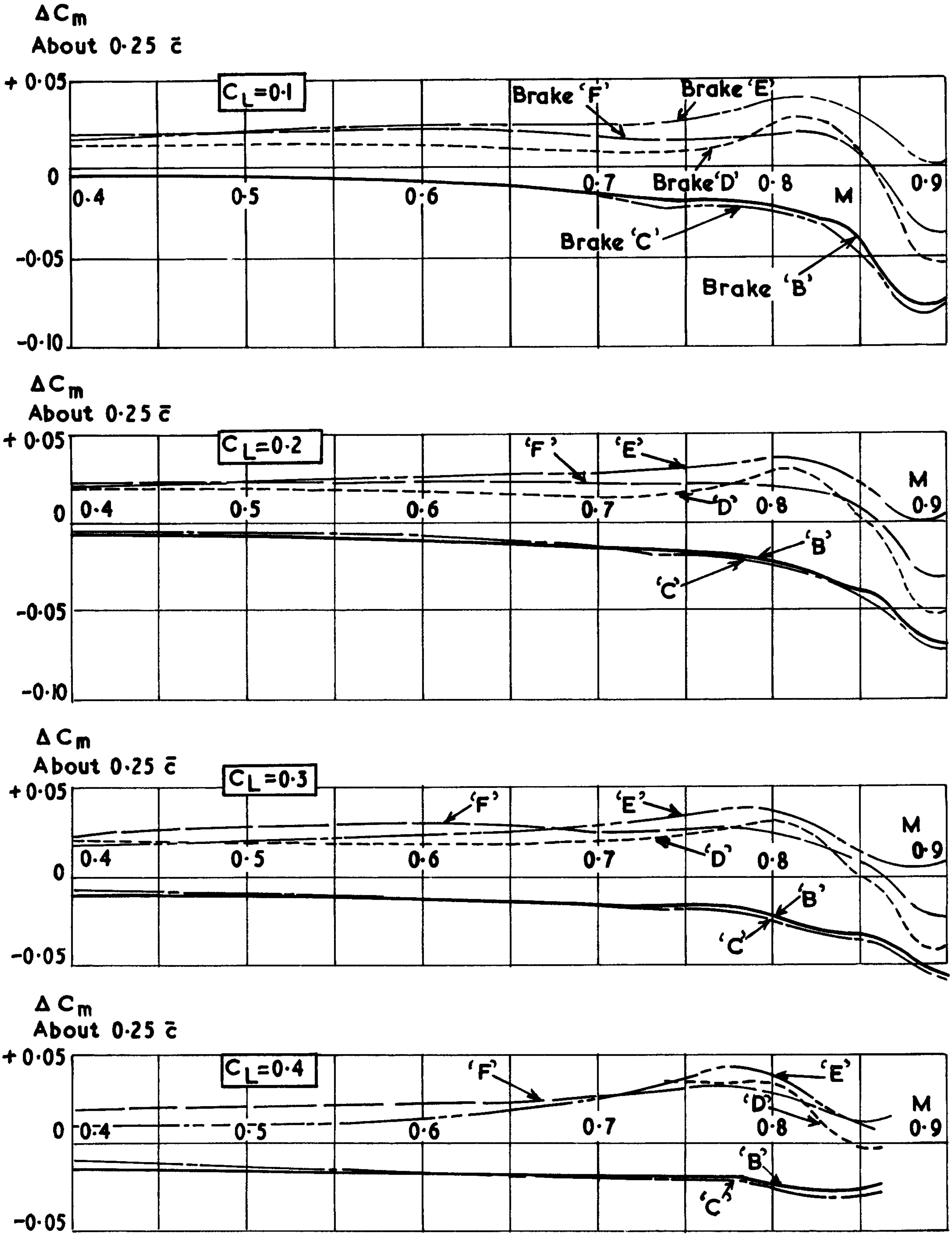
FIG. 5 (a)



Pitching-moment increments, ΔC_m due to air-brakes at constant lift coefficient

H.S.W.T. tests on Valiant half-model

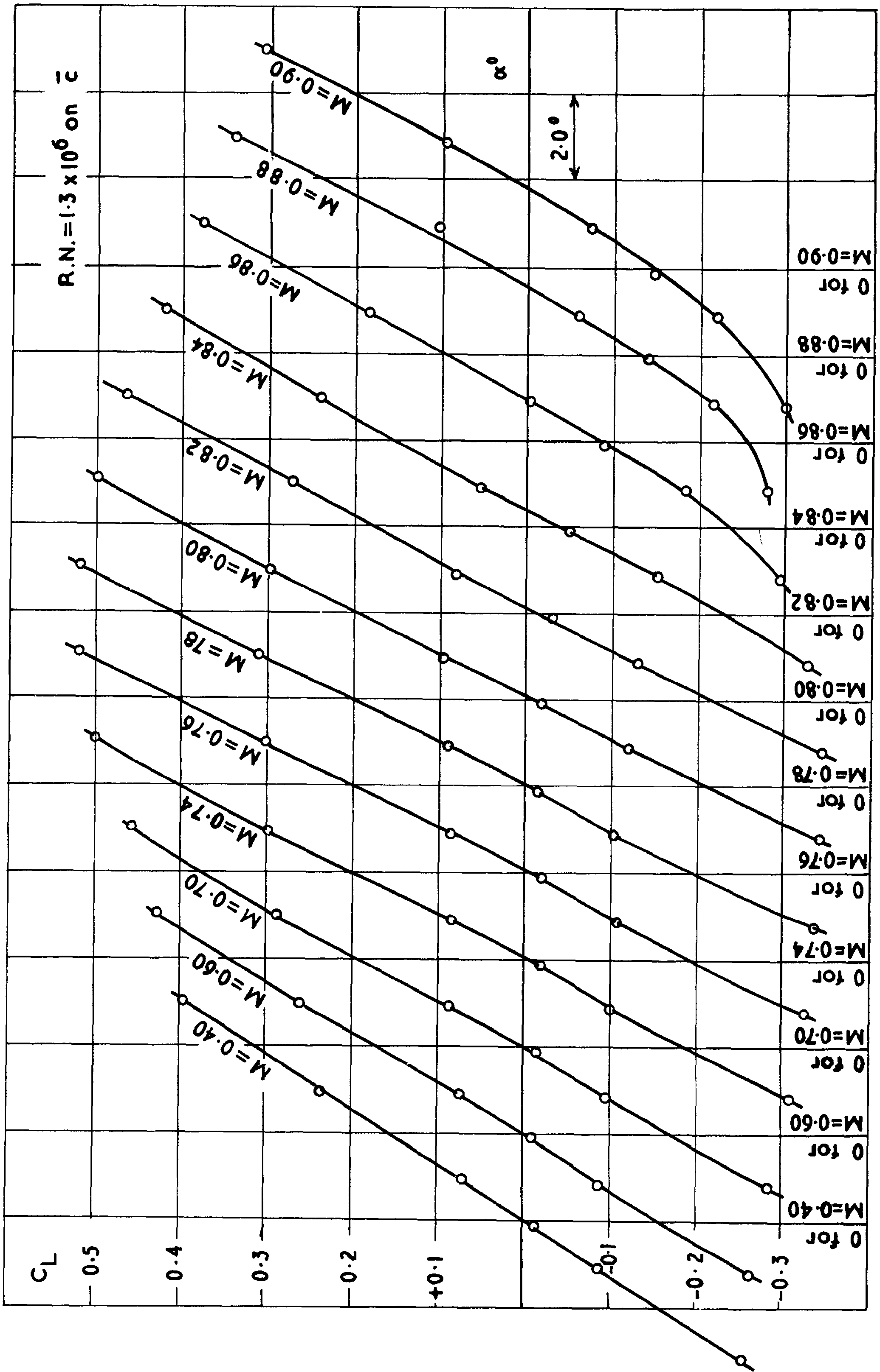
FIG. 5.(b)



Pitching-moment increments, ΔC_m, due to air-brakes, at constant lift coefficient.

H.S.W.T. tests on Valiant half-model.

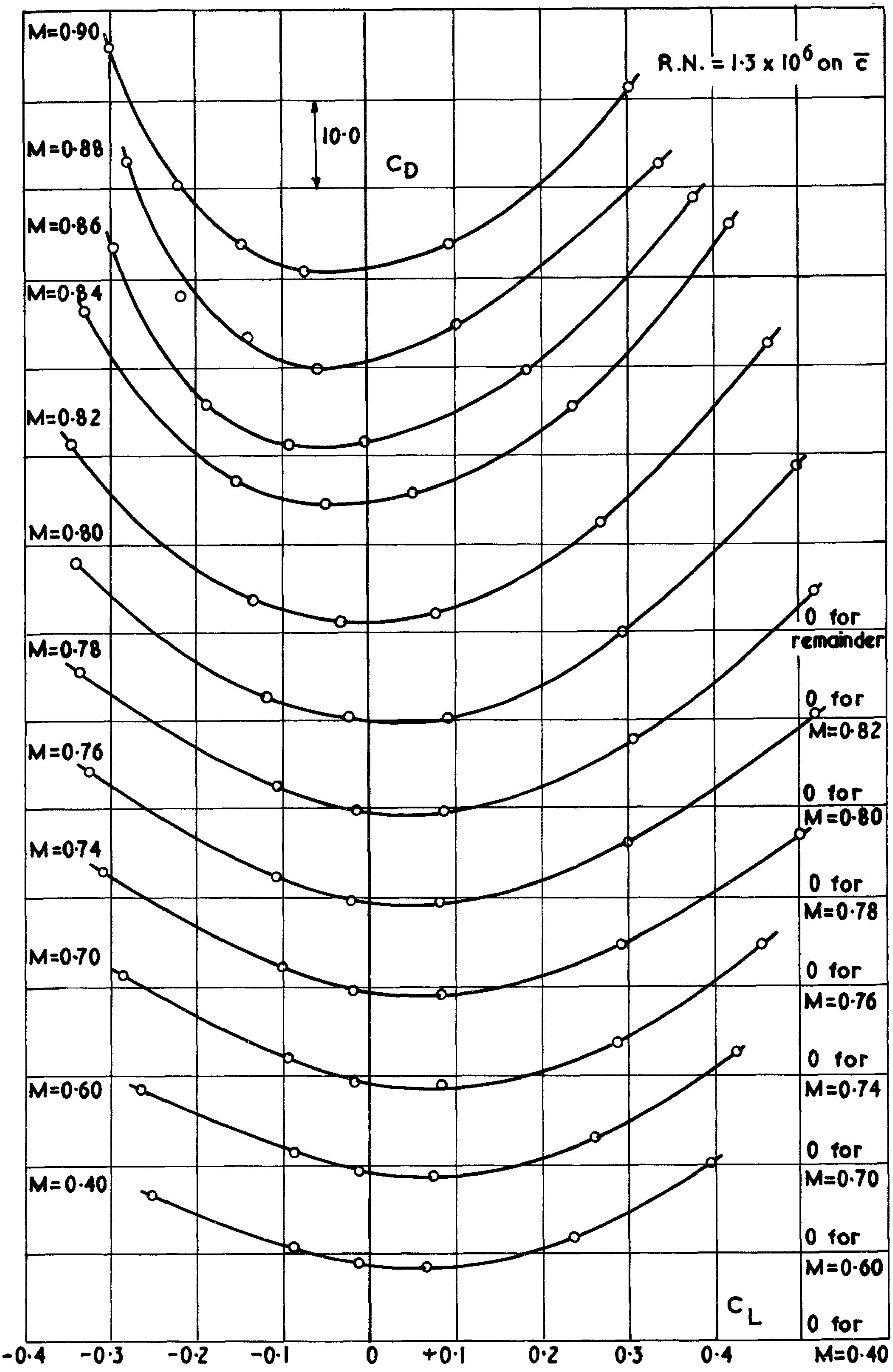
FIG.6.



Lift characteristics for model without tail and air-brakes

H.S.W.T. tests on Valiant half-model

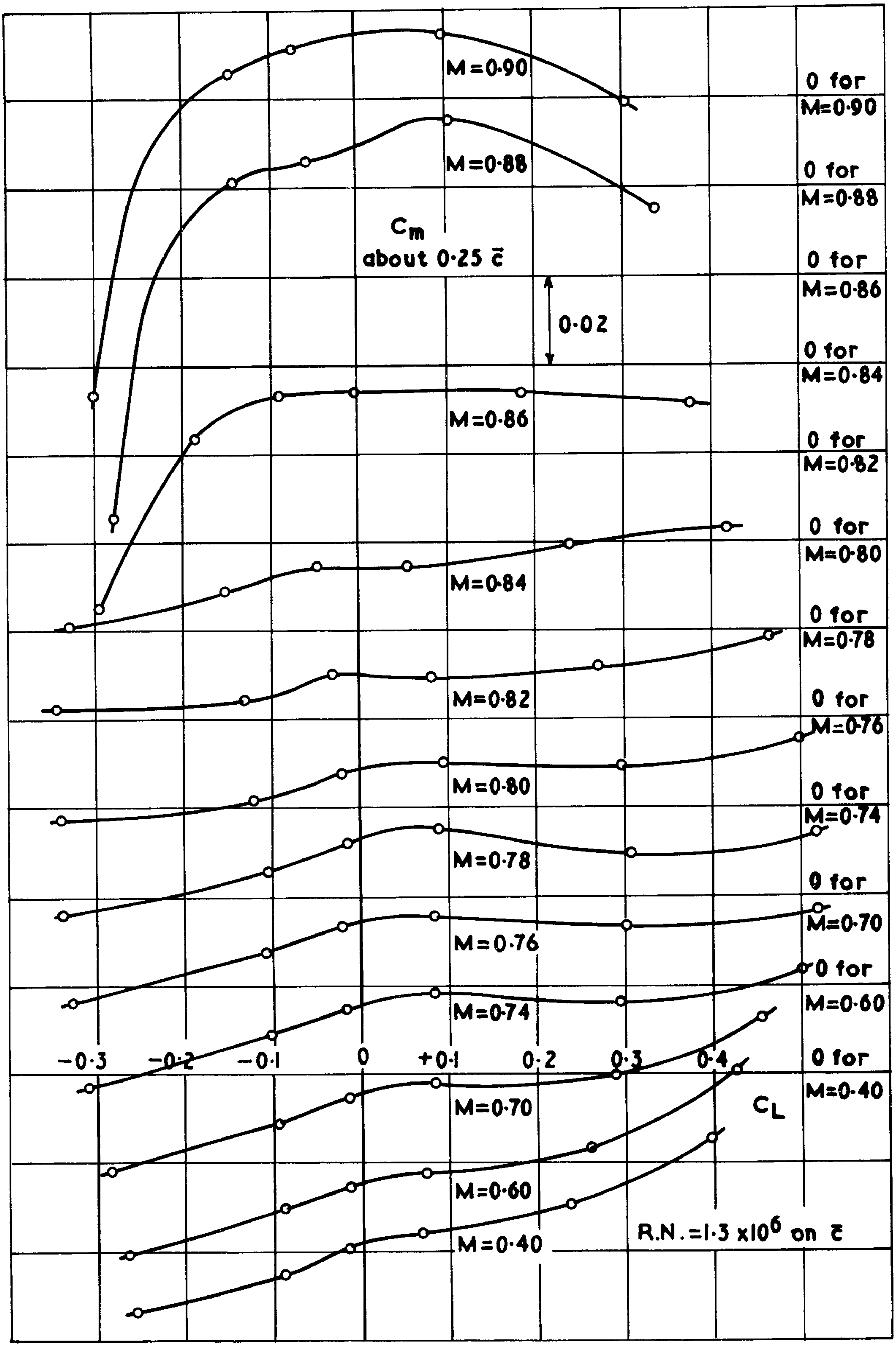
FIG. 7.



Drag characteristics for model without and air-brakes.

H.S.W.T. tests on Valiant half-model.

FIG. 8.

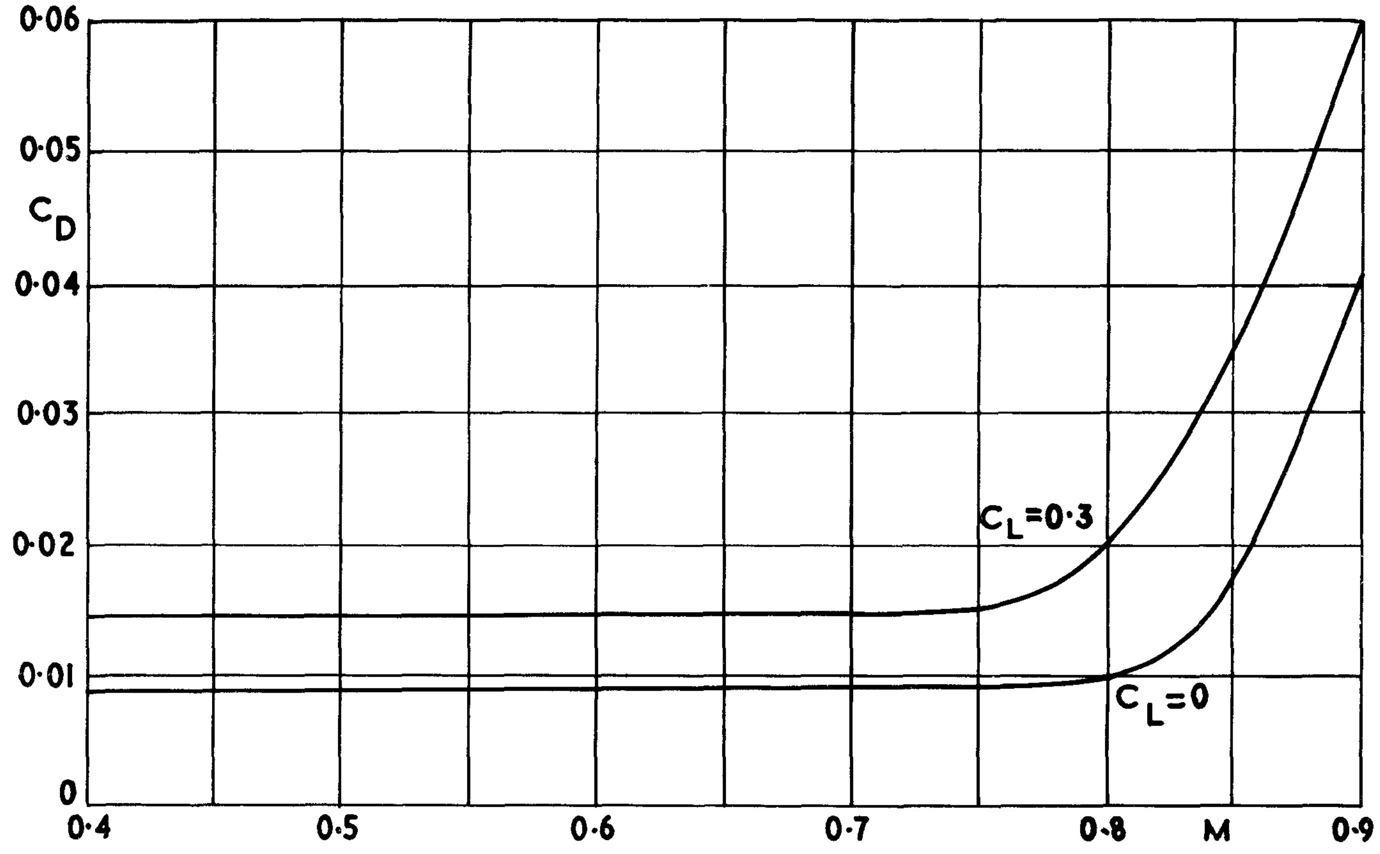


Pitching-moment characteristics for model without tail and air-brakes.

H.S.W.T. tests on Valiant half-model.

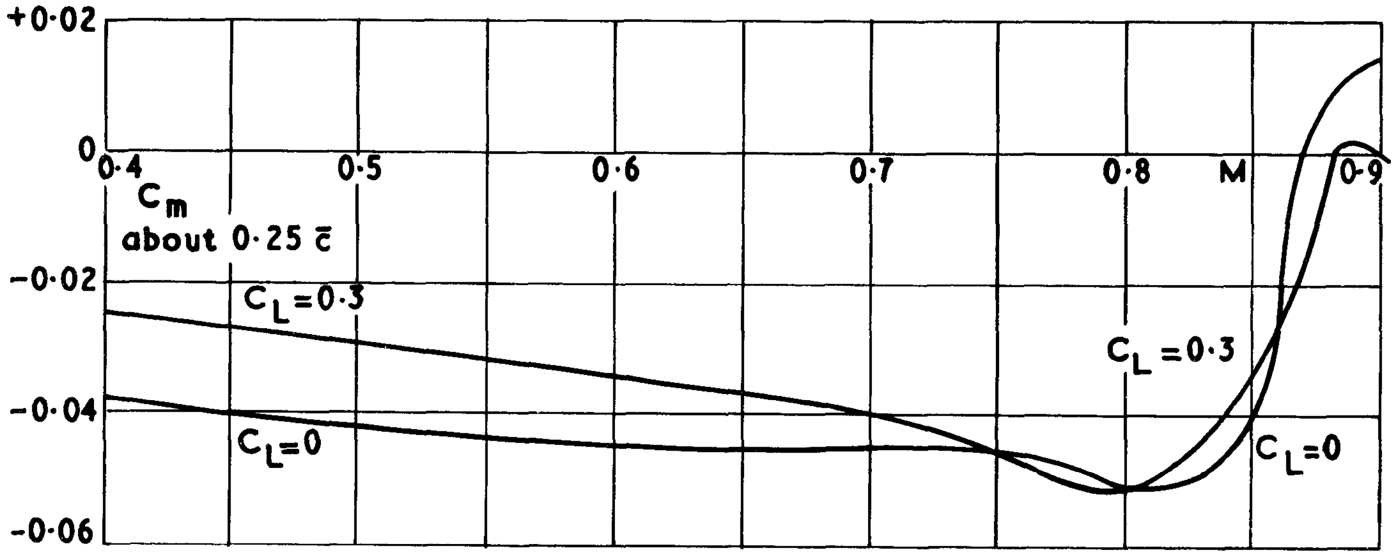
FIG.9.(a) & (b)

FIG.9.(a)



Variation of drag at constant lift, model without tail and air-brakes

FIG.9.(b)



Variation of pitching moment at constant lift, model without tail and air-brakes.

H.S.W.T. tests on Valiant half-model.

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TESTS TO HIGH SUBSONIC SPEEDS IN THE 10 FT × 7 FT TUNNEL, OF SEVERAL WING-MOUNTED AIR-BRAKES ON A HALF-MODEL OF A FOUR-JET BOMBER. (VICKERS VALIANT)

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At Mach numbers above 0.8, the lower-surface brake increments became unacceptably large (up to $\Delta C_m = -0.08$ and $\Delta C_L \doteq 0.2$), while the upper-surface brake suffered a severe loss of effectiveness due to a shock-induced separation occurring on the wing ahead of the brake. This was reflected in the results for brakes on both surfaces, which then tended to lie nearer to those for lower-surface brakes.

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