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A.R.C. Technical Report

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Tests on a 1/36 Scale Model of the Vickers M.T. 1000 in the Compressed Air Tunnel, N.P.L.

by

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of the Aerodynamics Division, N.P.L.

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Tests on a 1/36 Scale Model of the Vickers M.T.1000 (C.132D) in the Compressed Air Tunnel, N.P.L.

- By -

C. J. W. Miles and Mrs. R. C. Fox,
of the Aerodynamics Division, N.P.L.

30th June, 1954

SUMMARY

The report describes measurements of lift, drag and pitching moments on a 1/36 scale model, up to a Reynolds number of 7 millions. The experiments covered the effect of flaps (30° and 50°), dive brakes (30° and 50°) and of two tail planes of different span at two angles of incidence (+2° and -2°) relative to the wing.

The highest value of $C_{L\,max}$ measured was 1.61 (with 50° flaps). Scale effect on downwash at the tail apparently disappears above $R = 3 \times 10^6$.

Introduction

The main object of the experiments was to determine

(a) data for two settings for the trailing edge flaps,

(b) the effect of the dive brakes on the characteristics,

(c) the influence of tail plane setting on longitudinal stability

and (d) the possibility of further scale effect on downwash at the tail, at values of Reynolds number above 7 millions.

During the tests, the design was changed to incorporate a tail plane of smaller span. In consequence part of the original programme was repeated with the smaller tail.

Preliminary tests had been carried out on the model, before either flaps or tail were fitted, and also on a 9% thick rectangular aerofoil, with and without nose flaps, but having the same section as that used along the major portion of the span of the complete model. The results of the aerofoil series of tests will be reported separately. The values obtained on the original model aircraft, before fitting flaps and tail, were in very close agreement with those contained in the present report, and are therefore not included.

Model/

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Model

The model was made by Vickers Armstrong Ltd., and was 1/36 full scale. The wing and tail plane were made of metal, the fin of tufnol and the body of phenoglazed wood (see Fig. 1 for a general arrangement drawing).

The wing, of area 2.425 square feet and standard mean chord 0.624 feet, had a section very similar to those described in Current Paper No. 92 (Ref. 1), but with slightly greater camber and with no trailing edge reflex. The maximum thickness, which was situated at about 0.35c, increased from 0.13c at the root to 0.14c inboard and then decreased to 0.09c, remaining constant at this value over the outer two thirds of the span. Ordinates for a representative section ($t/c = 0.09$) are given in Table II and profiles for $t/c = 0.14$ and $t/c = 0.09$ are sketched in Fig. 2.

The flaps for each half wing comprised three separate sections (shown in detail in Fig. 3).

(i) Dive brakes, of 24.3% standard mean chord and length 12.4% of the semi span, in the inboard position.

(ii) Fowler flaps, of 28.5% standard mean chord and length 11.2% of the semi span, in the mid position.

(iii) Double slotted flaps, of 28.8% standard mean chord and length 35.8% of the semi span, in the outboard position.

Brackets were supplied which allowed the flaps, either separately or together, to be set at 0°, 30° and 50°, with respect to the wing chord. The gaps between the two halves of the dive brakes, and between the dive brakes and the Fowler flaps (see Fig. 3), could be covered with a metal plate in order to examine the effect of the unavoidable gaps in the full scale machine.

The tail plane was adjustable to +2° and -2° with respect to the wing root chord, and, together with the fin, could be replaced by a fairing block for the "no tail" cases. A sketch of the tail, showing the two different spans, is given in Fig. 4.

Full details and dimensions of the model are given in Table I.

Range of Tests

The various arrangements tested were as follows:-

Table/

Set No.	Dive Brakes (degrees)	Fowler Flaps (degrees)	Double Slotted Flaps (degrees)	Tail
6	0	0	0	None
4	0	0	0	Large +2°
5	0	0	0	Large -2°
16	0	0	0	Small +2°
15	0	0	0	Small -2°
14	30	0	0	None
11	30	0	0	Large +2°
21	30	0	0	Small +2°
7	30	30	30	None
8	30*	30*	30	None
10	30	30	30	Large +2°
9	30	30	30	Large -2°
20	30	30	30	Small +2°
19	30	30	30	Small -2°
13	50	0	0	None
12	50	0	0	Large +2°
22	50	0	0	Small +2°
1	50	50	50	None
3	50	50	50	Large +2°
2	50	50	50	Large -2°
17	50	50	50	Small +2°
18	50	50	50	Small -2°

*Gaps between the two halves of the dive brakes, and between the dive brakes and Fowler flaps covered with a plate.

For/

For sets 1 - 18 (inclusive) tests were carried out at Reynolds numbers (approx.) of 5.4×10^6, 6.4×10^6 and 7×10^6, together with a run at about 0.8×10^6 for comparison with results obtained in Messrs. Vickers' tunnel. In set 1 an extra Reynolds number, at 3×10^6 was included, and in sets 4, 5 and 6, in order to obtain more information concerning the scale effect on downwash at the tail, extra runs were made at Reynolds numbers (approx.) of 2×10^6 and 4×10^6. The tests in sets 19 to 22 (inclusive) were restricted to Reynolds numbers (approx.) of 5.4×10^6 and 6.4×10^6.

Lift, drag and pitching moments were measured over a range of incidences of the wing root chord, from about 0° to above the stall. In a few cases, where adverse pitching moments might have damaged the model supports, it was necessary to omit measurements at low angles of incidence.

Tables and Figures

A complete set of tabulated results is not included in the report. Typical curves of $C_L - \alpha$ and $C_m - C_L$ at a Reynolds number (approx) of 6.4×10^6 are shown in Figs.5 to 11 (inclusive). (6.4×10^6 has been selected rather than 7×10^6 because the ranges of observations, at this value of Reynolds number, give a more complete comparison.

C_L max - Log R curves are shown in Figs.12 and 13.

Table 3 gives values of $dC_L/d\alpha$ (per degree) at R (approx.) $= 6.4 \times 10^6$, for various model configurations and

Table 4 gives values of dC_m/dC_L for similar conditions.

Figures showing $C_L - \alpha$ and $C_m - C_L$ curves at $R \simeq 6.4 \times 10^6$

Fig. 5 The effect of flap angles 0°, 30° and 50° without tail.

Fig. 6 The effect of flap angles 0°, 30° and 50° with small tail at both +2° and −2°.

Fig. 7 The effect of flap angles 0°, 30° and 50° with large tail at both +2° and −2°.

Fig. 8 A comparison at flap angle 0° between the no tail, small tail +2° and −2° and large tail +2° and −2° conditions.

Fig. 9 A similar comparison to Fig. 8, but with flap angle 30°.

Fig.10 A similar comparison to Figs. 8 and 9, but with flap angle 50°.

Fig.11 A comparison at dive brake angles of 30° and 50° between the no tail, small tail +2° and large tail +2° conditions. To avoid confusion the curves for 0° dive brakes are not inserted, but are shown on the same scale in Fig. 8.

Figures/

Figures showing $C_{L\,max}$ - Log R curves

Fig.12(a,b) The variation at flap angles of 0°, 30° and 50° for the no tail, small tail +2° and -2° and large tail +2° and -2° conditions. Fig.12(c) shows the effect of sealing the chordwise gaps in the flaps at a flap angle of 30°, no tail.

Fig.13(a) The effect of tail plane area and (b) the effect of dive brakes at 30° and 50° respectively.

Results - Lift and $C_{L\,max}$

Reference to Figs. 5a to 11a shows that in most cases the $C_L - \alpha$ curves are straight to just below the maximum lift. The exceptions are in respect of no tail, small tail +2° and -2° and large tail -2°, in each case with all flaps 0°. Here there is a noticeable decrease in the slope of the curve, occurring at about 14° (see Figs. 5a, 6a, 7a and 8a). In all cases $dC_L/d\alpha$ for 0° flaps and 30° flaps is about the same, but is slightly less for the 50° flaps. Values of $dC_L/d\alpha$ for $R = 6.4 \times 10^6$ approx., are given in Table III.

From Figs. 12 and 13 it appears that in most cases $C_{L\,max}$ is still rising appreciably with Reynolds number, in a few it is tending towards a constant value at the highest Reynolds number attainable on the model (7×10^6). In two cases, (i) where there is a slight falling off and (ii) where there is a sudden increase, it has not been possible to confirm the observations and they are included with some reserve. The balance readings were often rather unsteady in the vicinity of maximum lift.

Excluding the point in (ii) above, the highest $C_{L\,max}$ is about 1.61 and occurs with no tail and flap angle 50°. The corresponding $C_{L\,max}$ for 0° flaps is 1.15.

Pitching Moment

Pitching moment coefficients are given about an axis situated at 0.11 standard mean chord. This corresponds to a model axis 7.133" aft of the nose of the wing root chord, and 0.156" above the wing root chord (model right way up). This axis is identical with the pitching moment axis of the tunnel balance when the model incidence is 0°. The length of the standard mean chord is 0.624 foot.

Reference to Figs. 5b to 11b (inclusive) shows that the $C_m - C_L$ curves are reasonably straight for most of the range of C_L up to $C_{L\,max}$, the range being rather less for the no tail condition. In all cases the curves show longitudinal instability at the stall and, in the no tail flap angles 30° and 50° cases, this instability is evident about 2° or 3° before the maximum lift is reached (Figs. 9b, 10b). Changes of slope in the $C_m - C_L$ curves are always associated with similar changes in the $C_L - \alpha$ curves. Values of dC_m/dC_L at $R \simeq 6.4 \times 10^6$ are given in Table I.

Drag

$C_{D\,min}$ at the highest Reynolds numbers, with no tail and flap angle 0°, is 0.011 and $\frac{dC_D}{dC_L^2} = 0.055$. The increment of drag coefficient due to the large tail unit is 0.002 to 0.003 and ΔC_D at moderate incidences, due to flap angle 50°, is about 0.125.

Effect/

Effect of Flaps on Lift

This is shown in Figs. 5a, 6a and 7a. The increment in lift, due to flap angles 30° and 50° with tail, at moderate incidence, is 0.55 and 0.65 respectively, irrespective of tail plane angle or size. With no tail however the increments are higher, namely 0.6 for flap angle 30° and 0.7 for flap angle 50°. In general ΔC_L due to flaps is less at $C_{L\,max}$ than at lower incidences. The effect of flap angle on $C_{L\,max}$, at different Reynolds number, is shown in Figs. 12a and 12b.

Covering the gaps in the dive brakes, and between the dive brakes and the Fowler flaps gives a slight increase in both lift coefficient and $C_{L\,max}$ (Fig. 5a). The increase in $C_{L\,max}$ is much smaller at the highest Reynolds numbers (Fig. 12c).

Effect of Flaps on Pitching Moment

With no tail the $C_m - C_L$ curves for flap angles 30° and 50° are almost coincident (Fig. 5b). With the small tail (Fig. 6b) the effect of flaps is to displace the $C_m - C_L$ curves in the opposite direction from the no tail condition, and with the large tail (Fig. 7b) the effect is similar but more pronounced. With tail the curves for flap angles 30° and 50° are well separated. Table IV gives values of $d\,C_m/d\,C_L$ at $R = 6.4 \times 10^6$ (approx.).

Effect of Dive Brakes

Fig. 11 shows the effect on the $C_L - \alpha$ and $C_m - C_L$ curves of dive brake angles 30° and 50° without tail, with small tail at +2° and with large tail +2°. The 50° dive brakes are seen to give a slightly higher lift and a more positive pitching moment than the 30° dive brakes. The small increase in $C_{L\,max}$ of the 50° over the 30° dive brakes is still present at the highest Reynolds number (Fig. 13b).

Whilst both the large and the small tails at +2° increase the slope of the lift curve and the negative value of $d\,C_m/d\,C_L$, over the no tail cases, the large tail produces the greater change in both respects (Fig. 11).

Effect of Tail

Comparisons of small and large tail planes at flap angles 0°, 30° and 50° are shown in Figs. 8, 9 and 10. It will be seen that in general the small tail gives a slightly greater lift than the large tail under similar conditions. The differences in the $C_m - C_L$ curves are more marked, the large tail producing the greater change in $d\,C_m/d\,C_L$.

Reference to Fig. 13a shows that the effect of tail size on $C_{L\,max}$, at flap angles 0°, 30° and 50°, is quite small over the whole range of Reynolds number.

Downwash at the Tail

Examination of several sets of $C_m - \alpha$ curves showed that for the higher values of Reynolds number, in each case, the curves were very nearly coincident. Below a Reynolds number of 3×10^6, however, in one or two conditions some scale effect was evident. Generally, therefore, it appears from the model tests that the mean downwash at the tail, as deduced from the $C_m - \alpha$ curves, shows no scale effect above about $R = 3 \times 10^6$.

Acknowledgment/

Acknowledgment

The authors wish to acknowledge the assistance given by Mr. C. Salter, M.A. both in the supervision of the experimental work and in the presentation of the results.

References

No.	Authors	Title, etc.
1	C. Salter, H. M. Lee and P. C. Owen	Tests in the Compressed Air Tunnel on two aerofoil sections, having a large scale effect on $C_{L\,max}$ at a critical Reynolds number. C.P. No. 92. (February 1951) Appendix - June 1952.

TABLE I/

TABLE I

Model Details

Wing Span = 3.883 feet   Area = 2.425 square feet

Chord (Fuselage ℄) = 1.320 feet, t/c = 0.123

Root Chord = 1.248 feet, t/c = 0.13

Tip Chord (before rounding) = 0.224 feet, t/c = 0.09

t/c increasing from 0.13, at the root, to 0.14, at 26.9% semi-span and decreasing to 0.09, at 32.2% semi-span, then remaining constant to tip.

Standard mean chord = 0.624 feet

¼ chord point S.M.C., aft of nose of wing root chord = 0.681 feet

Angle of Sweepback of L.E. to 32.2% semi-span = 45°

Angle of Sweepback of L.E. from 32.2% semi-span to tip = 30°

Wing Incidence (Root) to Body Datum = +4°

Wing Dihedral = +4° on each half wing

Geometrical twist from 26.9% semi-span (t/c = 0.14) to 32.2% semi-span (t/c = 0.09) = -2°

Flaps

Dive brakes   Chord = 0.152 feet, Total Area 0.0726 sq ft

Fowler flaps   Chord = 0.178 feet, Total Area 0.0773 sq ft

Double Slotted flaps   Mean Chord = 0.180 feet, Total Area 0.2470 sq ft

Tailplane

Large Span = 1.708 feet   Area = 0.671 sq ft

Root Chord = 0.542 feet, t/c = 0.09

Tip Chord (before rounding) = 0.252 feet, t/c = 0.08

Small Span = 1.431 feet   Area = 0.596 sq ft

Root Chord = 0.542 feet, t/c = 0.09

Tip Chord = 0.302 feet, t/c = 0.0817

Large and Small Tails

Angles of tail plane relative to the wing root chord = -2° and -2°

Angle of sweepback of tail plane L.E. = 30°

Tail plane dihedral = 15° on each half tail plane.

TABLE II/

TABLE II

Wing Ordinates for a section t/c = 0.09

x/c	y upper/c	y lower/c
0	0	0
0.005	0.0107	0.0096
0.0075	0.0127	0.0110
0.0125	0.0159	0.0134
0.025	0.0207	0.0163
0.05	0.0279	0.0205
0.075	0.0332	0.0236
0.10	0.0377	0.0257
0.15	0.0445	0.0290
0.20	0.0494	0.0310
0.25	0.0529	0.0323
0.30	0.0550	0.0338
0.35	0.0558	0.0342
0.40	0.0550	0.0337
0.45	0.0531	0.0326
0.50	0.0503	0.0310
0.55	0.0468	0.0290
0.60	0.0426	0.0264
0.65	0.0377	0.0234
0.70	0.0324	0.0201
0.75	0.0270	0.0167
0.80	0.0216	0.0134
0.85	0.0162	0.0100
0.90	0.0108	0.0067
0.925	0.0081	0.0050
0.950	0.0054	0.0033
0.975	0.0027	0.0017
0.9875	0.0013	0.0008
1.000	0	0

TABLE III/

TABLE III

Values of $d\,C_L/d\,\alpha$ (per degree) for small positive incidences at R (approx.) = 6.4×10^6.

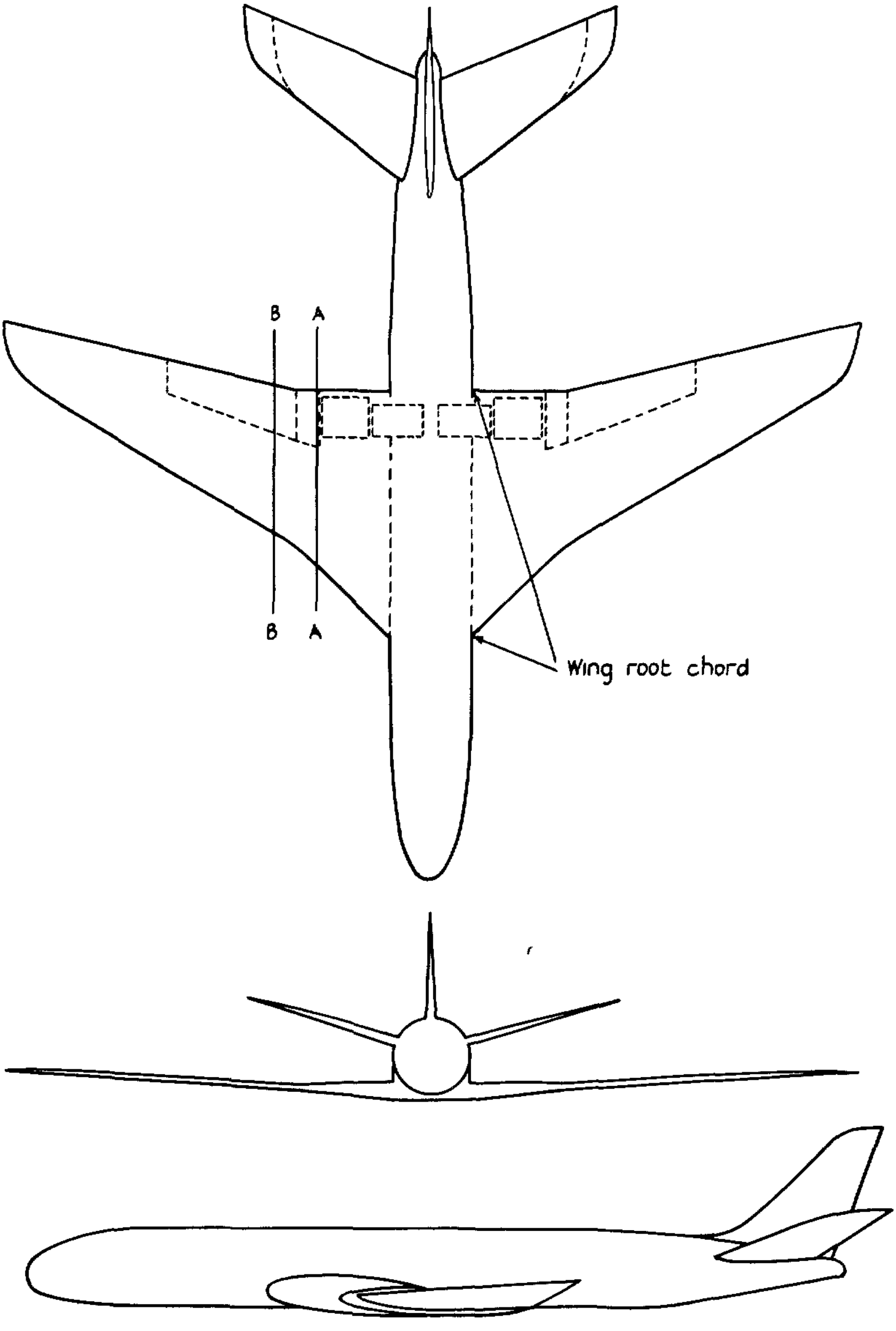
	No Tail	Large Tail +2°	Large Tail -2°	Small Tail +2°	Small Tail -2°
All Flaps 0°	0.071_5	0.079_5	0.079_5	0.078	0.078
Dive Brakes only 30°	0.071_5	0.079_5	-	0.078	-
All Flaps 30°	0.071	0.079_5	0.079_5	0.078	0.078
Dive Brakes only 50°	0.070_5	0.079	-	0.078	-
All Flaps 50°	0.066	0.074_5	0.074_5	0.073	0.073

TABLE IV

Values of $d\,C_m/d\,C_L$ for values of C_L at small positive incidences at R (approx.) = 6.4×10^6.

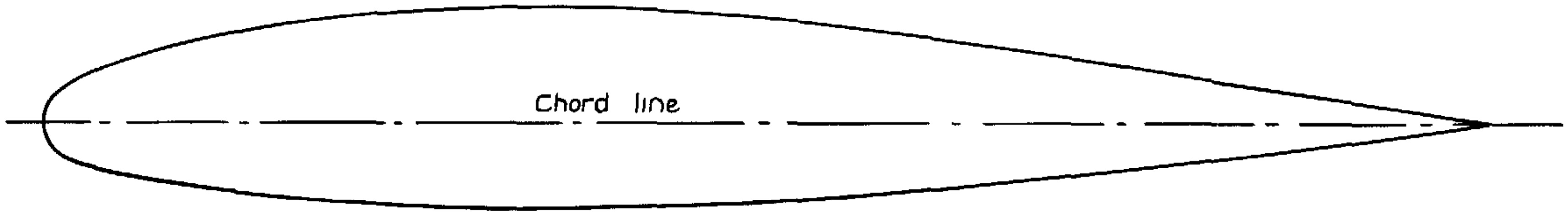
	No Tail	Large Tail +2°	Large Tail -2°	Small Tail +2°	Small Tail -2°
All Flaps 0°	-0.131	-0.415	-0.415	-0.352	-0.356
Dive Brakes only 30°	-0.132	-0.414	-	-0.353	-
All Flaps 30°	-0.135	-0.418	-0.416	-0.369	-0.370
Dive Brakes only 50°	-0.135	-0.417	-	-0.355	-
All Flaps 50°	-0.133	-0.418	-0.419	-0.367	-0.373

FIG 1

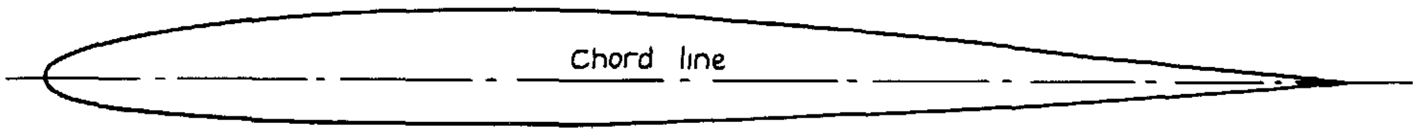


Vickers M T 1000 (C 132 D)
General Arrangement.

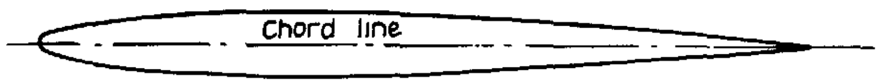
FIG. 2



Wing section at AA (Fig 1) $T/C = 0.14$



Wing section at BB (Fig 1) $T/C = 0.09$



Tailplane section at CC (Fig 4) $T/C = 0.085$

Vickers M T 1000 (C 132 D) Sections of wing and tailplane

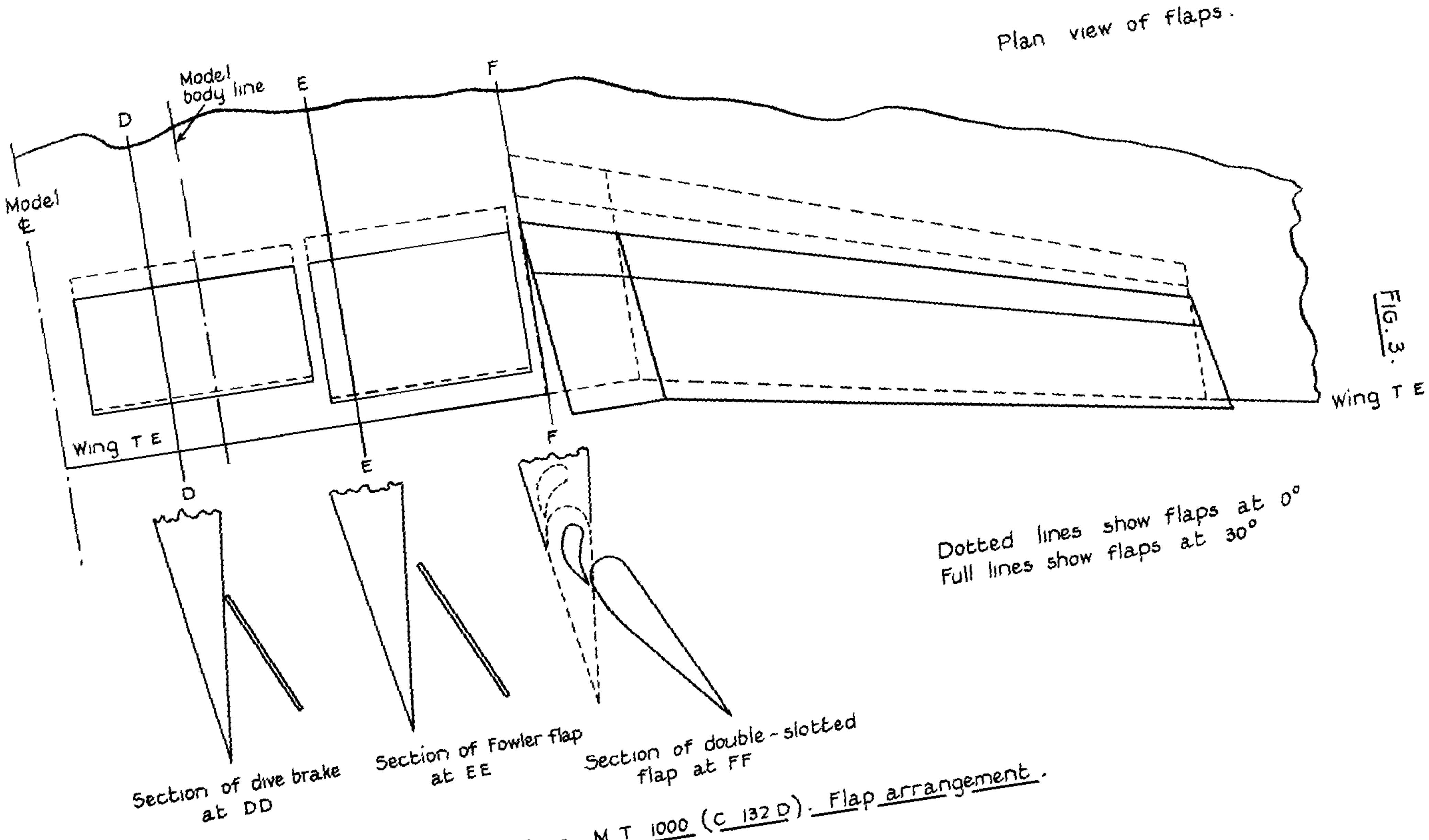
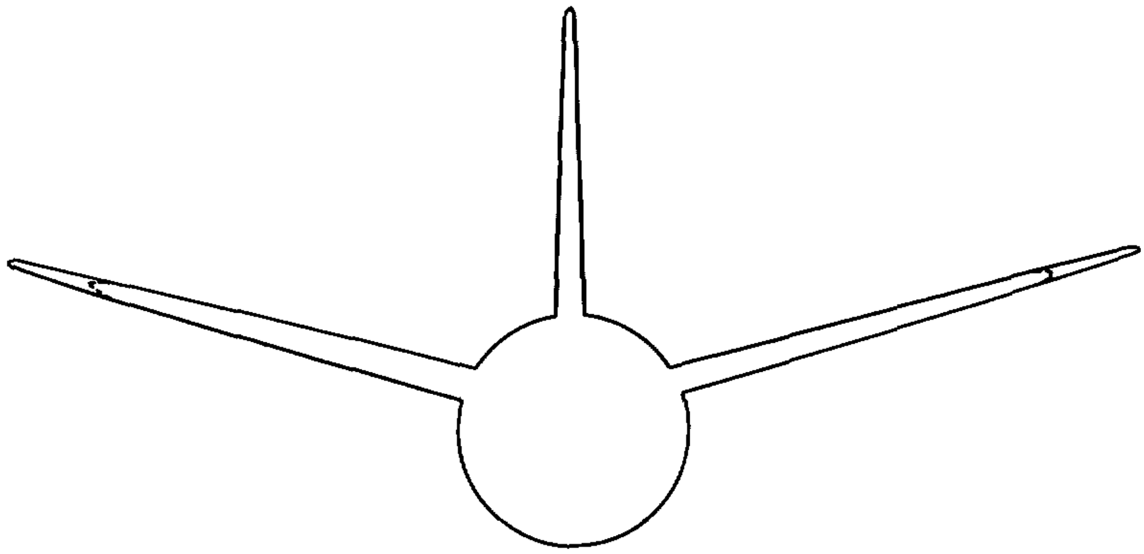


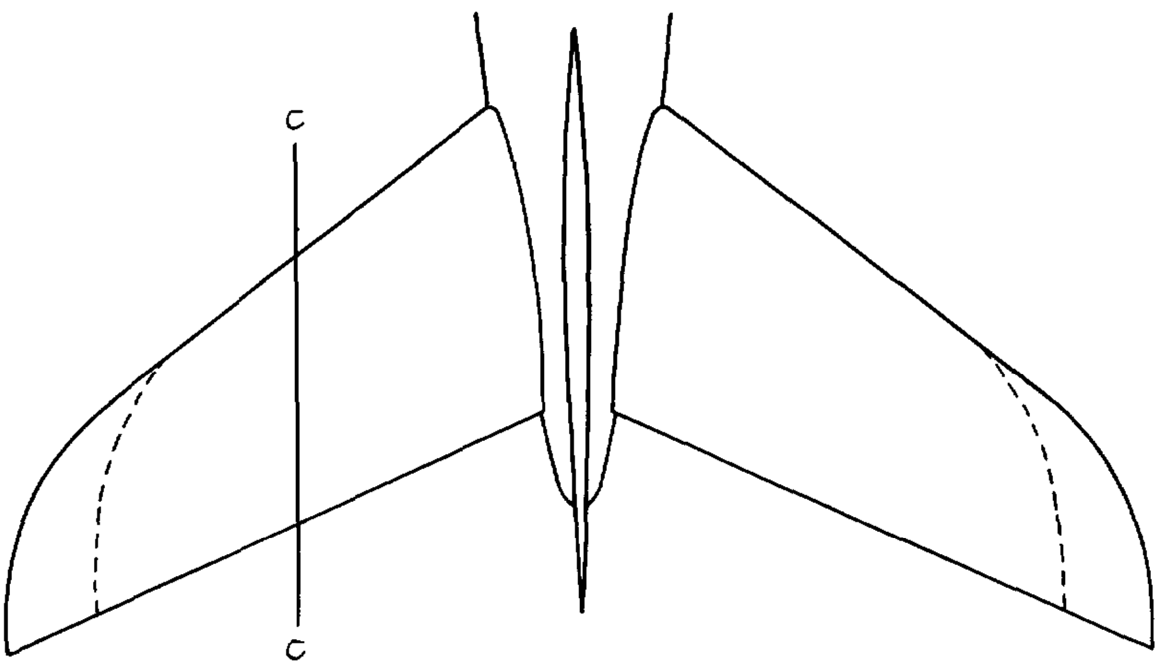
FIG. 3.

Vickers M T 1000 (C 132 D). Flap arrangement.

FIG 4.



Dotted lines show small tailplane
Full lines show large tailplane



Vickers M T 1000 (C 132 D) Tail arrangement

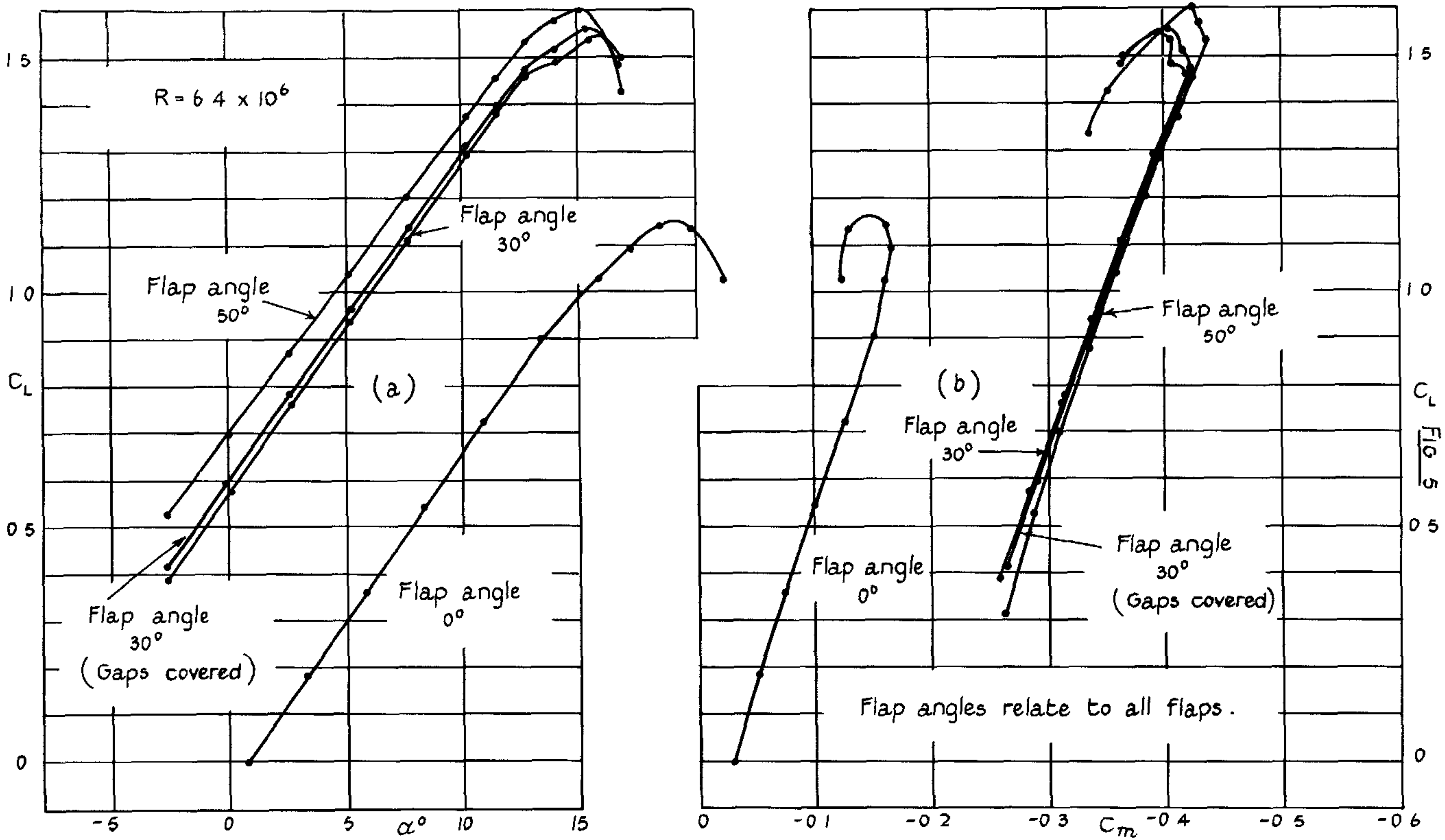
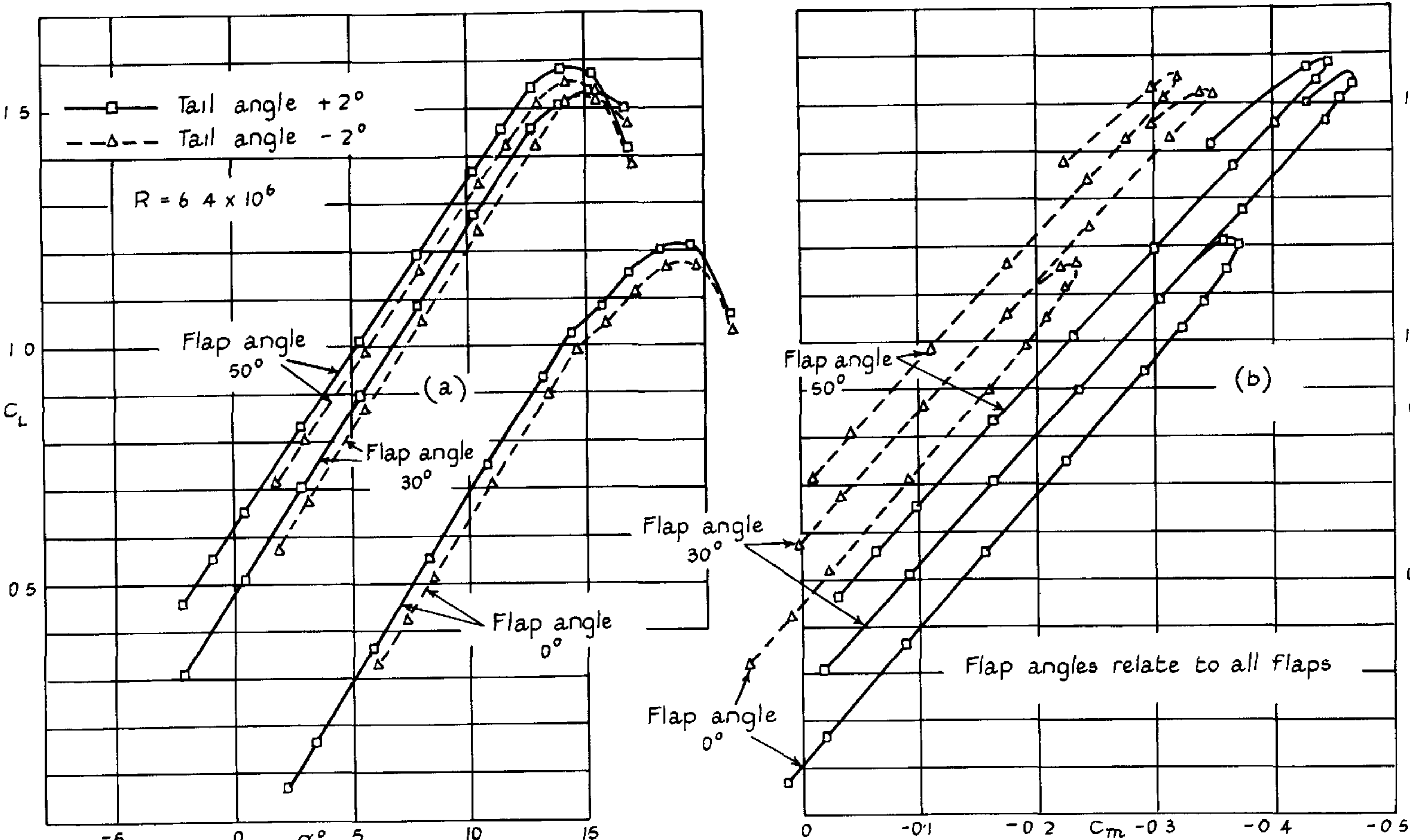


FIG 5

Vickers M T 1000 (C 132 D) Effect of flaps without tail.



Vickers M T 1000 (C 132 D) Effect of flaps with small tail

FIG 6.

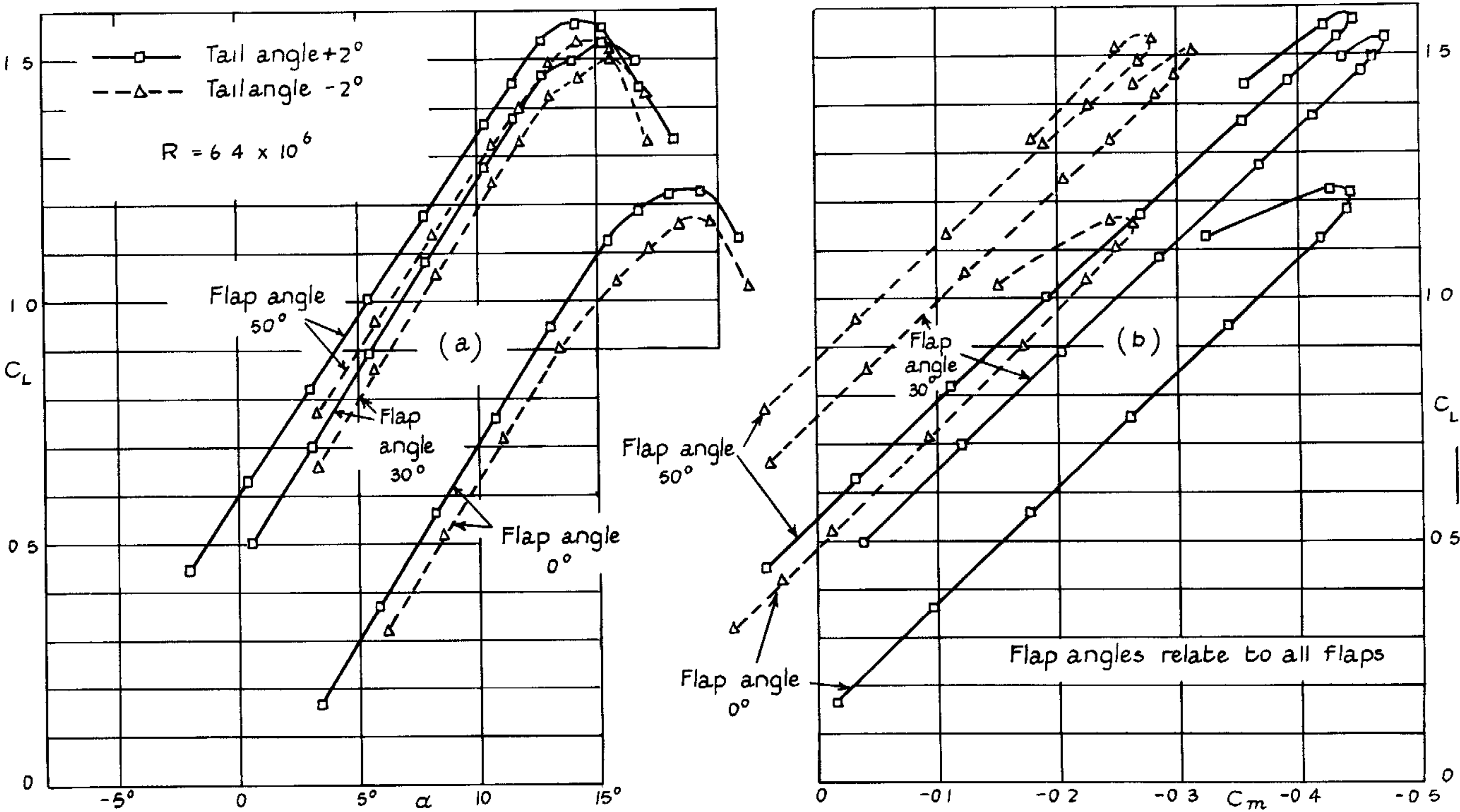
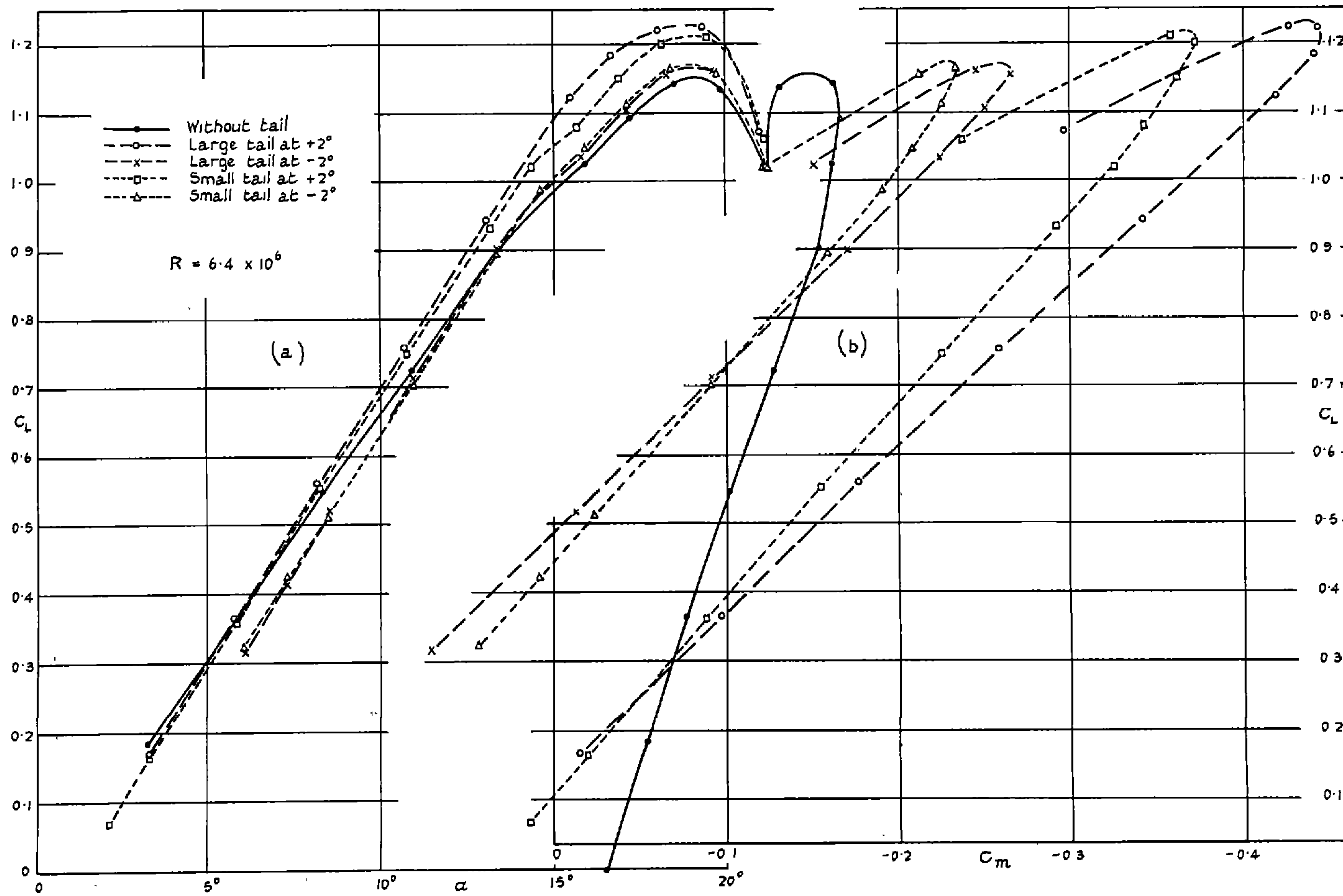


FIG 7.

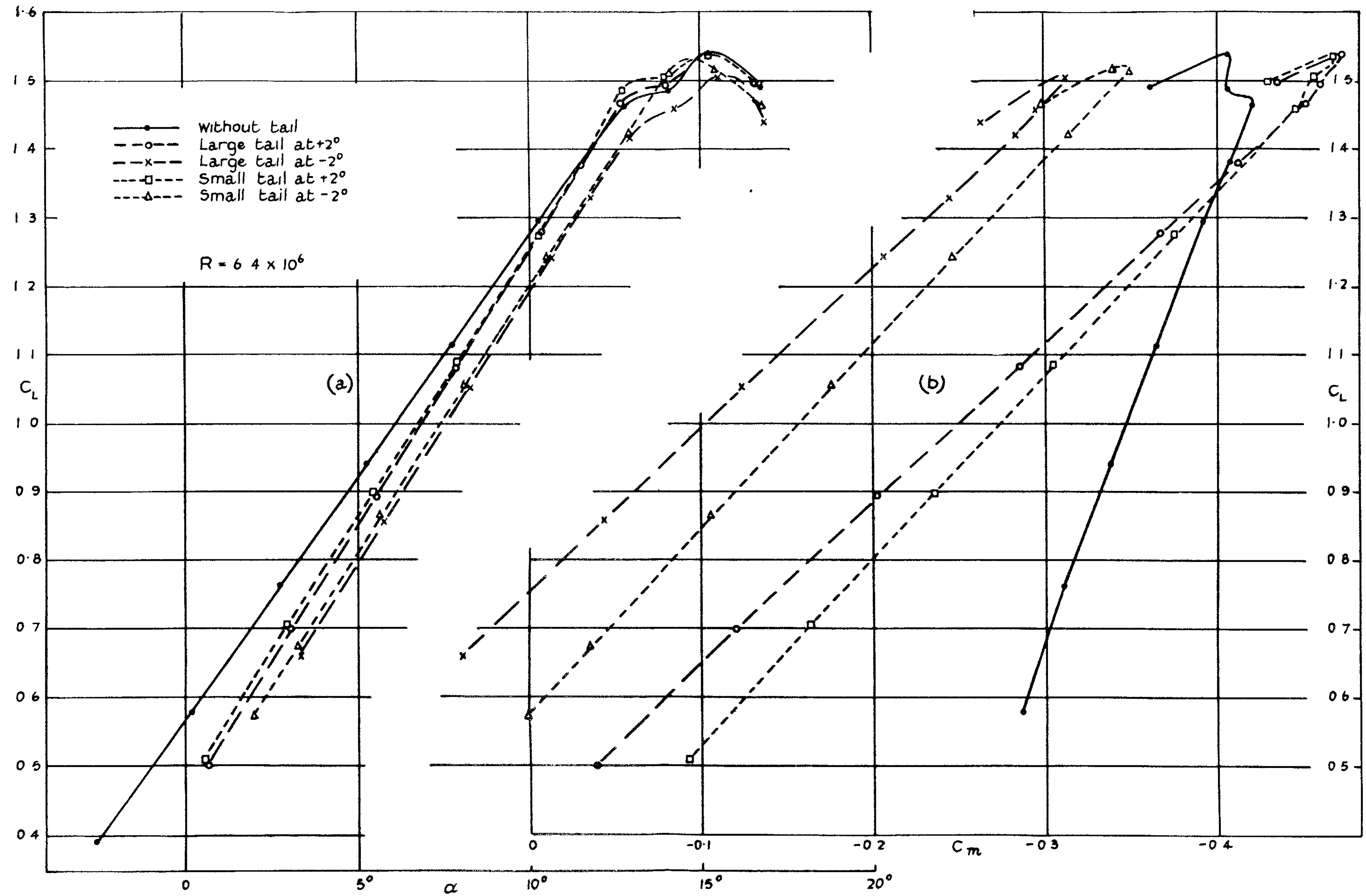
Vickers M T 1000 (C 132 D) Effect of flaps with large tail.



Vickers M.T. 1000 (C. 132 D). Comparison of large and small tail units

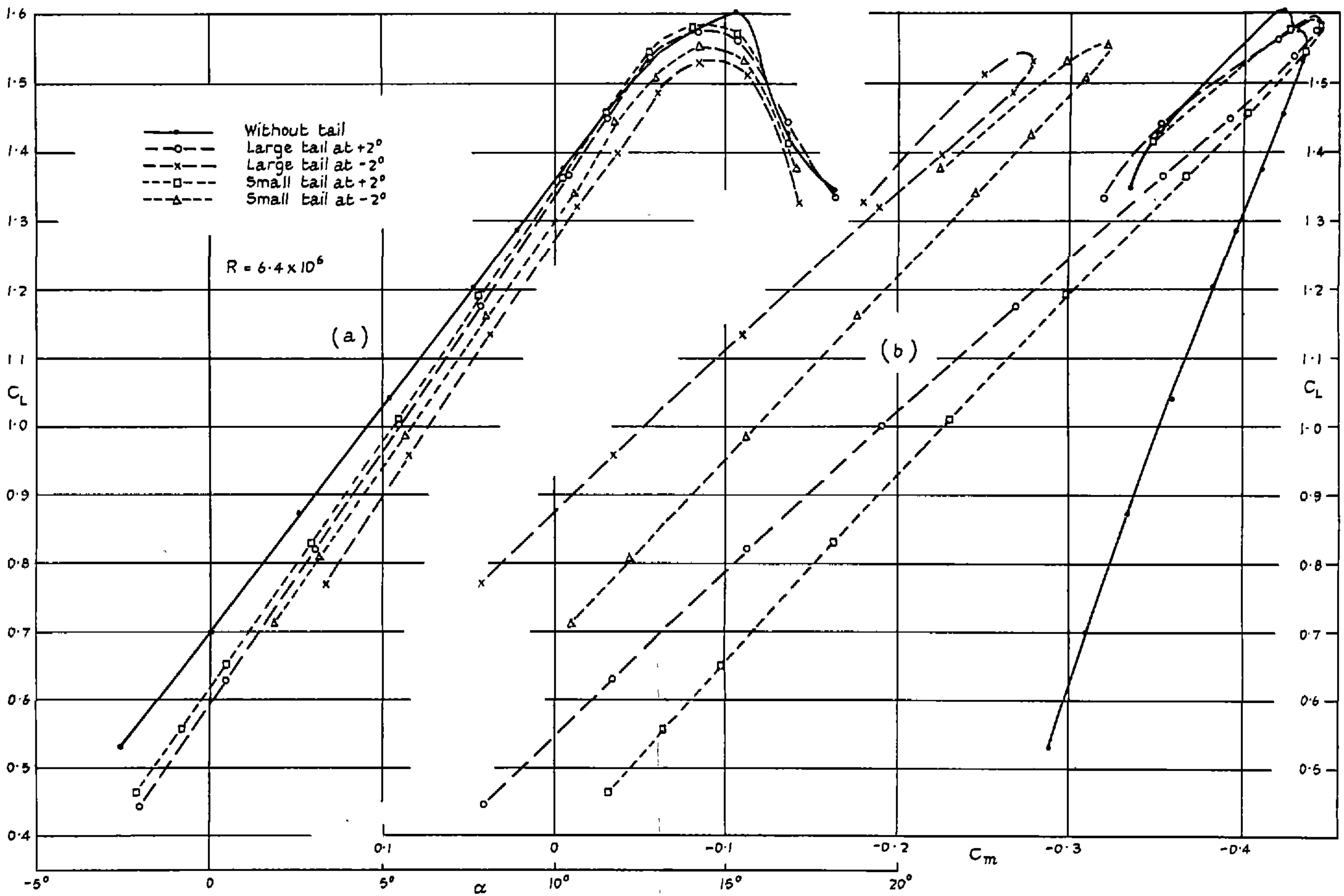
Flaps 0°.

FIG 9.



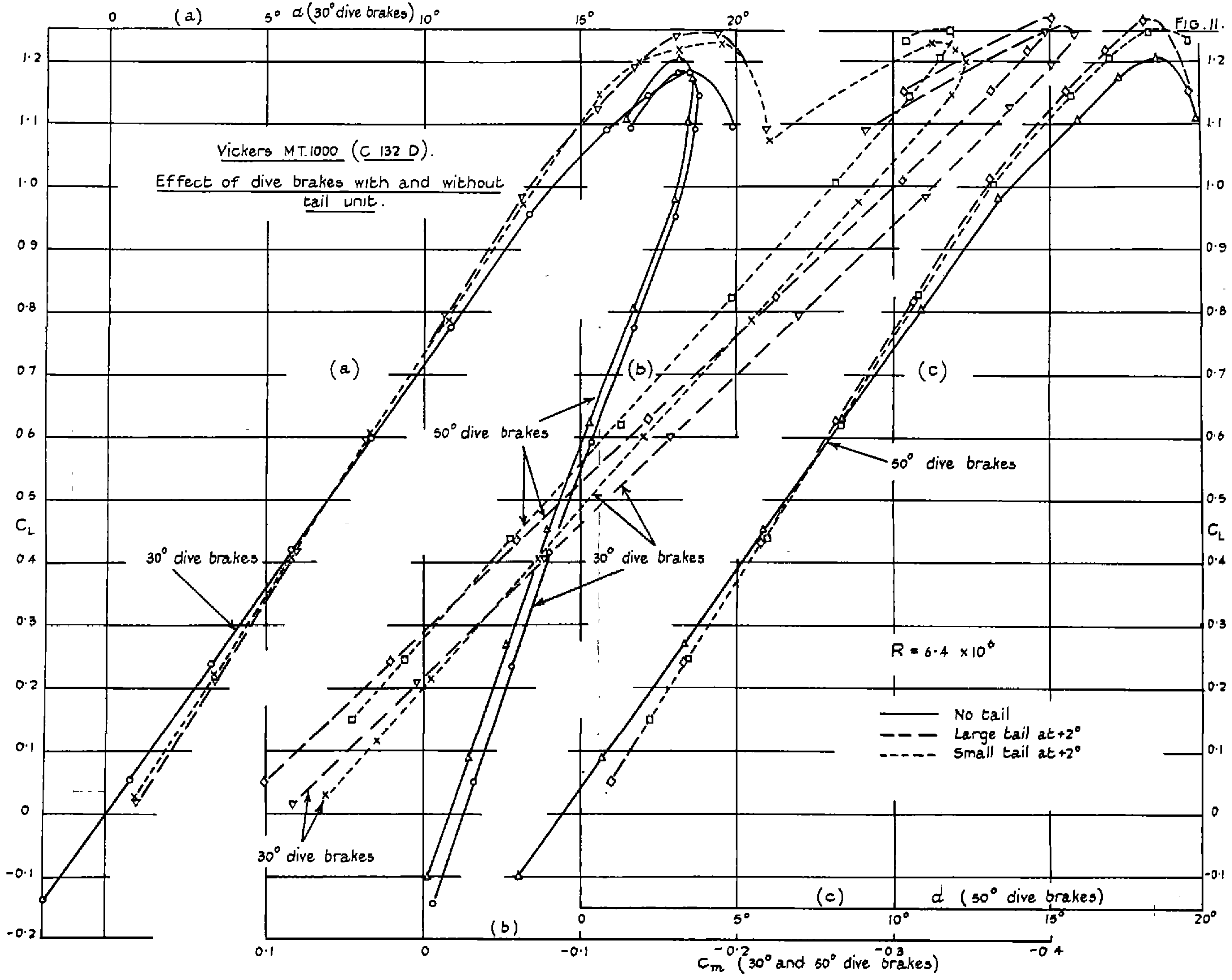
Vickers M T 1000 (C 132 D). Comparison of large and small tail units

All flaps at 30°



Vickers M.T. 1000 (C 132 D). Comparison of large and small tail units.

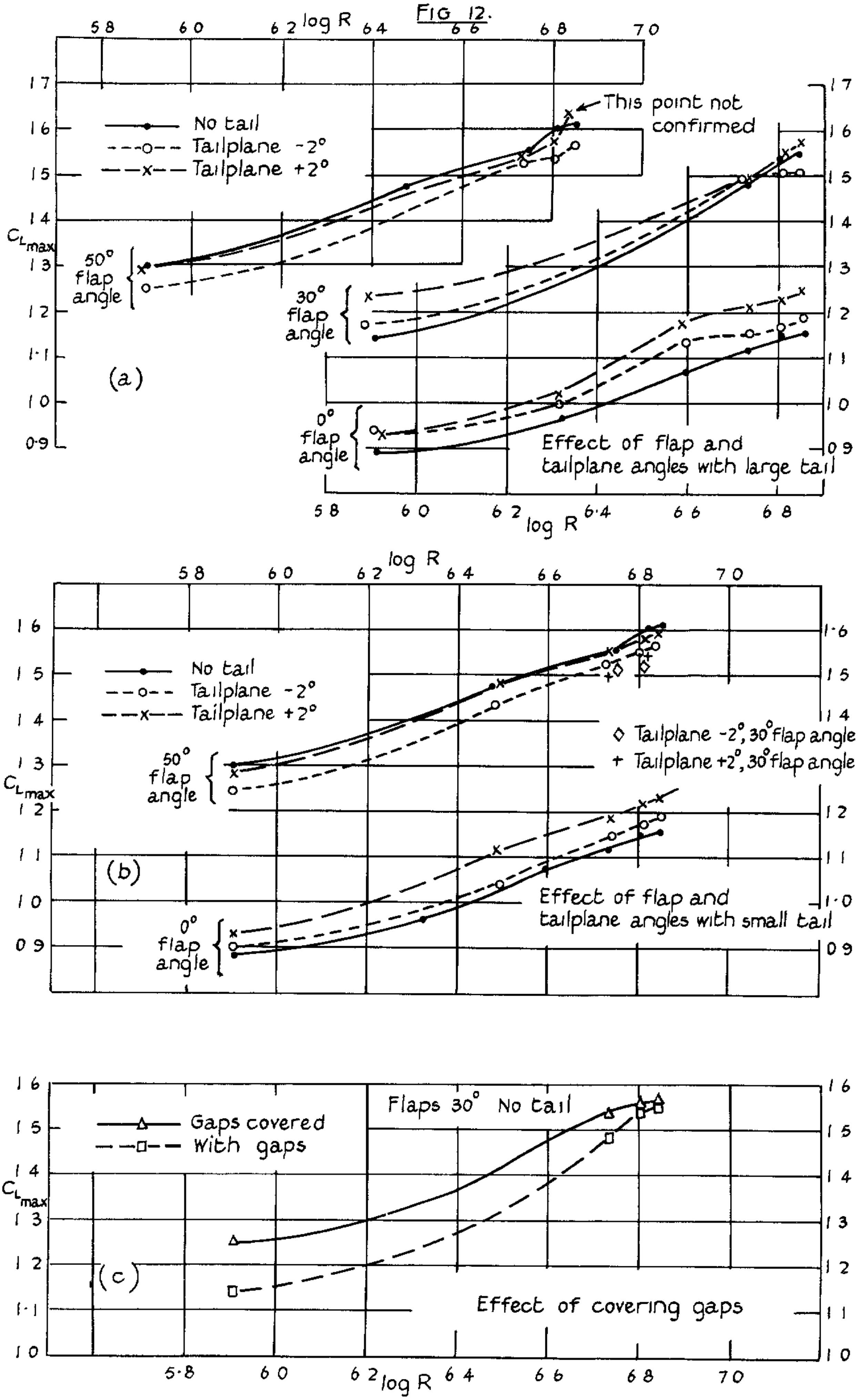
All flaps at 50°.



Vickers M.T.1000 (C 132 D).
Effect of dive brakes with and without tail unit.
(a)
(b)
(c)
α (30° dive brakes)
α (50° dive brakes)
0
5°
10°
15°
20°
C_L
C_m (30° and 50° dive brakes)
0·1
0
-0·1
-0·2
-0·3
-0·4
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
-0·1
-0·2
30° dive brakes
50° dive brakes
R = 6·4 ×10⁶
No tail
Large tail at +2°
Small tail at +2°

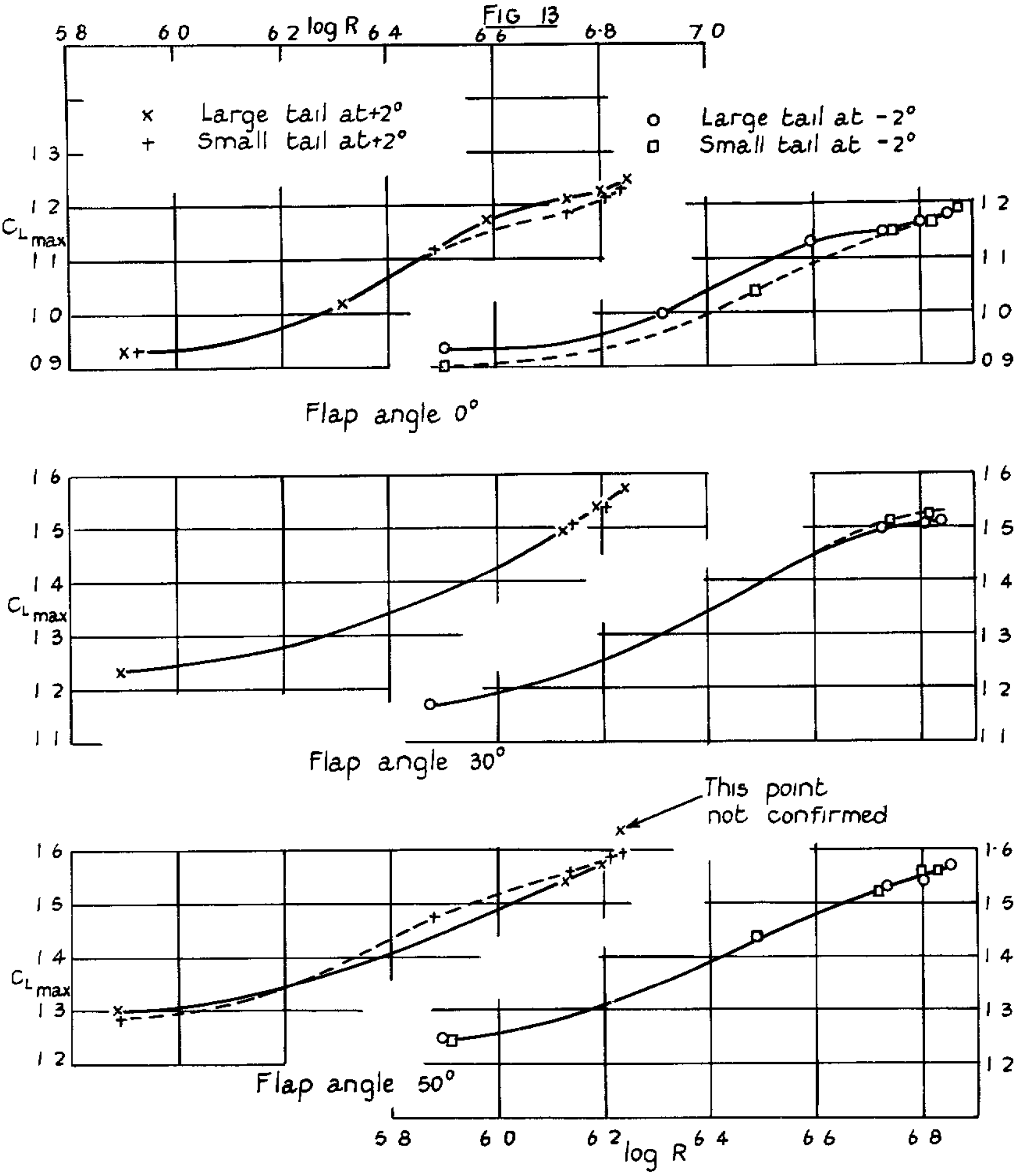
FIG. 11.

FIG 12.

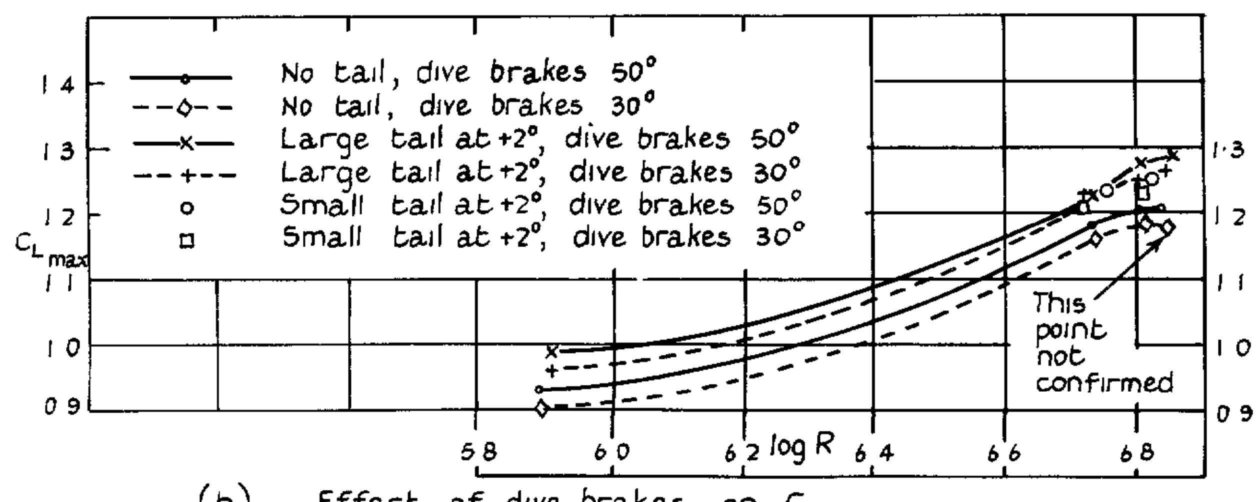


Vickers M T 1000 (C 132 D)

FIG 13



(a) Effect of tailplane area on $C_{L\,max}$



(b) Effect of dive brakes on $C_{L\,max}$

Vickers M T 1000 (C 132 D).

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