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Part 2. Longitudinal Stability and Control

by

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LOW SPEED FLIGHT TESTS ON A TAILLESS DELTA WING AIRCRAFT (AVRO 707B)
PART 2 LONGITUDINAL STABILITY AND CONTROL

by

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SUMMARY

Flight tests have been made to measure the static and dynamic longitudinal stability, the effect of ground on stability, and the elevator power of the Avro 707B which has a delta wing sweptback 44.5°. A comparison of the results with those of tunnel tests is made.

There is a loss of static stability, stick fixed and free, above a lift coefficient of 0.5. Stick force/g at low speed is small particularly at the aft cg position, although no great difficulties were encountered due to this or the lack of static stability during the approach and landing.

* Replaces R.A.E. Technical Report 67198 - A.R.C. 30846

CONTENTS

1 INTRODUCTION

Longitudinal stability tests have been made as part of a general investigation of the low speed characteristics of a small delta wing aircraft (Avro 707B). Results obtained from other parts of this programme are presented in Refs.1, 2 and 3. The tests described in this Report included static and dynamic stability measurements, aircraft response to elevator movement, and the effect of ground on longitudinal stability. A comparison of these results with tunnel tests is made. The tests described occupied about 30 hours flying time during the early part of 1953.

2 PROGRAMME OF TESTS

The tests consisted of:-

(a) Measurement of static longitudinal stability in the cruising and landing configurations, power off and with power on at 14000 rpm in the cruising configuration and 12000 rpm in the landing configuration. Also stability measurements were made undercarriage up, air brakes out, power off.

(b) Measurement of dynamic longitudinal stability in the cruising configuration with thrust for level flight.

(c) Measurement of aircraft response to elevator movement at a typical approach speed.

(d) Measurement of ground effect on longitudinal stability.

The instrumentation for these tests remained as described in Ref.1, which also includes a full description of the aircraft itself. The aerodynamic data relevant to this Report are given in Table 1.

3 STATIC STABILITY

The two basic configurations used were those for cruising and landing; the cruising configuration is the condition with airbrakes closed, undercarriage retracted, and the landing configuration that with undercarriage lowered and airbrakes extended. The cg range covered in these tests was from 0.305 $\bar{c}$ to 0.362 $\bar{c}$.

The tests were made by trimming the aircraft over a range of speeds in the required configuration and recording measurements of elevator angle, trim tab and spring tab angle. All the measurements were made between 7000 and 14000 ft. The curves of elevator angle to trim (Figs.2-6) have been corrected to zero trim tab angle using the values of $d\eta/d\beta$ previously obtained during flight tests by the firm, modified to allow for the increase in trim tab size. It has not been possible to obtain a direct measurement of $d\eta/d\beta$ during flying at the R.A.E. due to the difficulties involved in locking the spring tab system. The elevator angle to trim curves are of necessity at zero spring tab angle since during the test the stick force is trimmed to zero.

The neutral points, stick fixed, (Fig.7) were obtained from the basic curves of elevator angle to trim by the usual methods. The change in elevator angle to trim at a given lift coefficient with change in cg position gave the elevator power as shown in Fig.8. Finally the static margins in the various configurations were derived from the product of elevator power and trim curve slope at corresponding trimmed lift coefficients and are shown in Figs.9a and b.

The stick fixed neutral point positions and static margins are practically constant up to a lift coefficient of just over 0.4. Above this value there is a marked reduction in longitudinal stability in both the cruise and landing configurations. With power off, this trend is arrested at a lift coefficient of between 0.6 and 0.7. With power on, however, the deterioration continues up to higher lift coefficients and the same is true in the case with airbrakes extended but with power off. There are indications of subsequent improvements in stability at very high lift coefficients (> 0.8).

The recovery in stability, power off, continues to at least a lift coefficient of 0.8 in the cruise configuration, where it is restored to approximately the value at low lift coefficients. In the landing configuration, however, the reduction in stability between lift coefficients of 0.4 and 0.6 is much greater than in the cruise case and only a small improvement beyond a lift coefficient of 0.7 was noted.

The marked change in stability at lift coefficients between 0.4 and 0.6 is attributed to the spread inwards from the wing tips of a region of separated flow. These changes in flow pattern over the wings are described in Ref.3, where it is shown that the spread of the stalled area inwards starts at a lift coefficient of about 0.4 and at a lift coefficient of 0.6 it is spreading rapidly. The development of this stalled area, as shown in Fig.10, does not, however, account for the improvement in stability at lift coefficients of 0.6 and upwards, for at these values the separation has only moved inboard by 25-30% of the semi-span from the tip.

The effect of engine thrust on stability is complicated. At low lift coefficients in the cruise configurations the stability improves slightly with thrust, while in the landing case, thrust is slightly destabilising. At higher lift coefficients the effect of thrust is generally to delay the reduction in stability margin described above. This may be explained by the local air flow over the body and the inboard sections of the wing being particularly sensitive to intake conditions at the higher incidences.

The "tab angles to trim" curves (Figs.11-15) have been analysed to give neutral points and static margins stick free by methods similar to those used in the stick fixed case. The neutral points (Fig.16) in all conditions remain constant up to a C_L of 0.4. At lift coefficients greater than this they move forward with no indications of later moving aft as in the stick fixed case. There is a steady decrease in the static margins for the cruising configuration (Fig.18), both power on and off, at lift coefficients greater than 0.4. This stick free instability at high values of C_L is probably due to a positive value of b_1 of the control at high incidence. Engine thrust gives an increase in stability throughout. In the landing configuration a similar change with lift coefficient is shown, although the engine is destabilising below a C_L of approximately 0.5 and stabilising at higher lift coefficients.

Estimates of elevator and trim tab power have been made from the trim curves with the results given in Figs.8 and 17. There is a marked decrease in elevator power from cruising to landing configuration (at low values of lift coefficient the decrease in $d\,C_M/d\eta$ being from about 0.29 to 0.18) and a similar decrease in trim tab power. The effect of engine in both cases is not very marked, giving a decrease in trim tab power but an increase in elevator power at lift coefficients less than 0.5 and a decrease at higher values. A possible explanation of part of the decrease in elevator power and of most of the decrease in trim tab power resulting from changing from cruising to landing configuration is that the elevators are in the wake of the air brakes when these are extended. Fig.8 shows, that there is also a substantial reduction in elevator power when the undercarriage is extended.

4 DYNAMIC STABILITY

4.1 General handling

The aircraft was flown at three cg positions to investigate the handling characteristics with applied normal acceleration. The warning of the g stall was found to be long and progressive occurring well before the limiting characteristics of wing dropping or instability. The first warning is a high frequency buffet which is heard and faintly felt in the airframe; it appears to occur a little sooner at forward cg than at aft cg. No subsequent instability was experienced at forward cg though there was some lateral unsteadiness, but occasional stick free instability was experienced at the aft cg. The range of speed for these tests was 150 to 300 knots.

At the forward cg position (0.303 $\bar{c}$) as the normal acceleration is increased, a left wing heaviness starts, and then a general lateral unsteadiness replaces the wing heaviness with occasional wing 'pecking' (i.e. small amounts of wing dropping). The limits to which g was applied were about 3 g at 300 knots and 1.75 g at 150 knots. No lightening of elevator force was found; stick force/g was not heavy (about 10 lb) but stick movement/g was moderately large. Aileron effectiveness was good throughout.

At the aft cg position (0.356 $\bar{c}$) during the approach to the g stall there was some lightening of stick force and occasional marked stick free instability. The stick force/g at this cg position was very small; at 200 and 250 knots about 1-3 lb and at 300 knots about 5 lb. Stick movement/g was also quite small. Flight with stick force/g close to zero was not difficult except that the elevator circuit inertia was more noticeable than usual and some slight "switchbacking" occurred on take-off after unstick. Aileron effectiveness was quite adequate throughout.

4.2 Manoeuvre margins

The standard R.A.E. pull out technique (Ref.4) was used to obtain stick force and elevator angle/ g and hence the manoeuvre points and manoeuvre margins. Fig.19 shows typical time records of pull outs at 200 and 150 knots. A number of pull outs were made over the available range of normal acceleration between 150 and 300 knots, in the cruising configuration with power for level flight. This was repeated at each of three cg positions and Fig.20 and 21 show the stick force, elevator angle and spring tab angle plotted against the excess g applied for the pull outs at 150 and 250 knots. The scatter of the points is not excessive and the results for stick force/g are reasonably consistent.

Fig.22 shows a plot of stick force/g, elevator angle/g, and spring tab angle/g against speed at three cg positions. It will be noted that the shape of the stick force/g and spring tab angle/g curves are not similar as would be expected where the spring tab angle applied is proportional to the stick force. This is because the elevator is fitted with main and subsidiary torsion bars, and at the higher speeds the low "spring strength" of the subsidiary torsion bar allows the tab to "blow off". At the aft cg between 150 and 250 knots the stick force/g is extremely small as mentioned in para. 4.1. The manoeuvre points stick fixed and free are given in Fig.23 and manoeuvre margins stick fixed in Fig.24. The manoeuvre margin decreases steadily over the C_L range 0.1 to 0.4 which is the maximum lift coefficient which could safely be used for these tests. It is interesting to note that at lift coefficients greater than 0.3 with cg aft the aircraft was being flown with the stick free manoeuvre point ahead of the cg and also during the landing approach the aircraft was statically unstable both stick fixed and free but no great difficulties were found whilst flying in this condition in calm weather.

Figs.25 and 26 show the lift coefficient for the onset of instability (i.e. stick free, dynamic) and buffet boundaries, and the extent of the stalled area at the trailing edge of the wing for instability and buffet, plotted against Mach number (cg 0.338 $\bar{c}$). This information was compiled from pilots' reports and time histories and from tuft pictures taken during pull outs. It will be noted that both the lift coefficients for instability and those for onset of buffet decrease in a similar manner with increasing Mach number.

Fig.27 shows the area of wing stalled, as deduced from the tufts, at onset of buffet and when instability occurs at various speeds and lift coefficients. Over the range of Mach number covered the area of wing stalled is approximately the same when buffet occurs and similarly when instability occurs. Instability does not seem to start until about half the aileron has been stalled but when this has started there is then a rapid deterioration with only a very small increase in stalled area.

5 ELEVATOR RESPONSE

It was suspected that there might be some lag between the movement of the elevator and the response of the aircraft, because of the comparatively large effect on overall lift of elevator deflection. Aircraft response to elevator movement was assessed by fitting a sensitive accelerometer, covering the range 0.5 to 1.5 g, mounted so that it measured acceleration normal to 3° glide flight path. The aircraft was trimmed in a 3° glide at 125 knots and the stick pulled back until the attitude was increased by about 3° and a time record of elevator angle, normal acceleration, angle of pitch, stick force and spring tab angle was made. Typical time records with air brakes in and out are given in Fig.28.

From the records it was found that there was no appreciable lag before the attitude changed after an elevator movement but there does seem to be a very small region of negative (< 1.0) g in the air brakes out case. No lack of response was reported by the pilots.

6 GROUND EFFECT

Measurements of the effect of ground on elevator angle to trim were made during the tests described in Part 1 of this Report. Figs.29 and 30 show the results obtained from these tests; the scatter of the points is fairly large but the trends of the curves are quite clearly defined. The ground appears to have a stabilising effect which becomes more marked with increase of lift coefficient. In all cases the aircraft was flown undercarriage down but with airbrakes in (Fig.29) and out (landing configuration, Fig.30). The height of the aircraft as given on the figures represents the height of the mean quarter chord point of the wing above the ground obtained as an average from all the runs made.

7 FLIGHT AND TUNNEL COMPARISON

Comparisons of flight results have been made with results obtained from tunnel tests done by the firm in their own tunnel (Ref.5 and 6), by the N.P.L. in the Compressed Air Tunnel (Ref.7) and by the R.A.E. in No.2 $11\frac{1}{2}$ft tunnel (Ref.8). These are shown in Figs.31 to 37 in which the flight results have been corrected to the cg positions at which the tunnel results apply. A summary of the differences between the various tunnel models and the aircraft itself are given in Table 2. The Reynolds number of the tests were:- flight 10 to 30×10^6, C.A.T. 12.5×10^6, R.A.E. tunnel 4.7×10^6, and Avro tunnel 1.4×10^6.

It is shown in Fig.32 that all the tunnel results give a more positive value of C_{m_o} than was derived from the flight tests. The slopes of the pitching moment curve obtained from the C.A.T. tests[7] agree well with that of the flight curve at the same cg position up to C_L of 0.6 but at the higher values of C_L, where there are considerable areas of separated flow, agreement is not so good. Both the R.A.E. and the Avro tunnel results show a more stable slope of the pitching moment curve than the corresponding flight results.

The changes in elevator angle to trim and pitching moment due to extending the air brakes are given in Figs.33 and 34 respectively where the values obtained from flight tests are compared with the Avro tunnel results[6].

Flight and tunnel values of elevator power $\left(\frac{\partial C_m}{\partial \eta}\right)$ are compared in Fig.35. The agreement between the C.A.T. values and those obtained from flight tests is excellent. The poorer agreement between the R.A.E. tunnel results and the flight values than between the Avro tunnel results and flight is explained by the R.A.E. model being not representative in the following respects:- there were no engine intakes, and a dummy fuselage was used (see Table 2). Both tunnel results[6] and flight values show a reduction in elevator effectiveness due to opening the air brakes (Fig.36).

The comparison of tunnel[9] and flight results on the effect of ground on elevator angles to trim show that the increase of stability due to ground was greater in the tunnel than found in flight (Fig.37). This may be explained by the considerably lower Reynolds number (2.0×10^6) of the tunnel tests.

8 CONCLUSIONS

(i) The aircraft is stable, stick fixed, in all conditions up to lift coefficients of about 0.5; there is a decrease in stability at high lift coefficients but in the cruising configuration above a C_L of 0.7 there is a recovery of stability.

(ii) There is a loss of stability, stick free, at lift coefficients greater than 0.5 and at the aft cg (0.362 $\bar{c}$) the aircraft is unstable throughout the range.

(iii) There is a loss in elevator power from cruising to landing configuration.

(iv) At the aft cg stick force/g is very small but the aircraft could be flown satisfactorily in calm weather both when the stick free manoeuvre point was ahead of the cg and when static instability, stick fixed and free, was present.

(v) There is no lack of aircraft response to elevator deflection.

(vi) The effect of ground on elevator angle to trim is stabilising, increasing with increasing lift coefficient.

(vii) Comparison with the results of various tunnel tests showed that:

(a) in all cases the flight results give a larger $-C_{m_0}$

(b) the agreement between the longitudinal stability as measured in flight and in the C.A.T. is good but tunnel tests done at a lower Reynolds number showed poorer agreement with flight

(c) the elevator power from C.A.T. tests agreed well with flight results.

Table 1

GENERAL AERODYNAMIC INFORMATION

Wing	
Span	33 ft
Gross area	366.5 sq ft
Standard mean chord	11.11 ft
Sweepback of 0.25 $\bar{c}$ (inboard)	44.3°
Sweepback of 0.25 $\bar{c}$ (outboard)	44.8°
Wing section	NACA 0010 (mod)
Elevators	
Total area (per elevator)	18.71 sq ft
Area aft of hinge line (per elevator)	13.18 sq ft
Mean chord aft of hinge line	2.24 ft
Control chord aft of hinge/local wing chord	0.150
Span perpendicular to centre line	5.885 ft
Spanwise limits	$(0.136\text{-}0.492)\ \frac{b}{2}$
Type of balance	Set back hinge with elliptical nose
Percentage balance	42.0%
Stick gearing	0.691 rad/ft
Range of movement	$+7^\circ$ to -25.5°
Elevator angle when in line with fairing	-3°
Trailing edge angle	12.5°
Control gap width	0.192 in
Elevator spring tab	
Type	Unbalanced
Area aft of hinge (per tab)	1.467 sq ft
Mean chord aft of hinge	0.4 ft
Spring tab chord/local control chord	0.24-0.168
Span	3.667 ft
Range of movement	$\pm 12^\circ$

Main and subsidiary torsion bars are fitted

Table 1 (Cont'd)

Elevator trim tab

Type	Circular nose
Area aft of hinge (per tab)	1.066 sq ft
Mean chord aft of hinge	0.485
Trim tab chord/local control chord	0.203-0.172
Span	2.198 ft
Range of movement	$+16^{\circ}$ to -14°

Weights

All up weight at take-off	9600 lb
Mean all up weight for tests	8700 lb

Table 2

COMPARISON OF FULL SCALE AIRCRAFT AND TUNNEL MODELS

	Full scale aircraft	Tunnel tests				
		Measurements of aileron and elevator hinge moments on the E15/48 (Avro 707B) Ref.8	707B aircraft W.T. Report 707/8 Ref.9	707B aircraft W.T. Report 707/16 Ref.6	707B aircraft W.T. Report 707/28 Ref.5	Compressed air tunnel tests Ref.7
Scale	Full	$\frac{1}{3}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	1/10
Reynolds No.	10.0×10^6 up to 30×10^6	4.7×10^6	2.0×10^6	1.4×10^6	1.4×10^6	12×10^6
cg position (Apex definition)	$0.305\ \bar{c}$–$0.362\ \bar{c}$	$0.295\ \bar{c}$	$0.330\ \bar{c}$	$0.330\ \bar{c}$	$0.330\ \bar{c}$	$0.3237\ \bar{c}$
Fuselage	-	Dummy fuselage	As full scale	As full scale	As full scale	The same diameter and length as full scale with a fairing representing the jet
Wing tips	Set at -2° to wing chord	Set at 0° to wing chord (starboard wing only)	Set at 0° to wing chord	Set at 0° to wing chord	Set at -2° up to wing chord	Set at 0° to wing chord
Elevators	Set at 0° to wing chord	Set at 0° to wing chord (symmetrical nose balance)	Set at 0° to wing chord	Set at 0° to wing chord	Set at 0° to wing chord	Set at 0° to wing chord
Ailerons	Set at -3° to wing chord	Set at -2° to wing chord	Set at 0° to wing chord	Set at 0° to wing chord	Set at -2° to wing chord	No ailerons fitted therefore trailing edge is not bent upwards at 2°
Fin and rudder	-	No fin and rudder	As full scale	As full scale	As full scale	No fin and rudder
Air brakes	Upper air brake 4 in chord, 60° angle lower air brake 5 in chord, 60° angle	Air brakes not as fitted to full scale aircraft	Air brakes not as fitted to full scale aircraft	Upper airbrake 4 in chord, 60° angle lower air brake 5 in chord, 60° angle	No air brakes fitted	Airbrakes not as fitted to full scale aircraft
Air intake	N.A.C.A. type submerged intake	No intake fitted	Original rear fuselage intake	Original rear fuselage intake	N.A.C.A. type submerged intake	No intake fitted
Undercarriage	Normal	None	None	None	None	None
Transition	-	Transition fixed on both surfaces at 15% local chord (by a wire)	Free	Free	Free	Free

SYMBOLS

b	span
C_L	lift coefficient $\dfrac{\text{Lift}}{\frac{1}{2}\rho V^2 S}$
C_M	pitching moment coefficient $\dfrac{\text{Pitching moment}}{\frac{1}{2}\rho V^2 S \bar{c}}$
$\bar{c}$	standard mean chord
$h\bar{c}$	distance of cg aft of leading edge of mean chord
h_m	value of h for zero stick travel per g i.e. at the manoeuvre point, stick fixed
h'_m	value of h for zero stick travel per g i.e. at the manoeuvre point, stick free
h_n	value of h when $K_n = 0$ i.e. at the neutral point, stick fixed
h'_n	value of h when $K'_n = 0$ i.e. at the neutral point, stick free
K_n	static margin, stick fixed
K'_n	static margin, stick free
S	wing area
V	forward speed
W	all up weight of aircraft
β_T	trim tab angle
β_S	spring tab angle
η	elevator angle
ρ	air density

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9	A.V. Roe & Co	1/8 scale model tests in the Blackburn and General Aircraft Ltd. tunnel on 707B. W.T. Report 707/8 (1950)

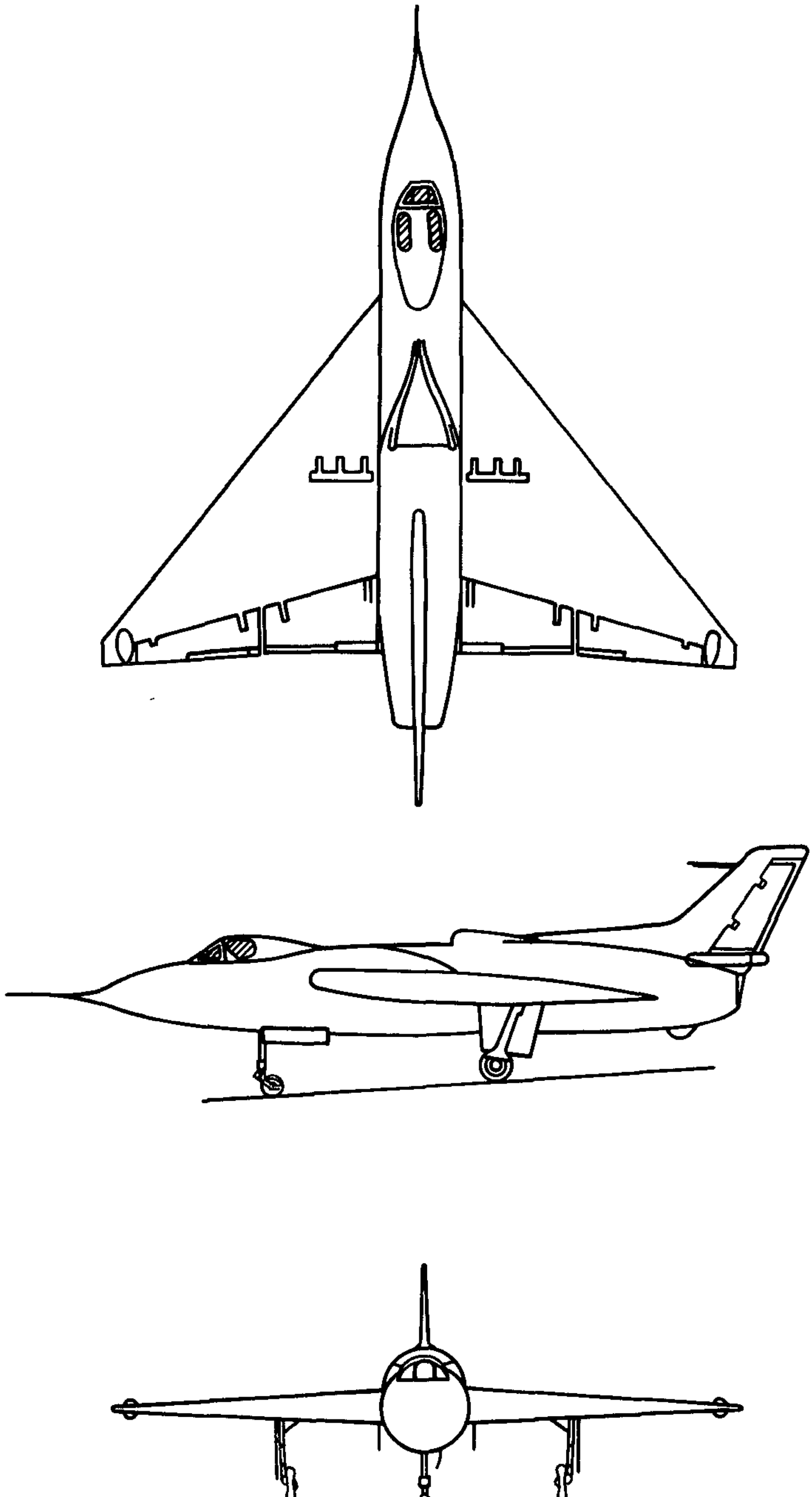


Fig.1 Avro 707B general arrangement

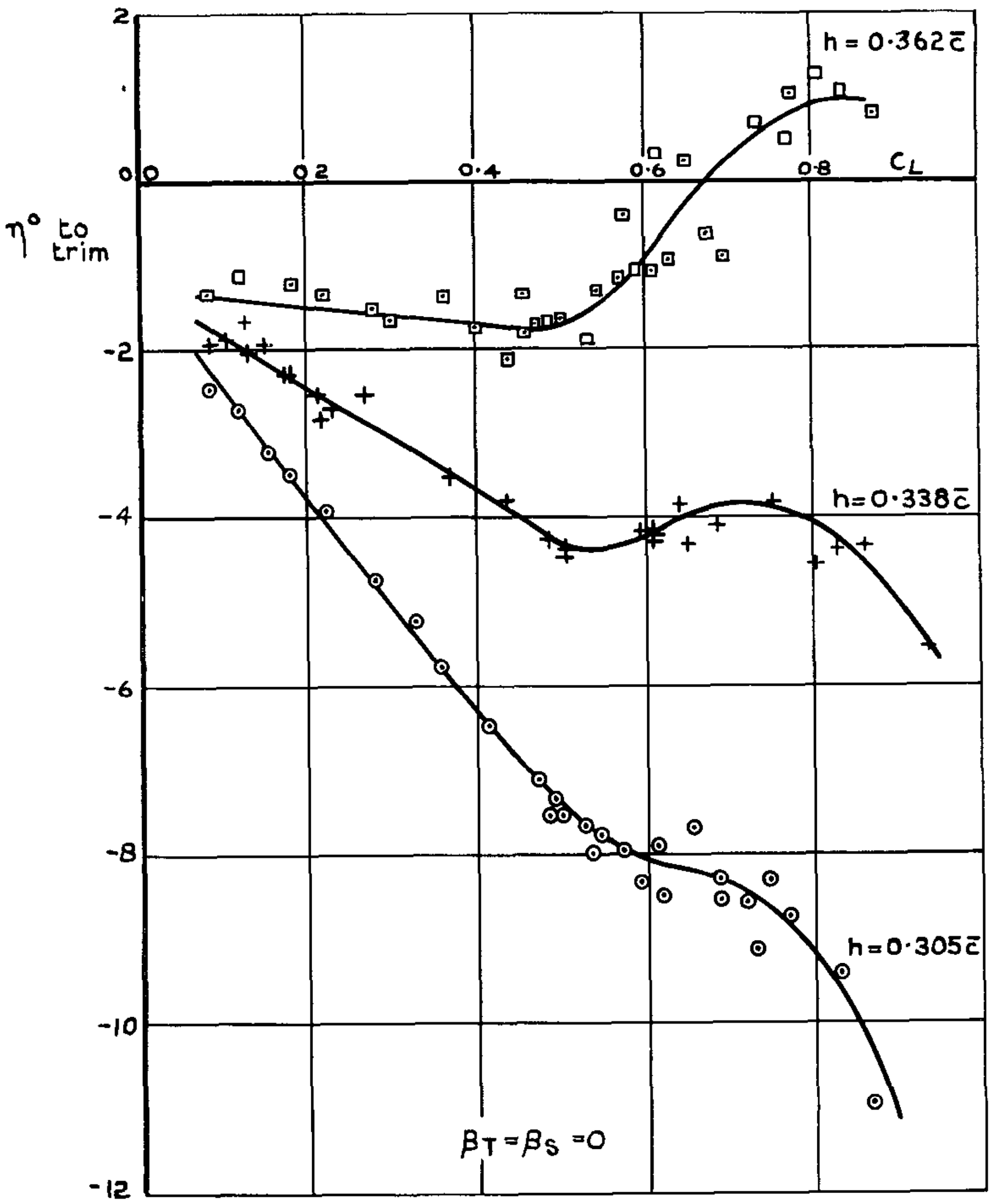


Fig. 2 Elevator angles to trim.
Cruising configuration,
engine rpm — idling

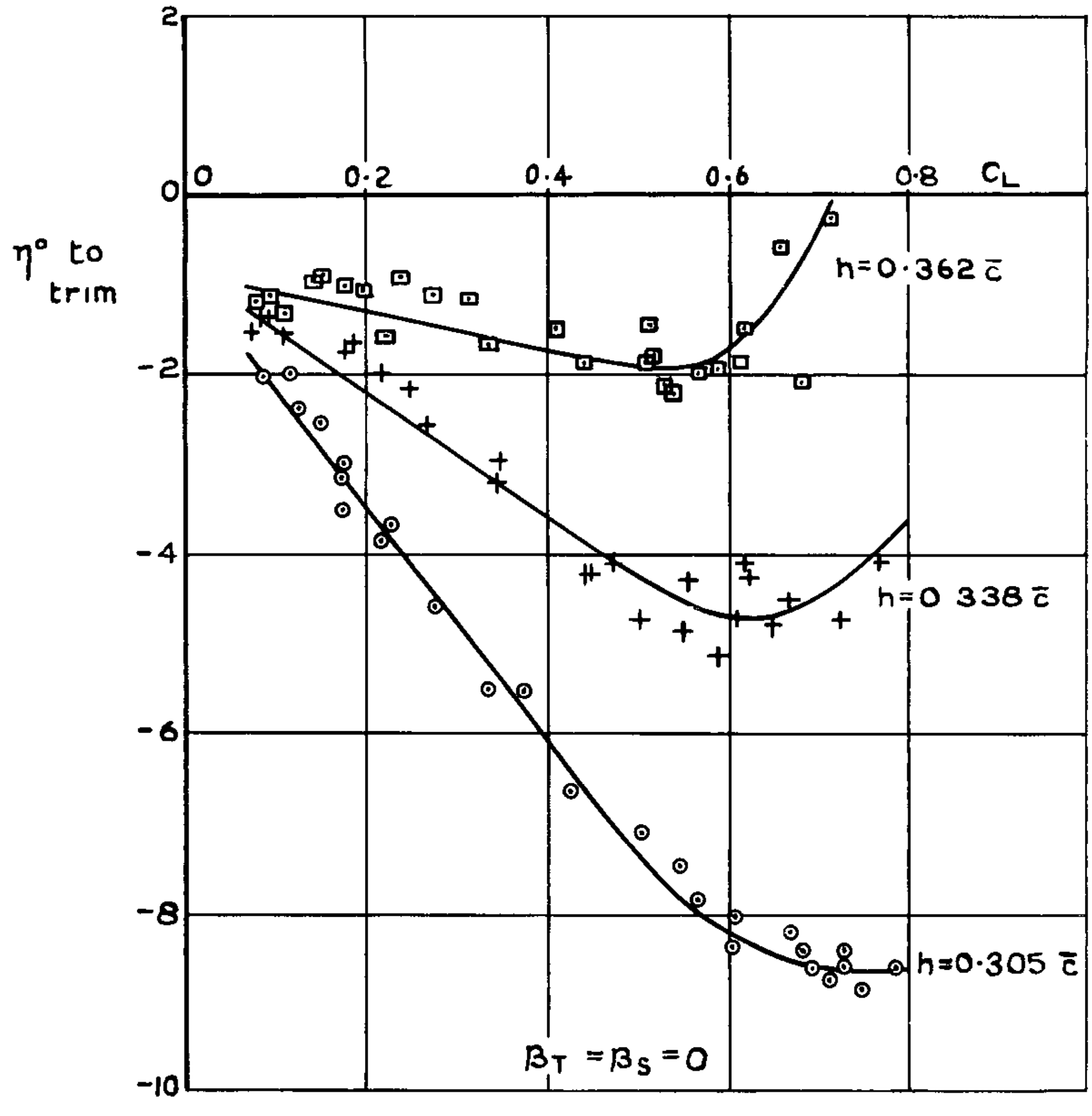


Fig 3 Elevator angles to trim.
Cruising configuration,
engine rpm – 14000

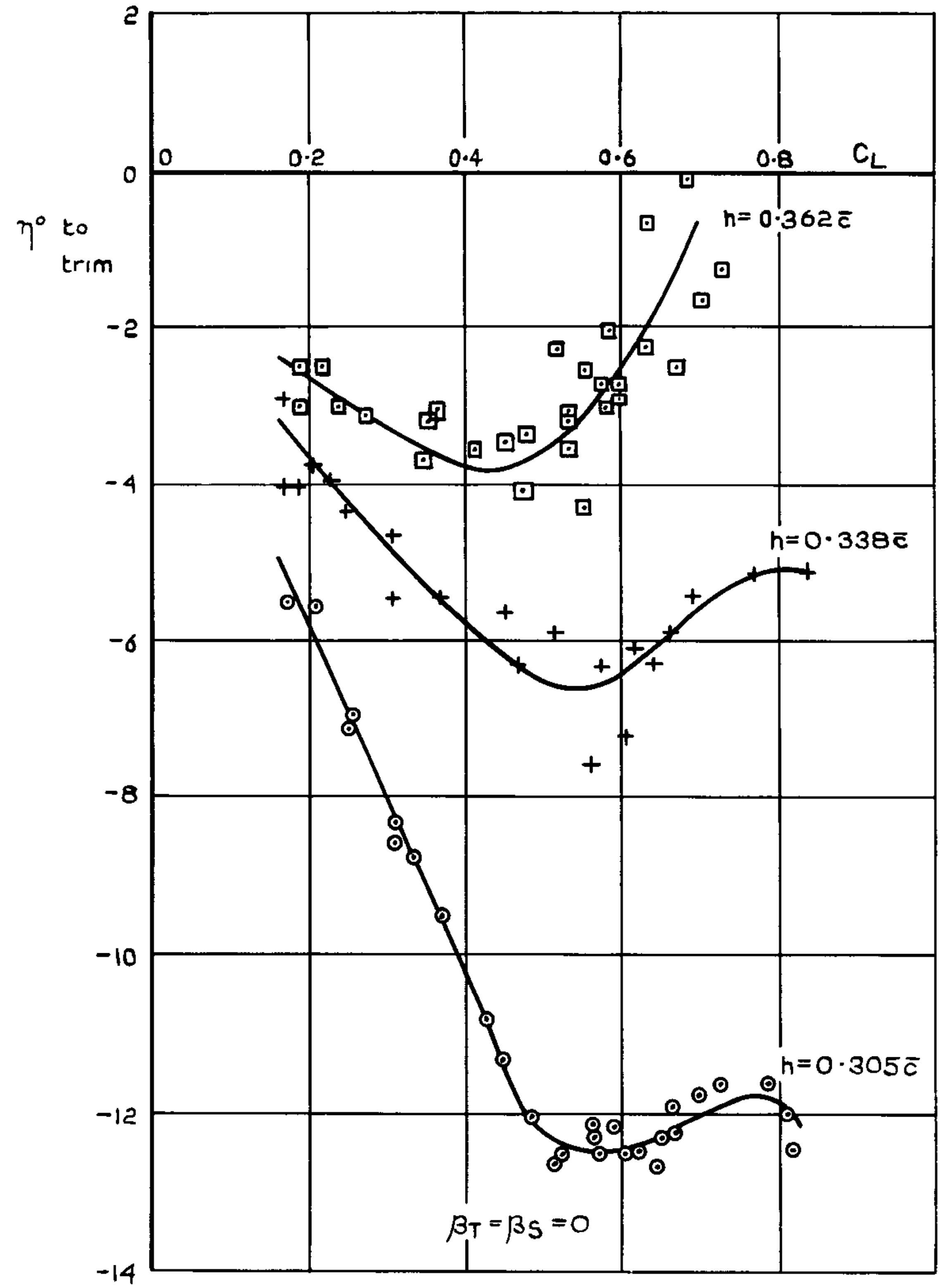


Fig. 4. Elevator angles to trim
Landing configuration,
engine rpm – idling

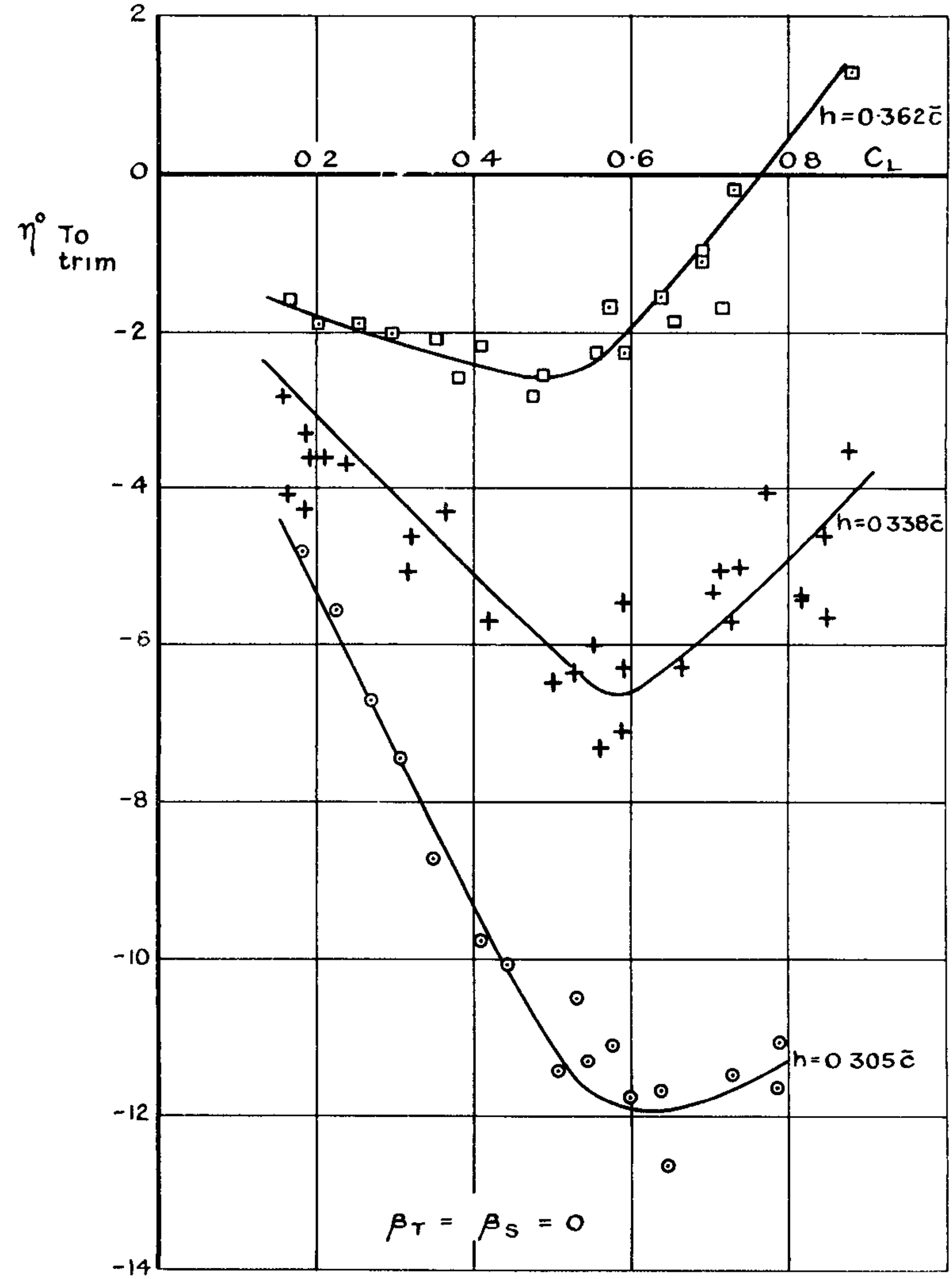


Fig. 5 Elevator angles to trim. Landing configuration, engine rpm — 12000

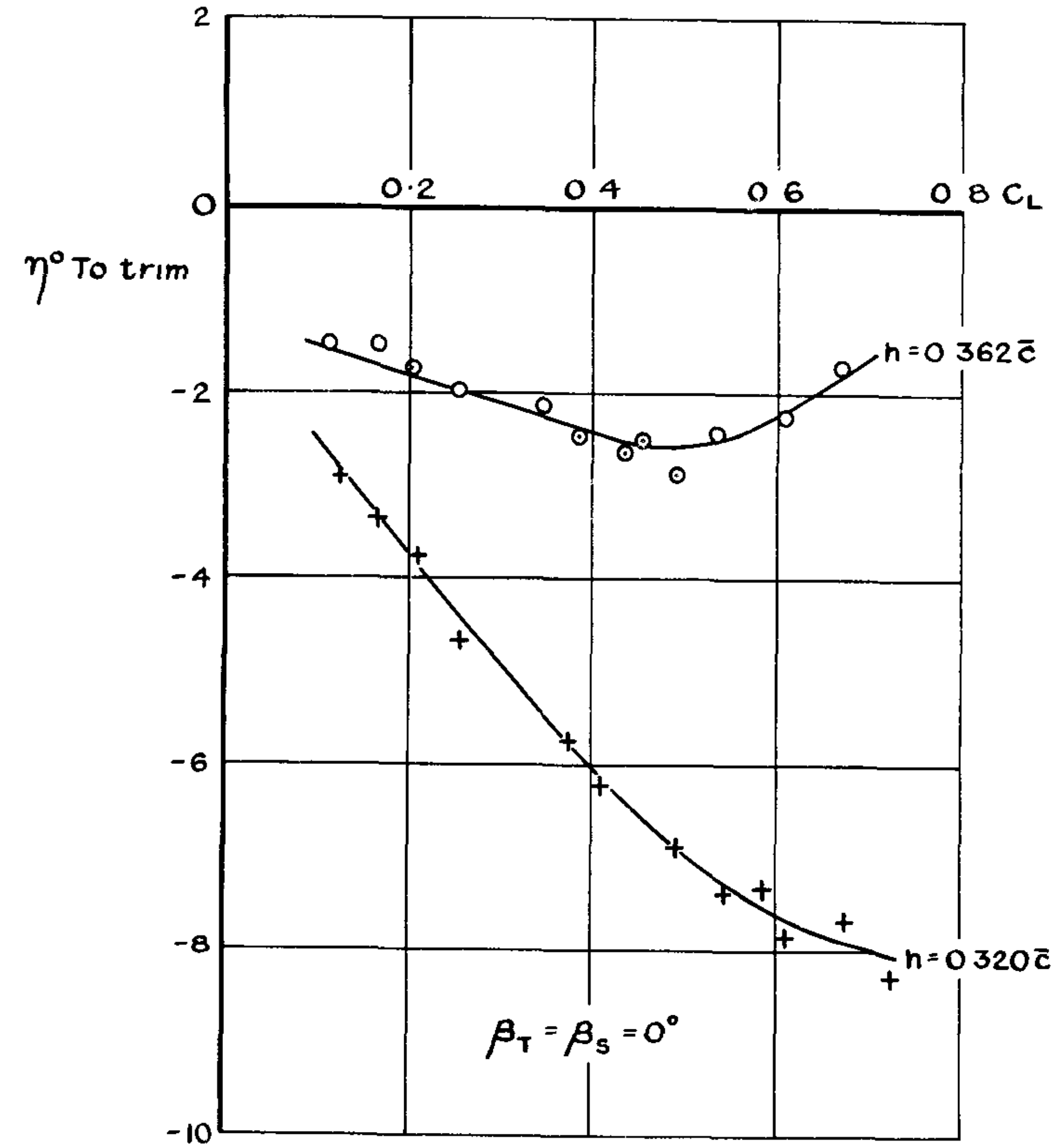
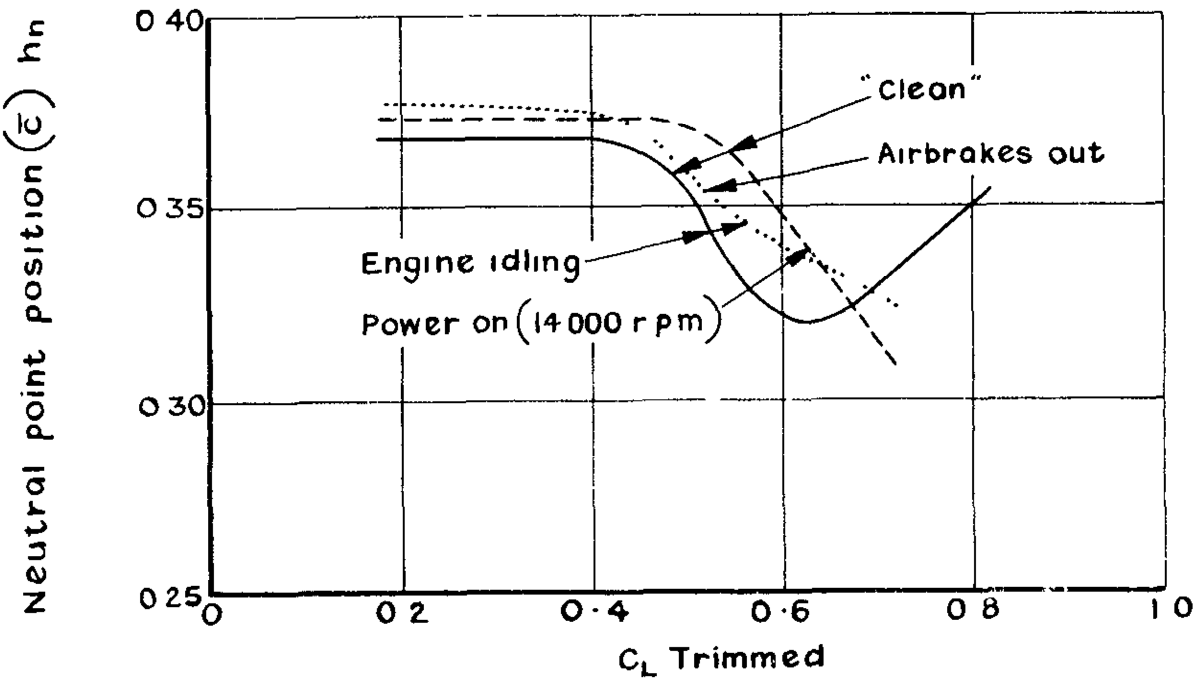
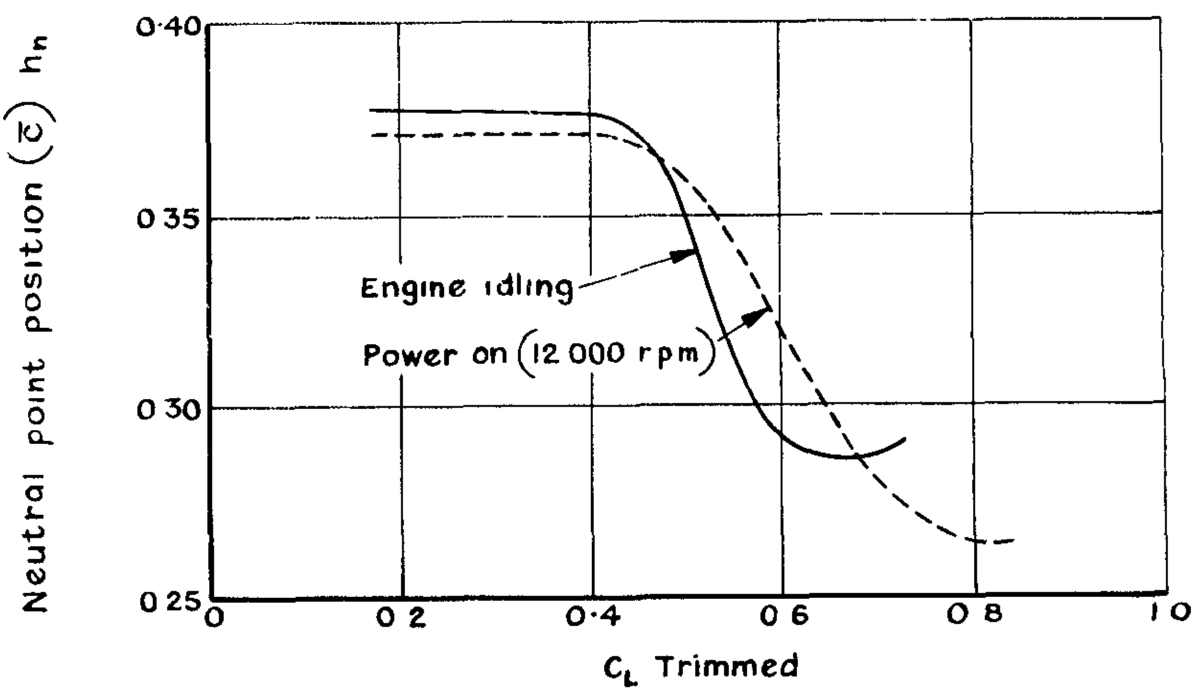


Fig.6 Elevator angles to trim. Air brakes out, undercarriage up, engine rpm – idling



a. Cruise configuration



b. Landing configuration

Fig. 7 a & b Stick-fixed neutral points

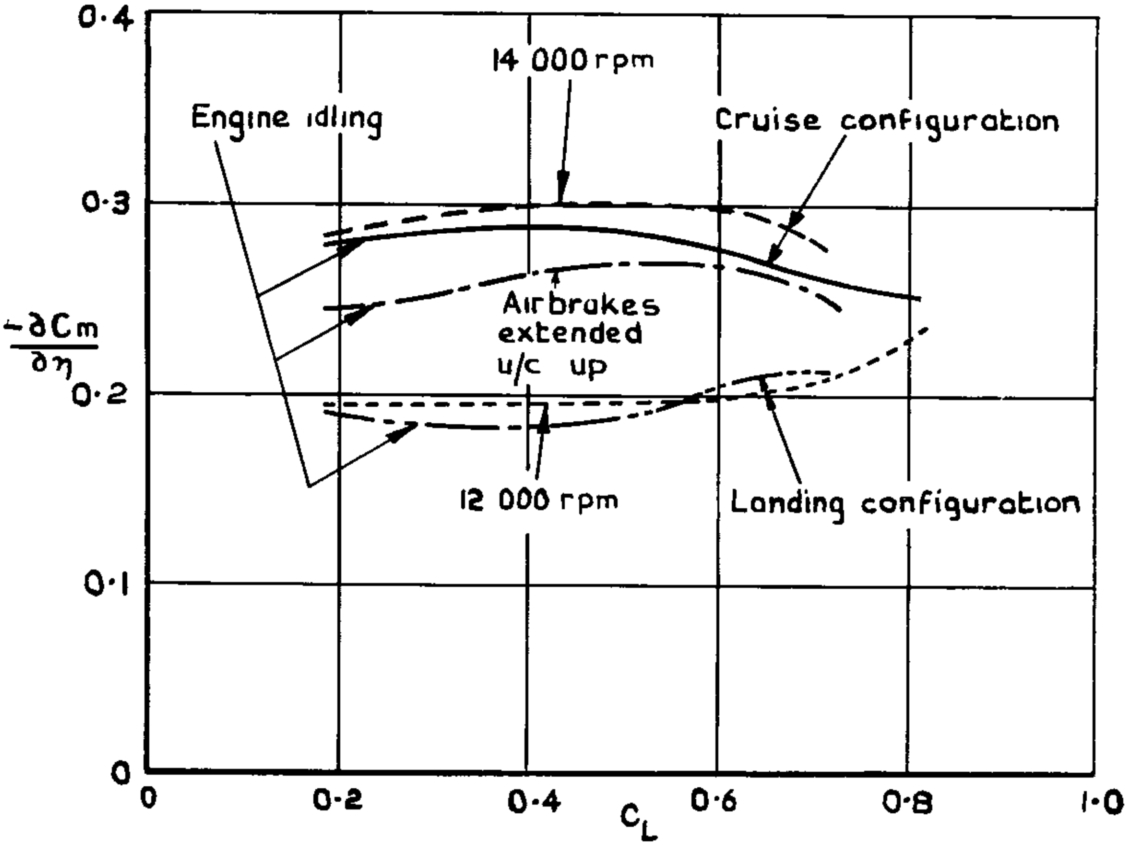
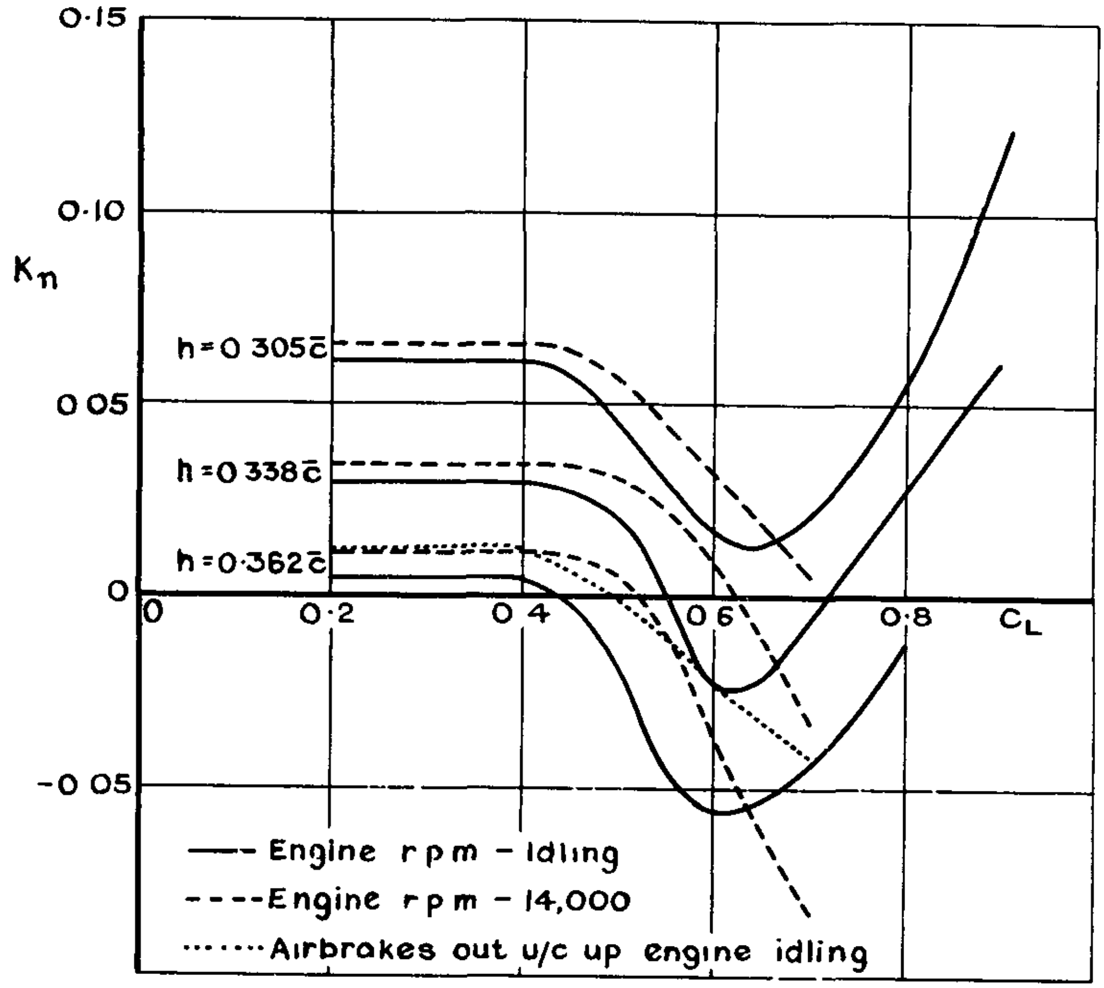
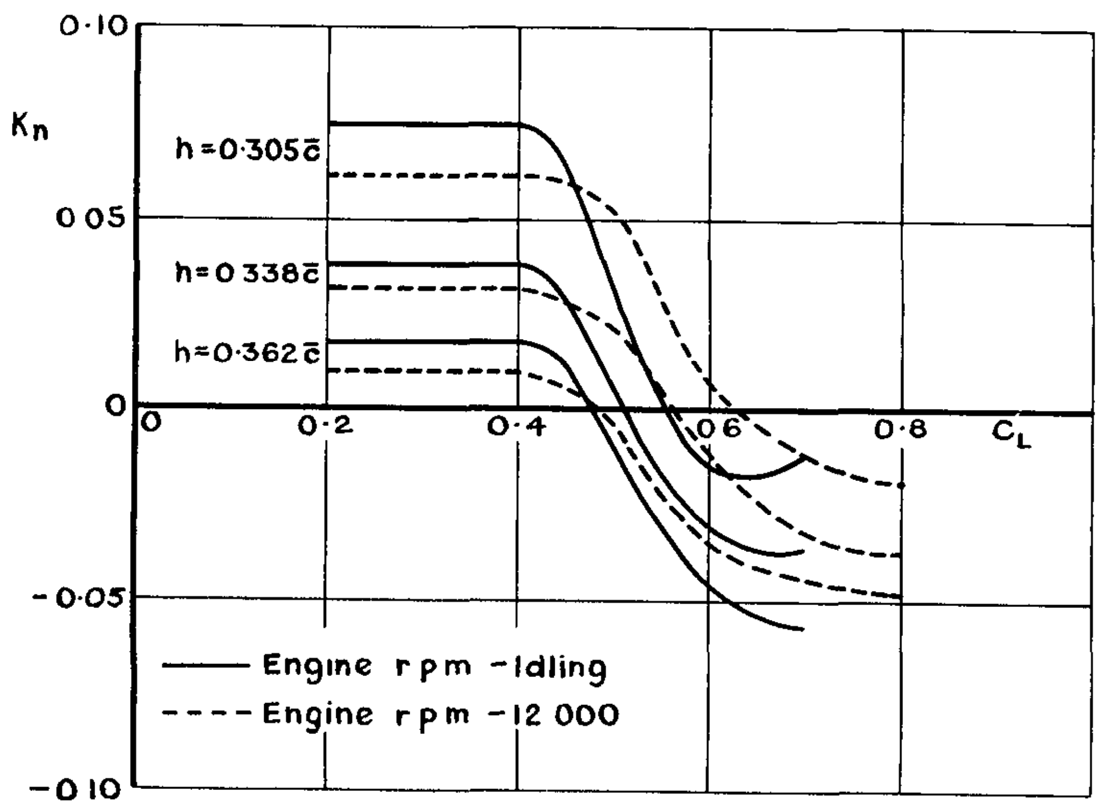


Fig. 8 Elevator power



a. Cruising configuration



b. Landing configuration

Fig.9 a & b Static margins-stick fixed

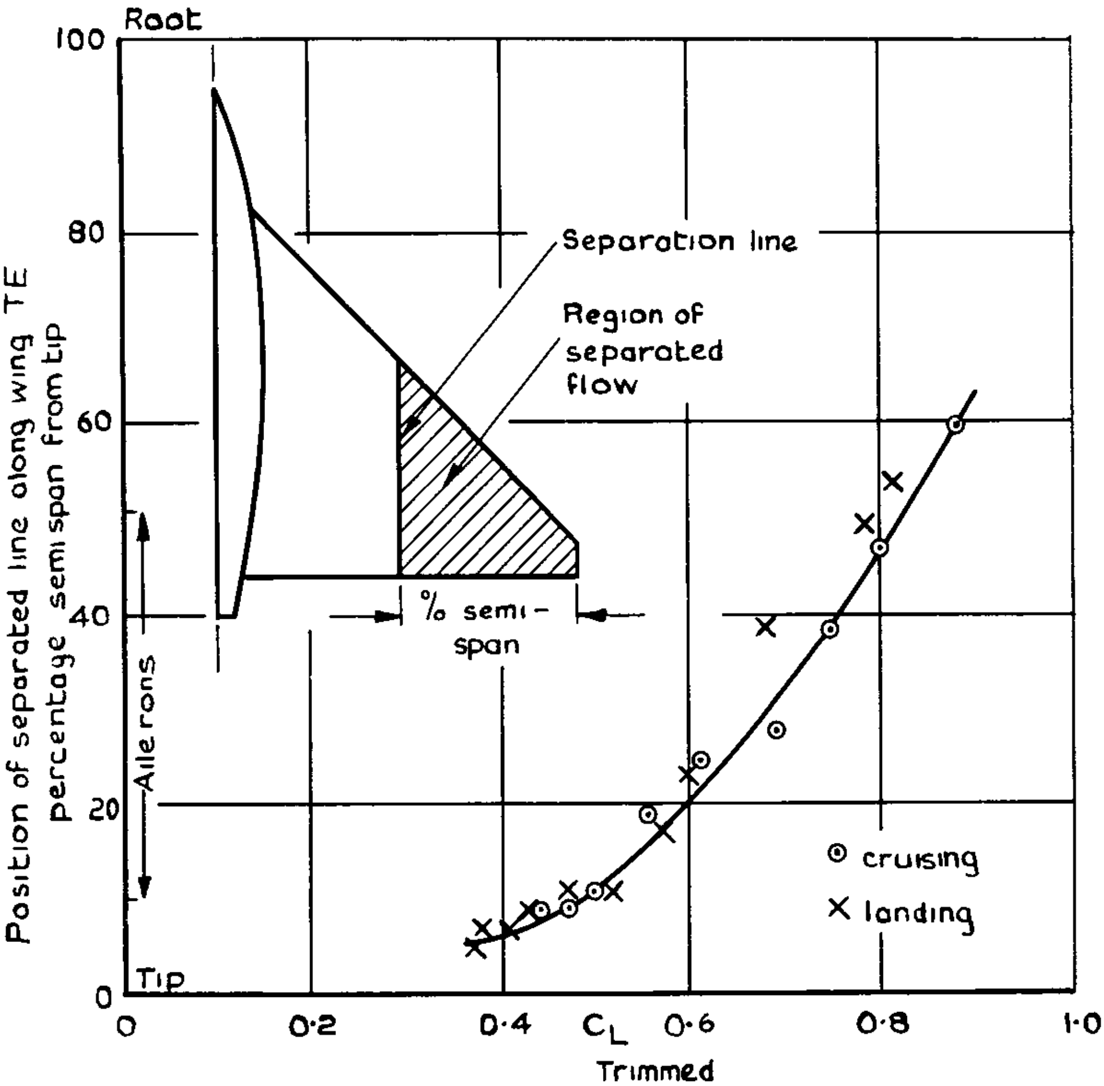


Fig.10 Growth of separated flow area with increase in lift coefficient

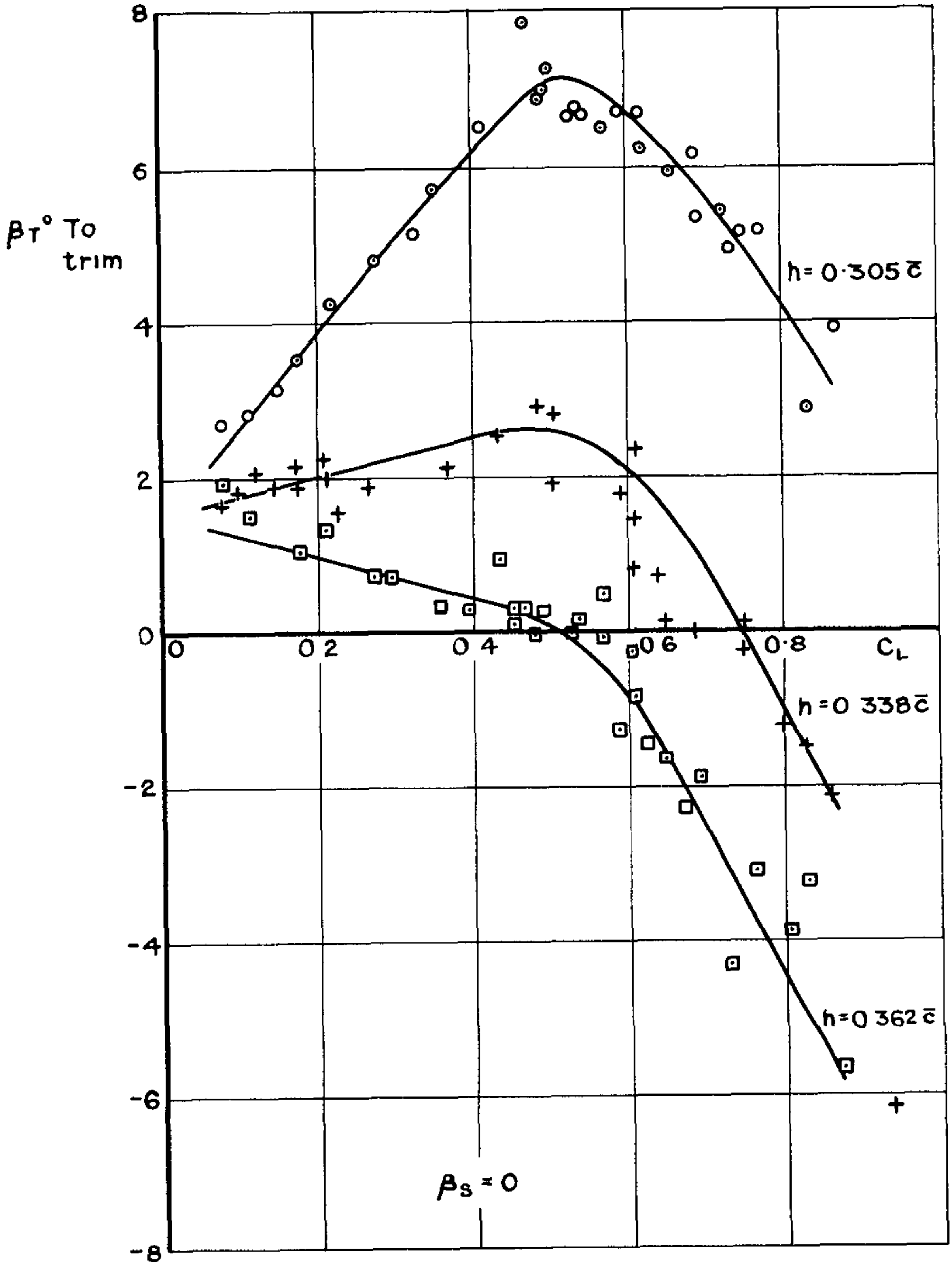


Fig 11 Tab angles to trim. Cruising configuration, engine r p m - idling

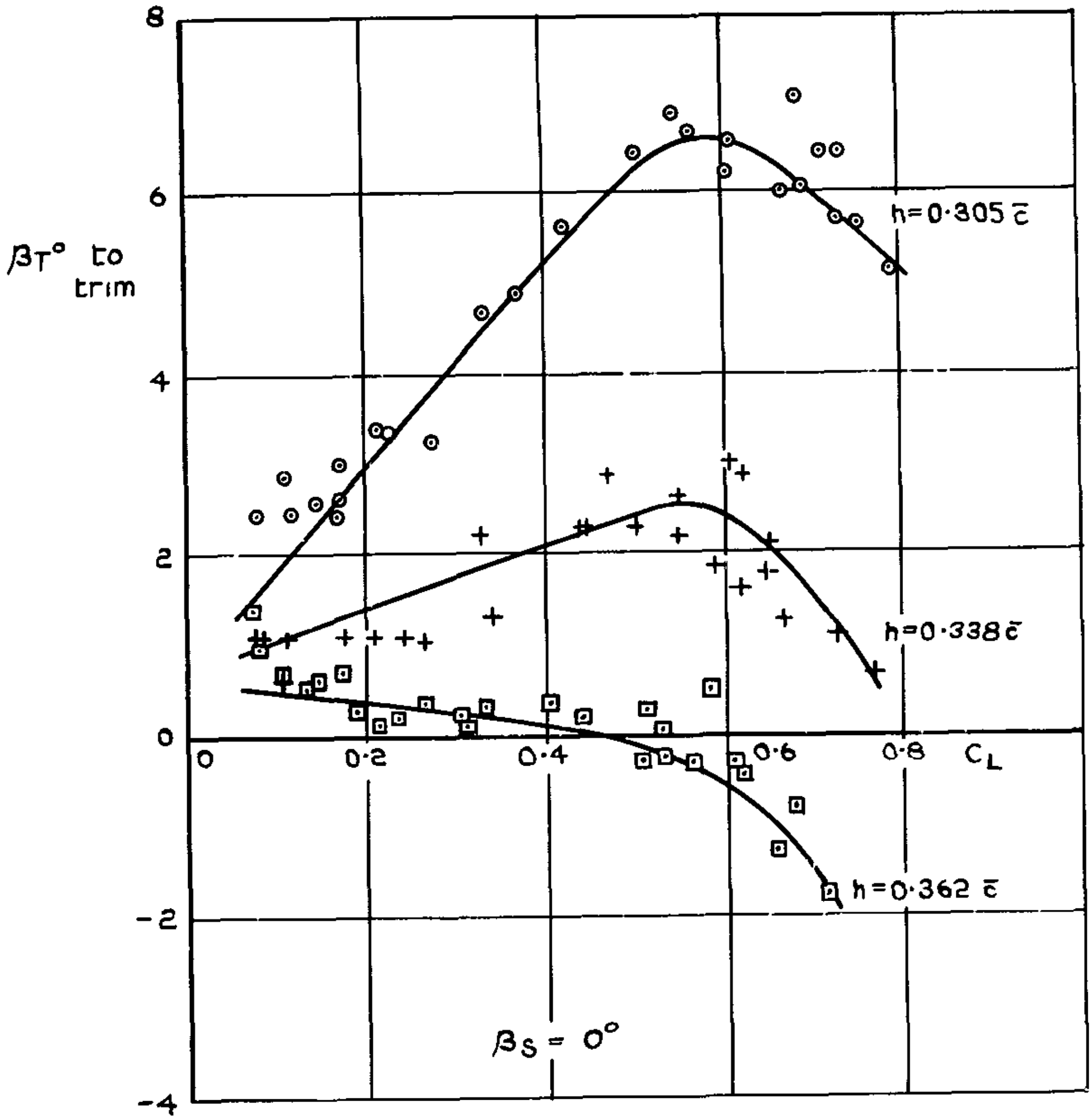


Fig. 12. Tab angles to trim. Cruising configuration, engine rpm – 14 000

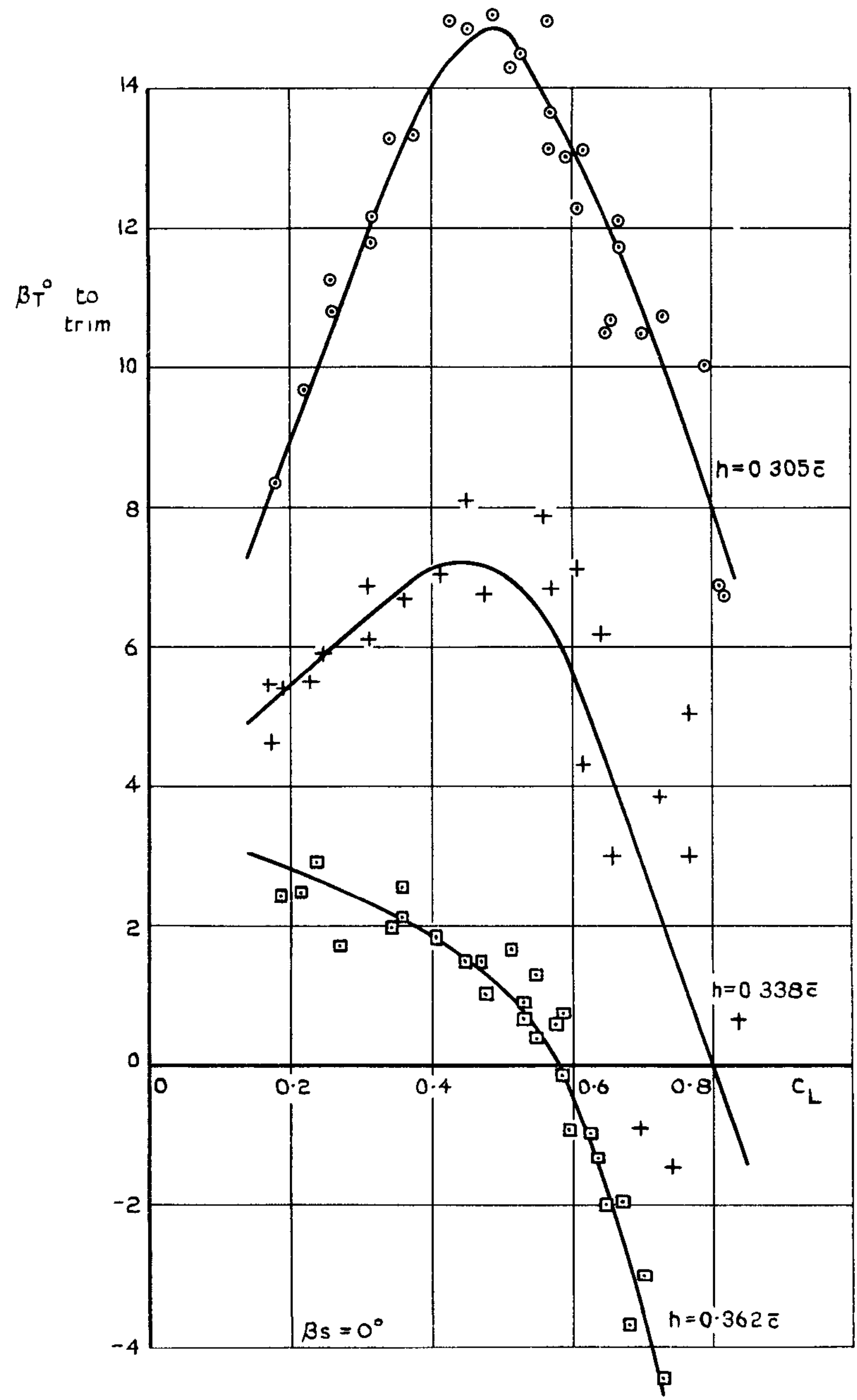


Fig 13 Tab angles to trim. Landing configuration, engine rpm – idling

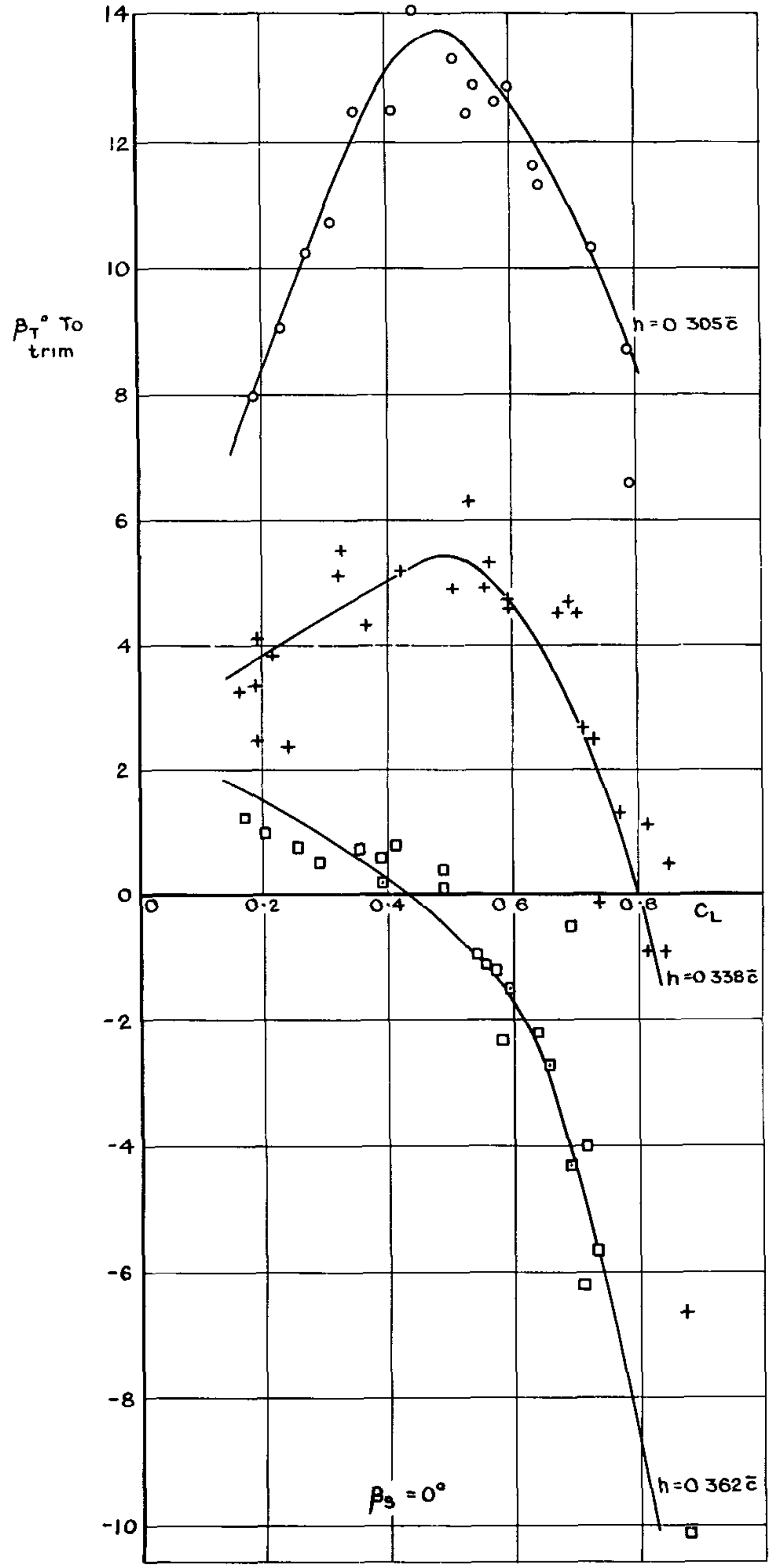


Fig.14 Tab angles to trim. Landing configuration, engine rpm-12000

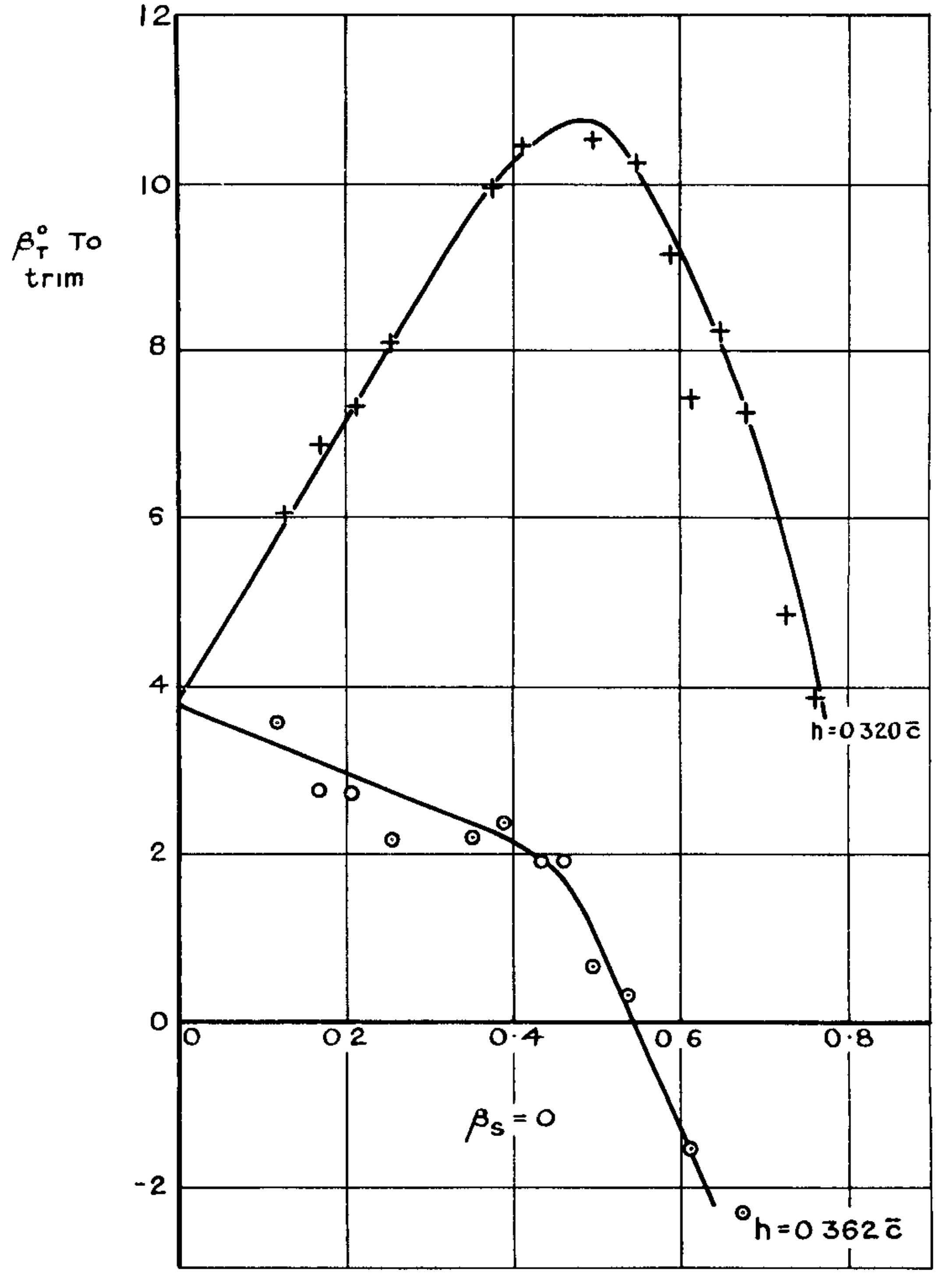


Fig. 15 Tab angles to trim Air brakes out, undercarriage up, engine rpm – idling

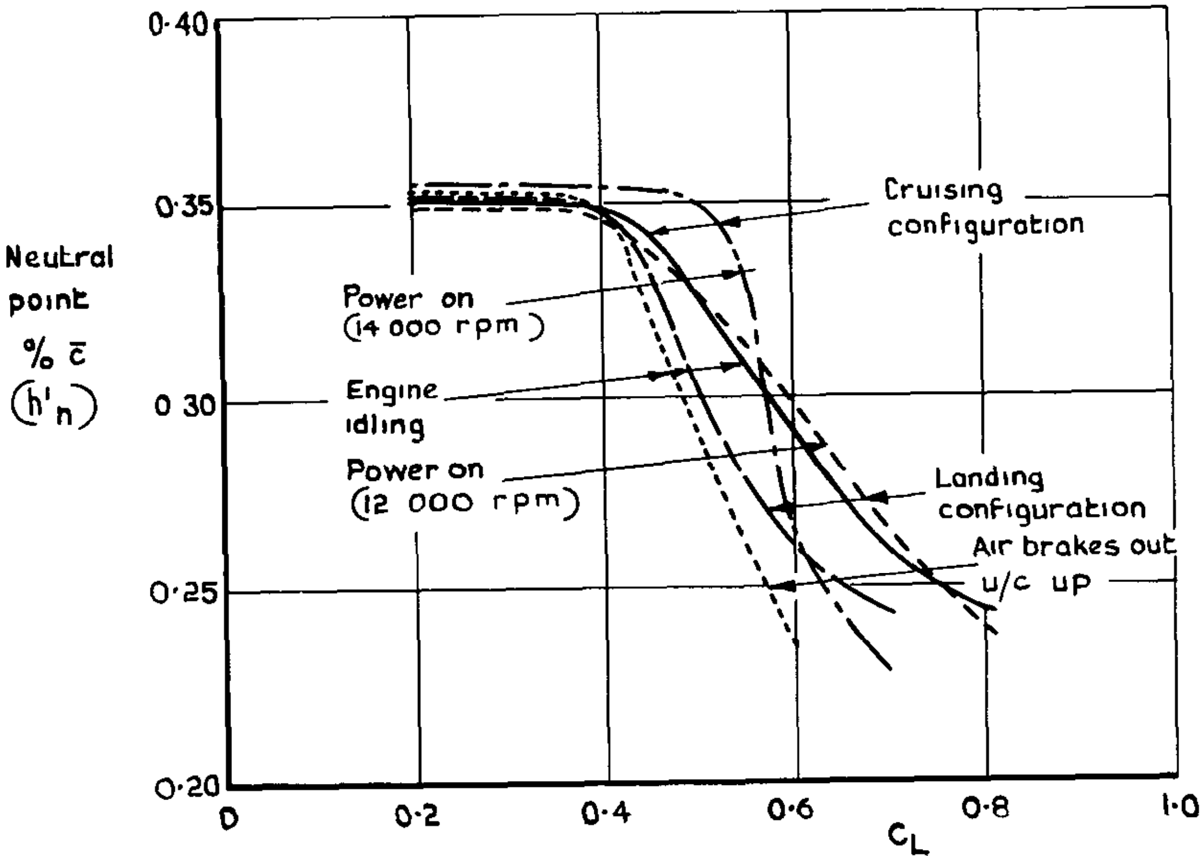


Fig. 16 Stick free neutral points

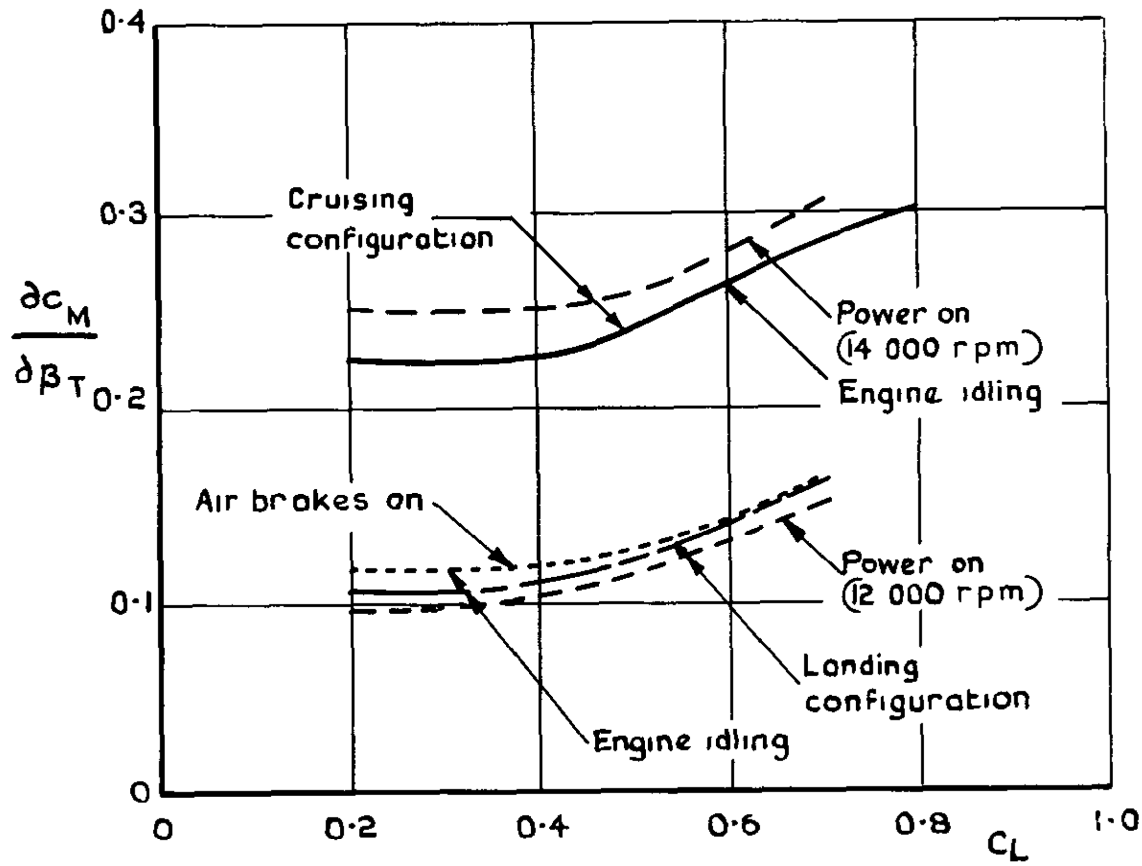
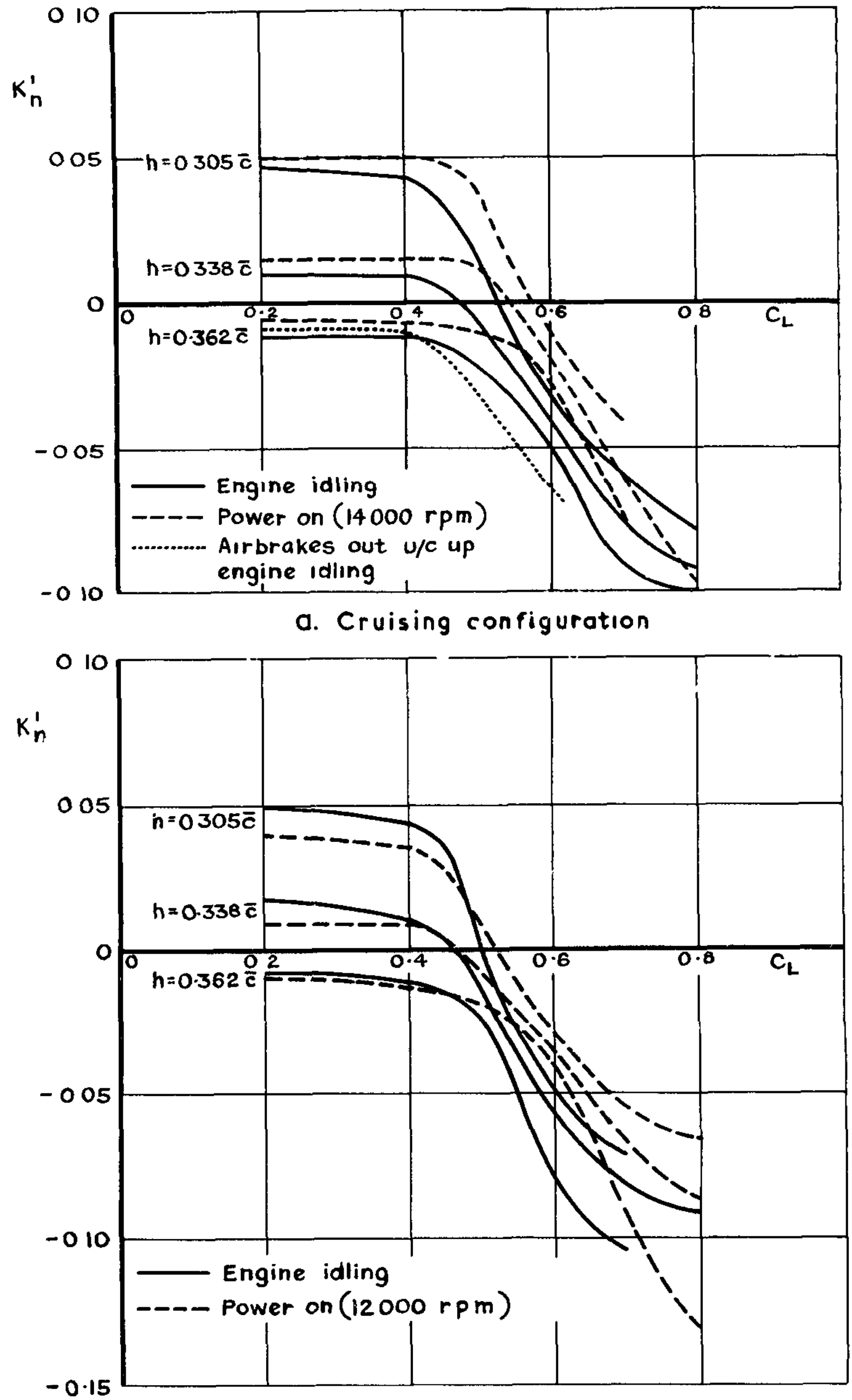


Fig. 17 Trim tab power



a. Cruising configuration

b. Landing configuration

Fig 18 a & b Static margins–stick free

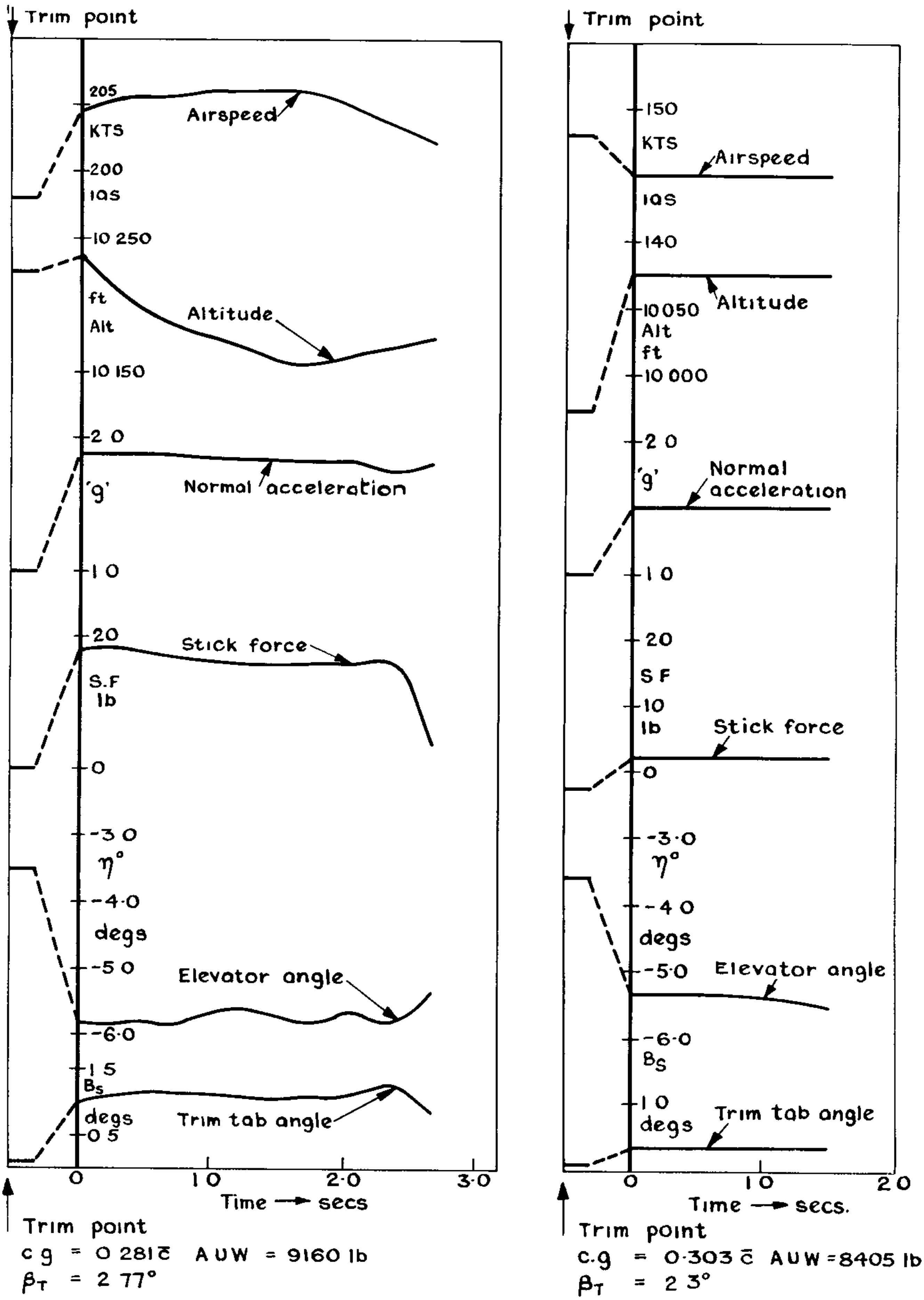


Fig. 19 Typical time records of pull outs. Cruising configuration-power for level flight from 10 000 ft

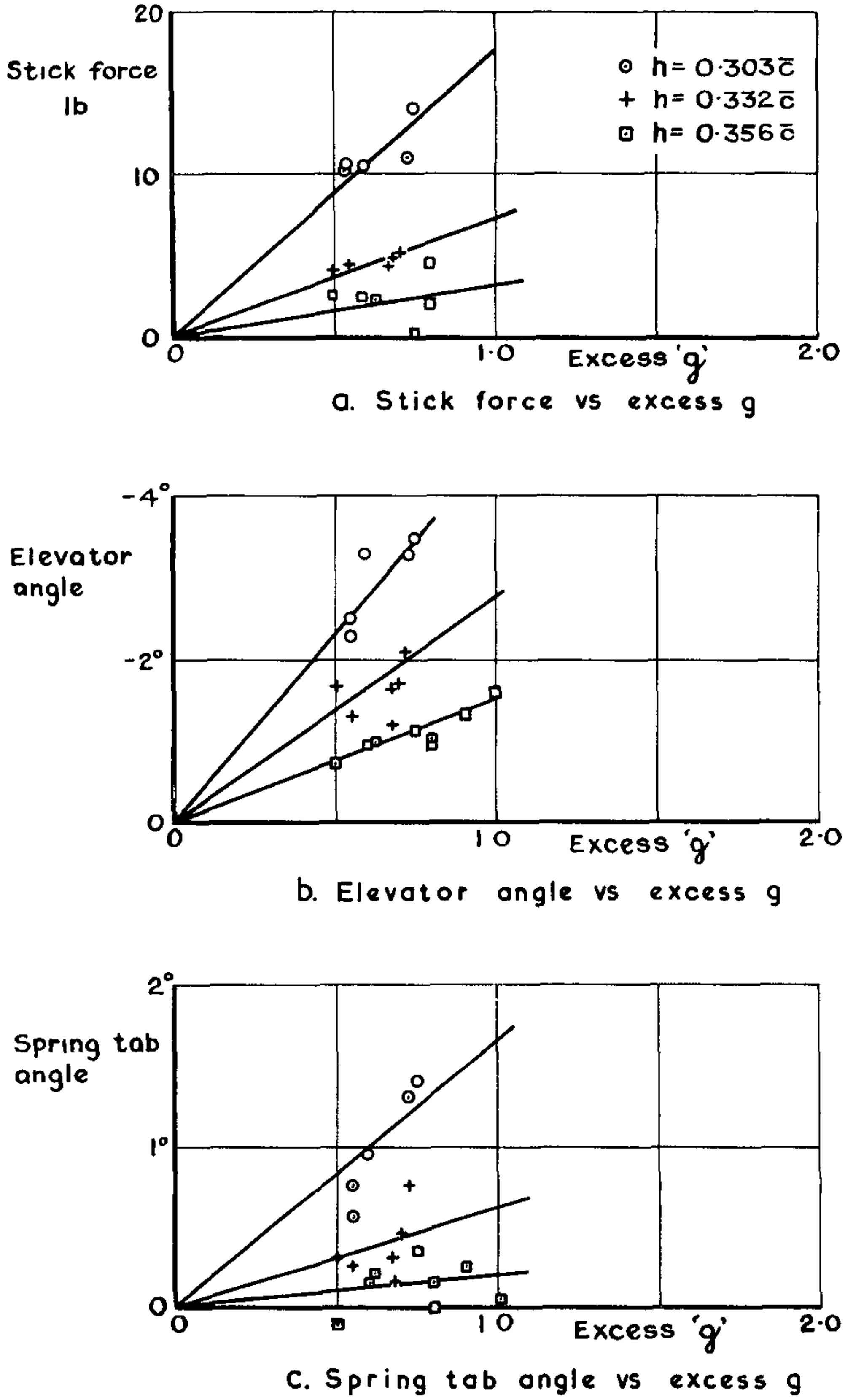


Fig. 20 a – c Variation of stick force, elevator angle, and spring tab angle with excess g Cruising configuration, power for level flight, height 10 000 ft, 150K I.A.S.

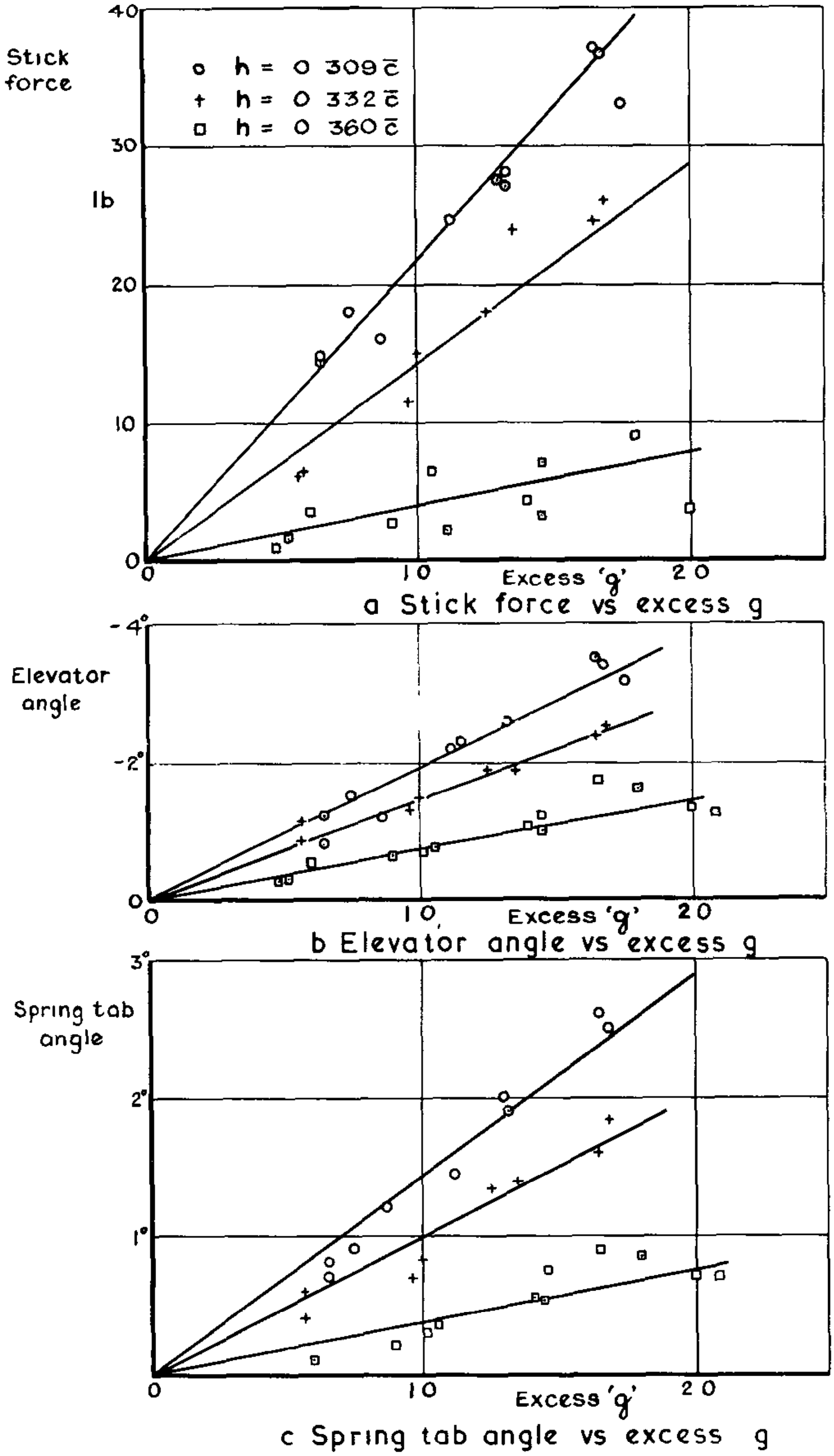


Fig. 21 a – c. Variation of stick force, elevator angle, and spring tab angle with excess g. Cruising configuration, power for level flight, height 10 000 ft, 250 K ias.

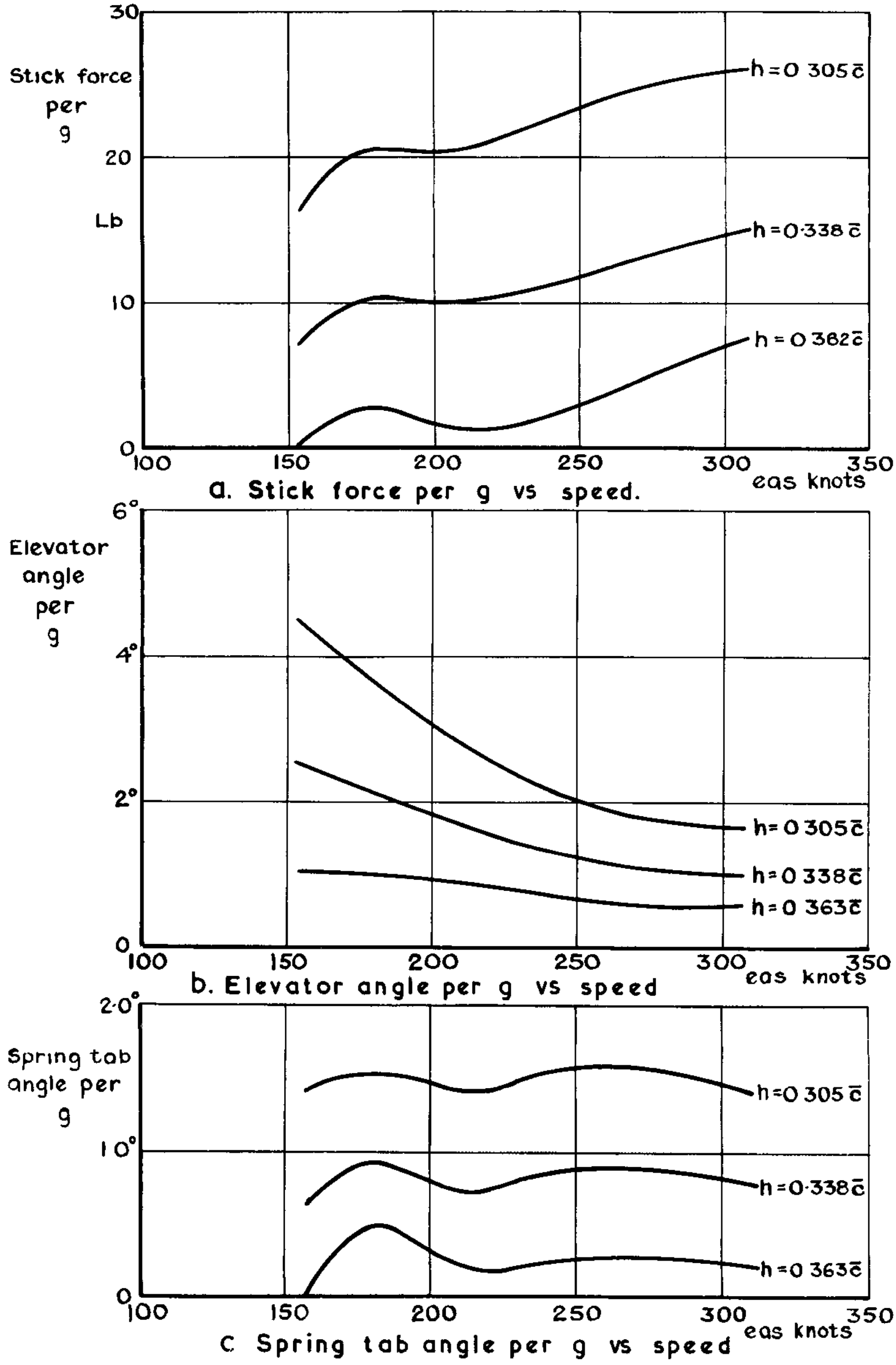


Fig 22 a-c Stick force, elevator angle and spring tab angle per g against speed. Cruising configuration, power for level flight

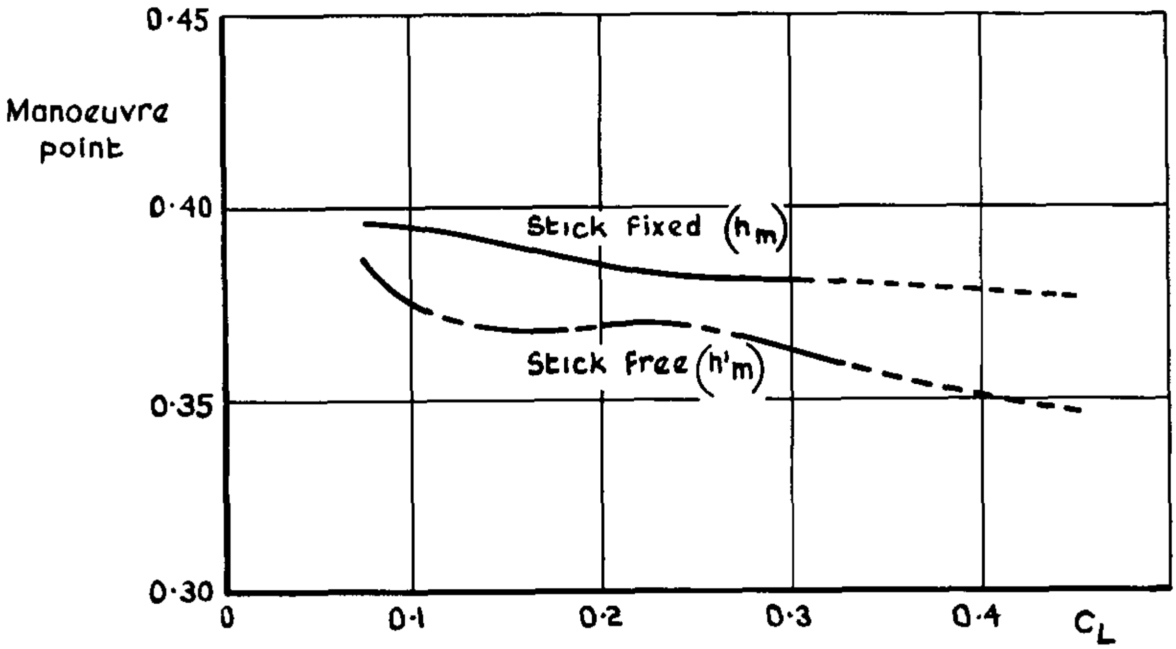


Fig. 23 Manoeuvre points.
Cruising configuration

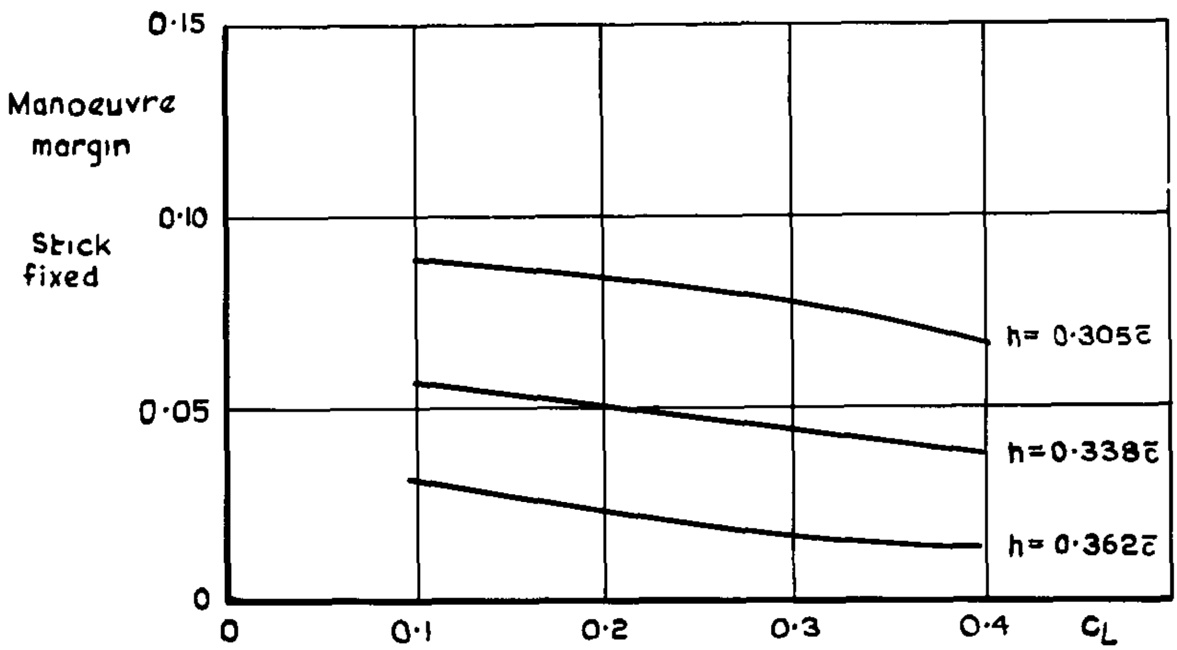


Fig. 24 Manoeuvre margin.
Cruising configuration

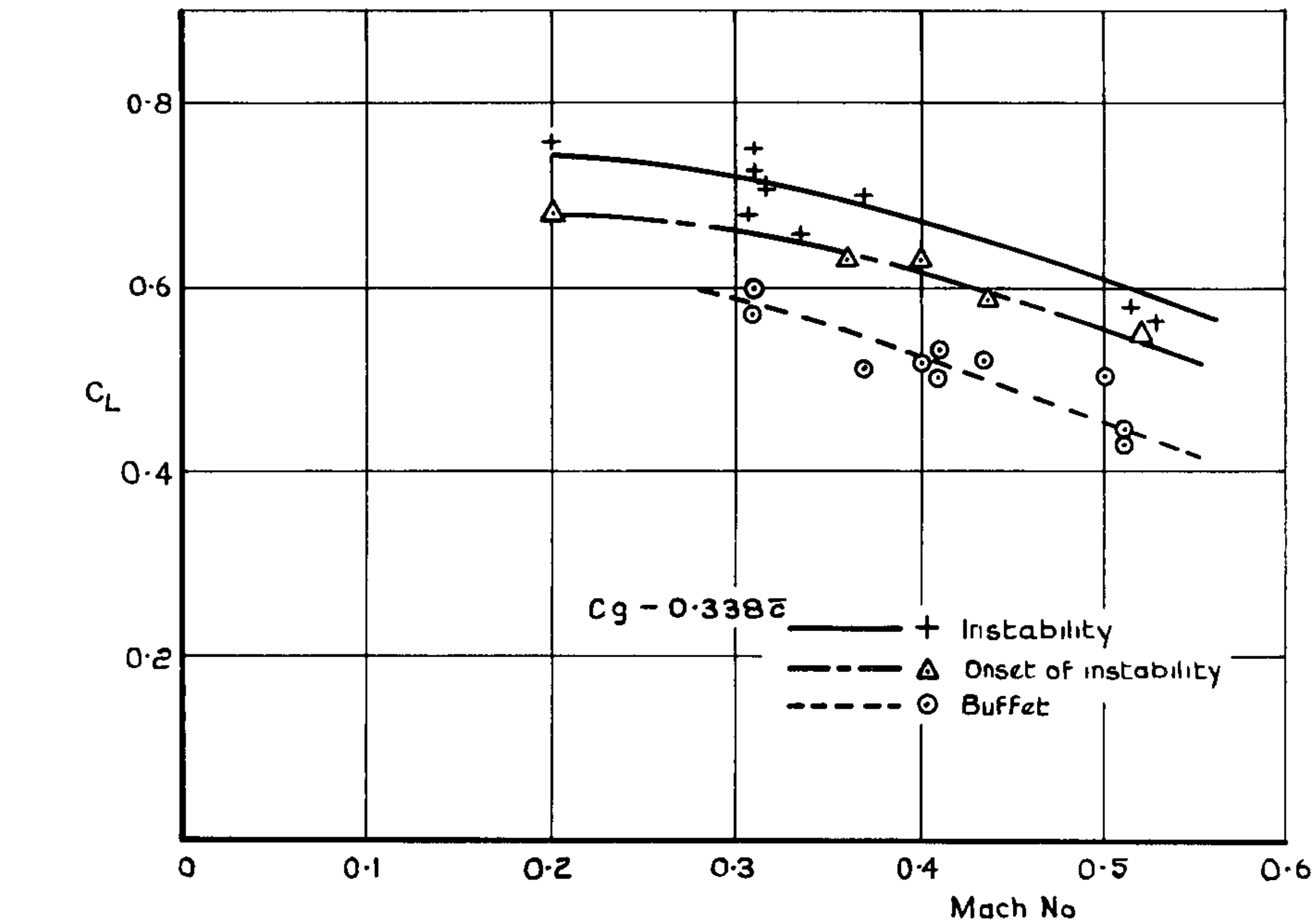


Fig. 25 Instability and buffet boundaries plotted against Mach number

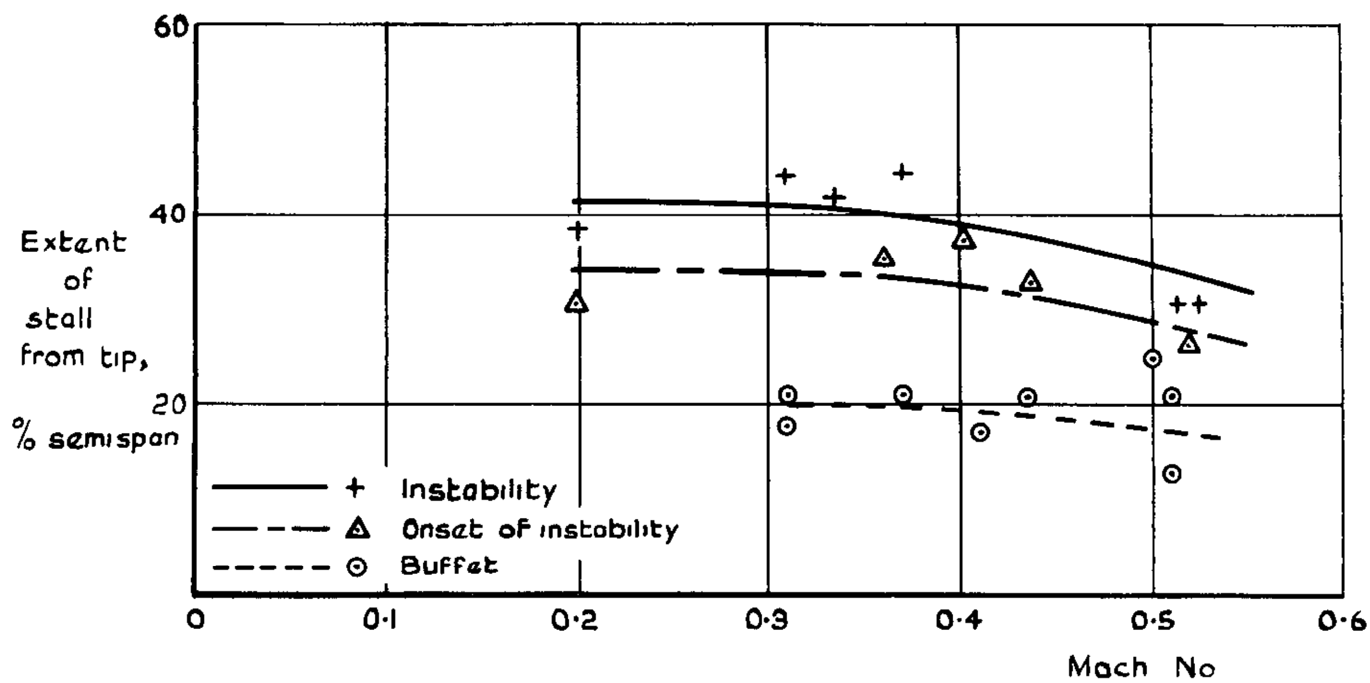


Fig 26 Position of stall on wing at trailing edge (%semispan) for instability and buffet plotted against Mach number

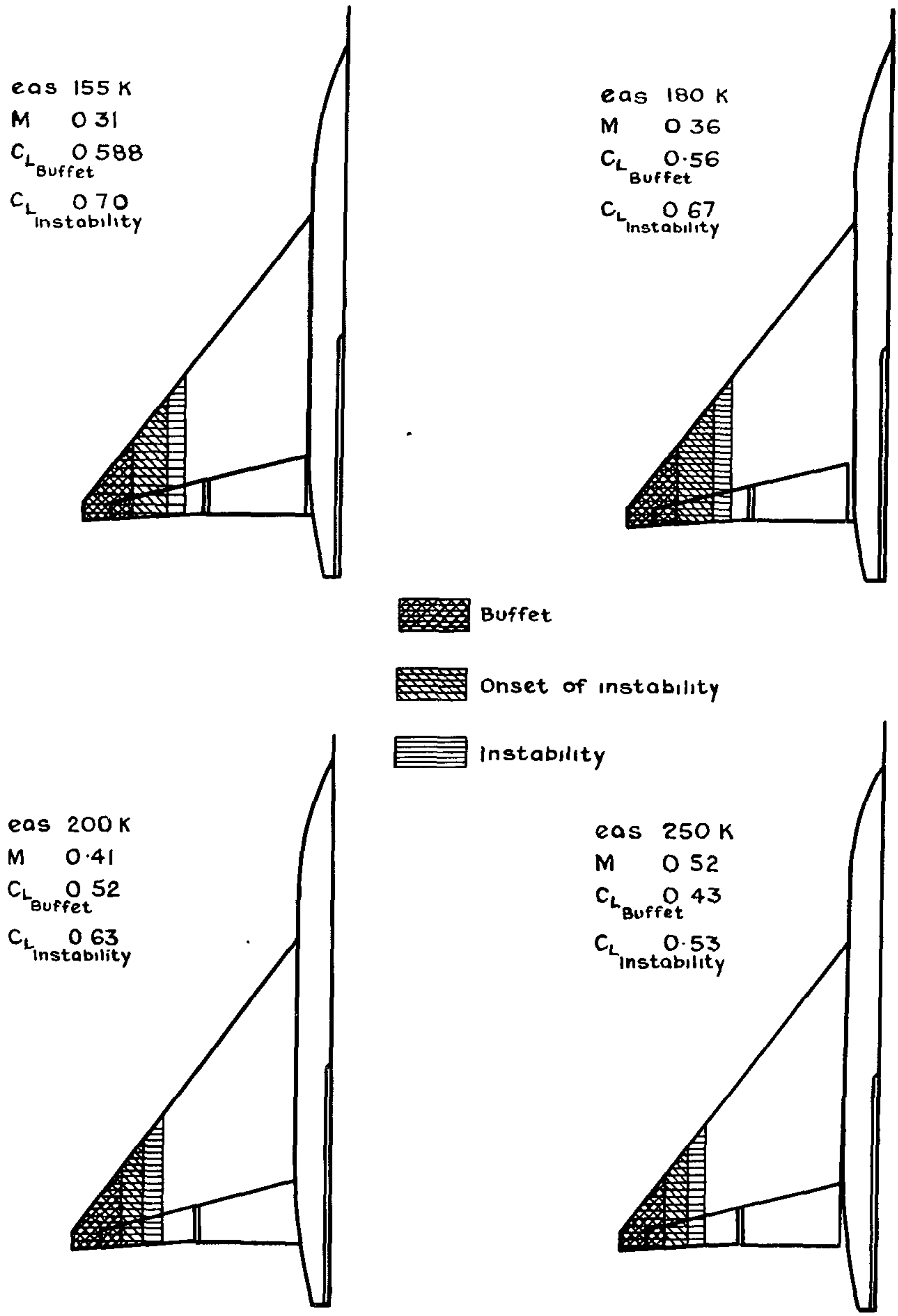


Fig.27 Area of wing stalled for instability and buffet with applied g

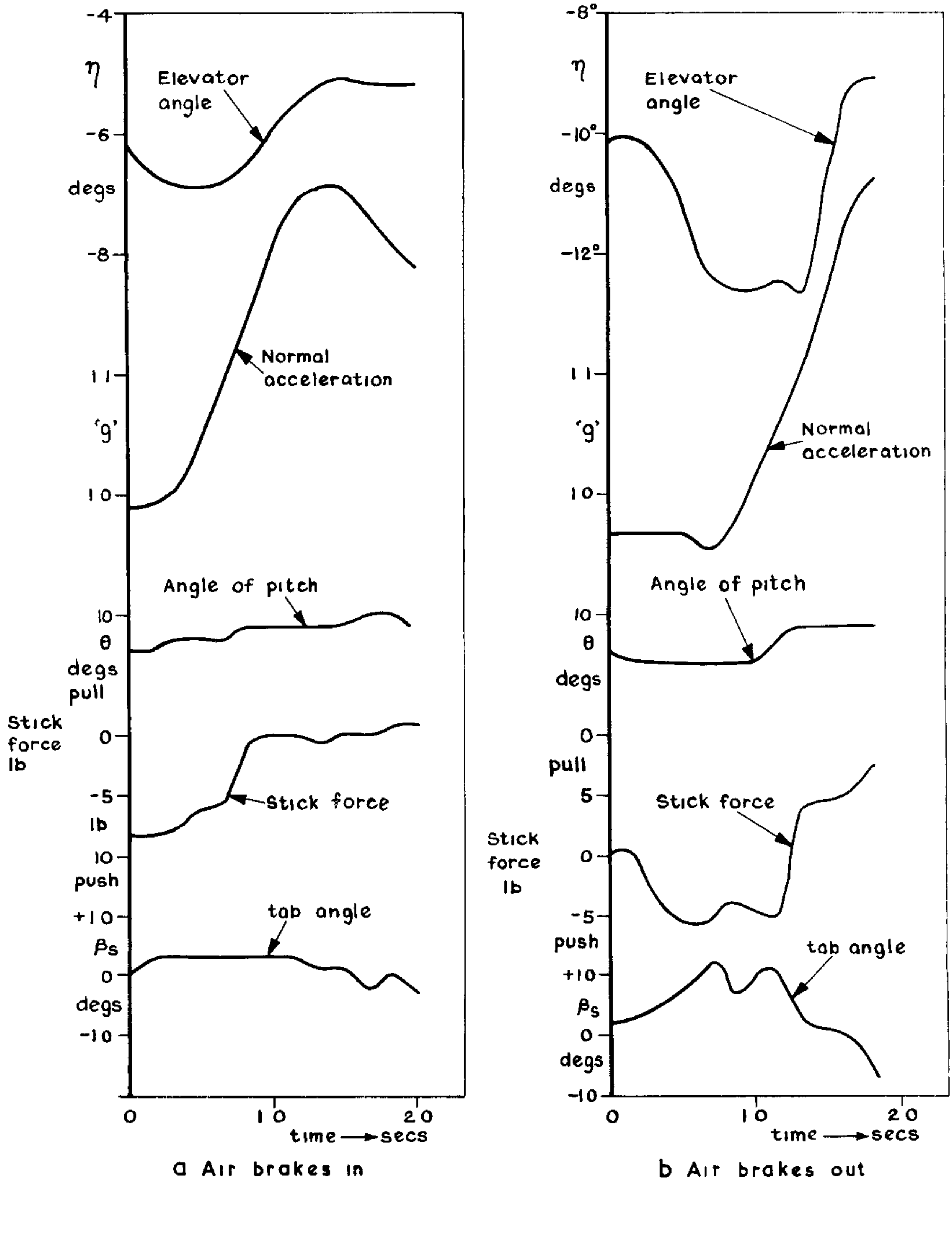


Fig.28 a & b Elevator response at 125 knots
(a) air brakes in, (b) air brakes out

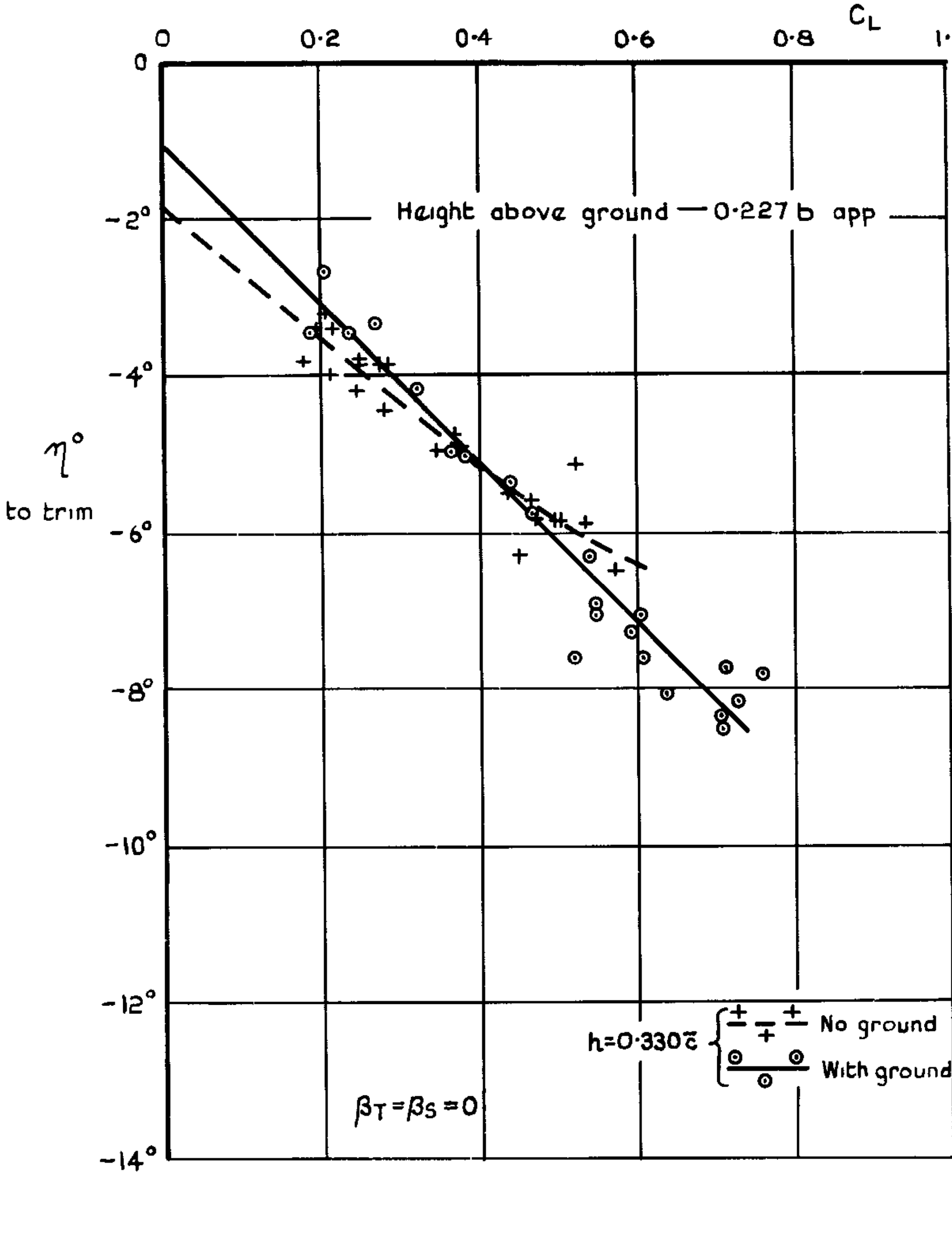


Fig 29 Change of elevator angles to trim due to ground effect — cruising configuration (air brakes in) with undercarriage down

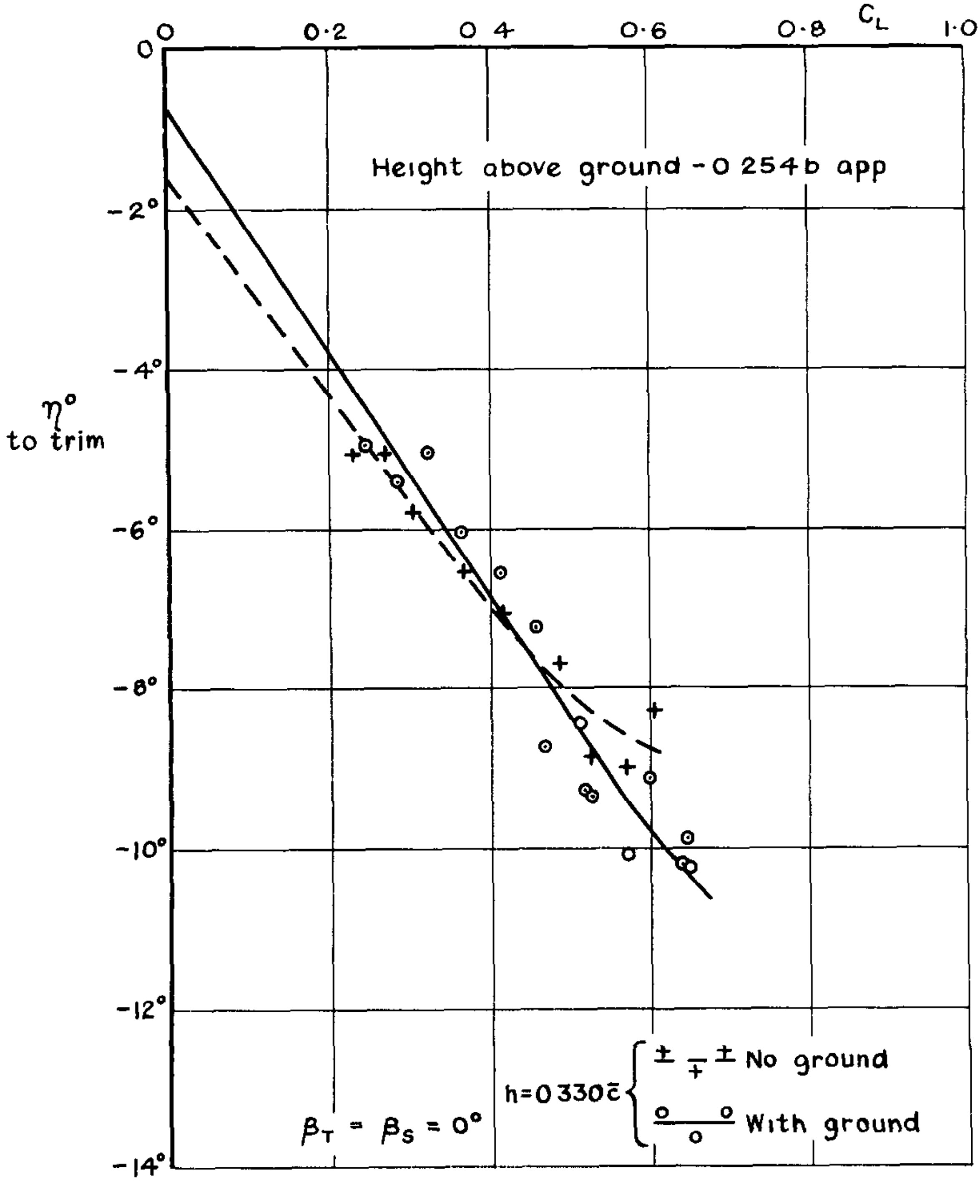


Fig 30 Change of elevator angles to trim due to ground effect-landing configuration (air brakes out and undercarriage down)

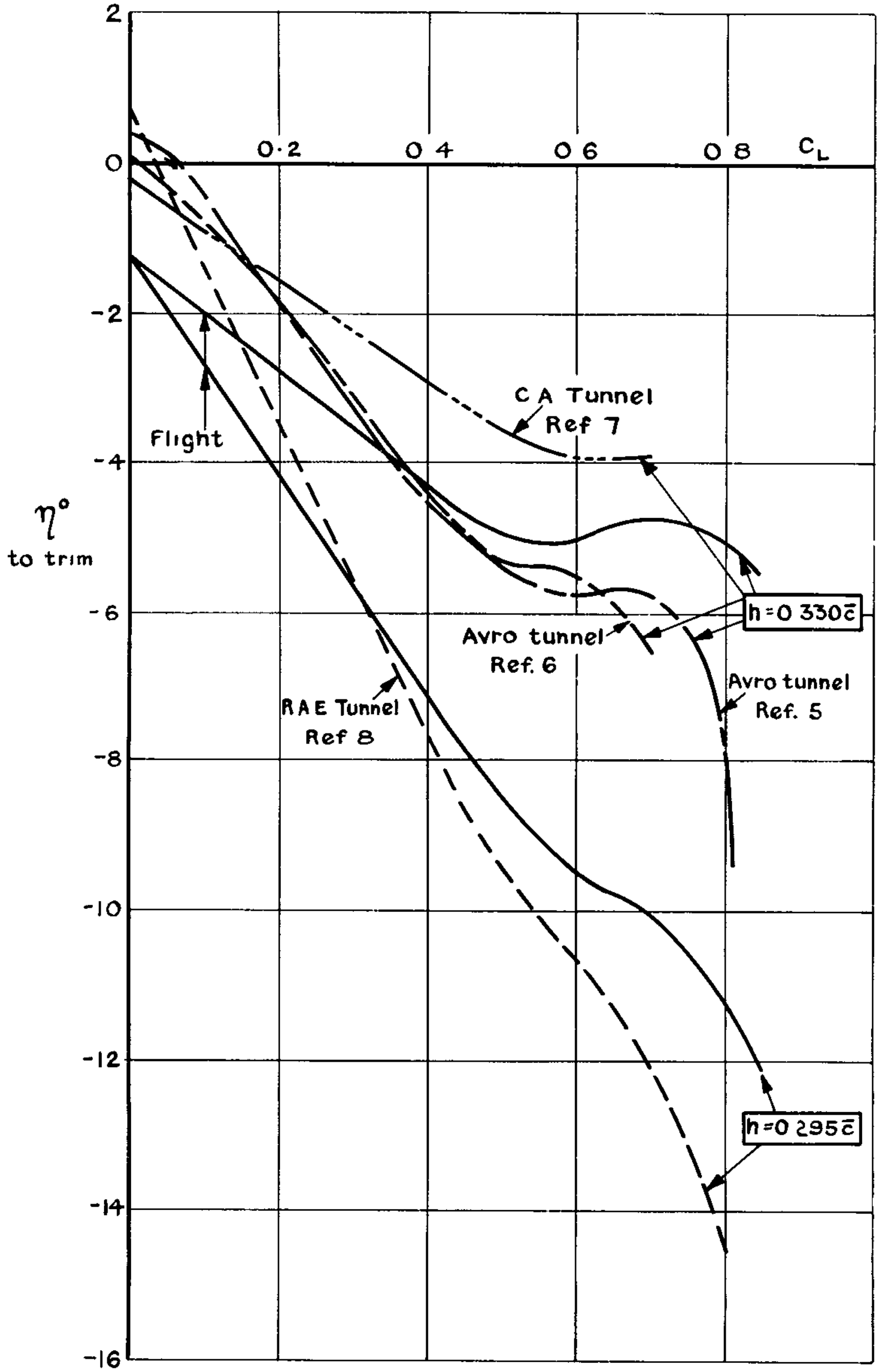


Fig. 31 Comparison of flight and tunnel results
Elevator angles to trim.

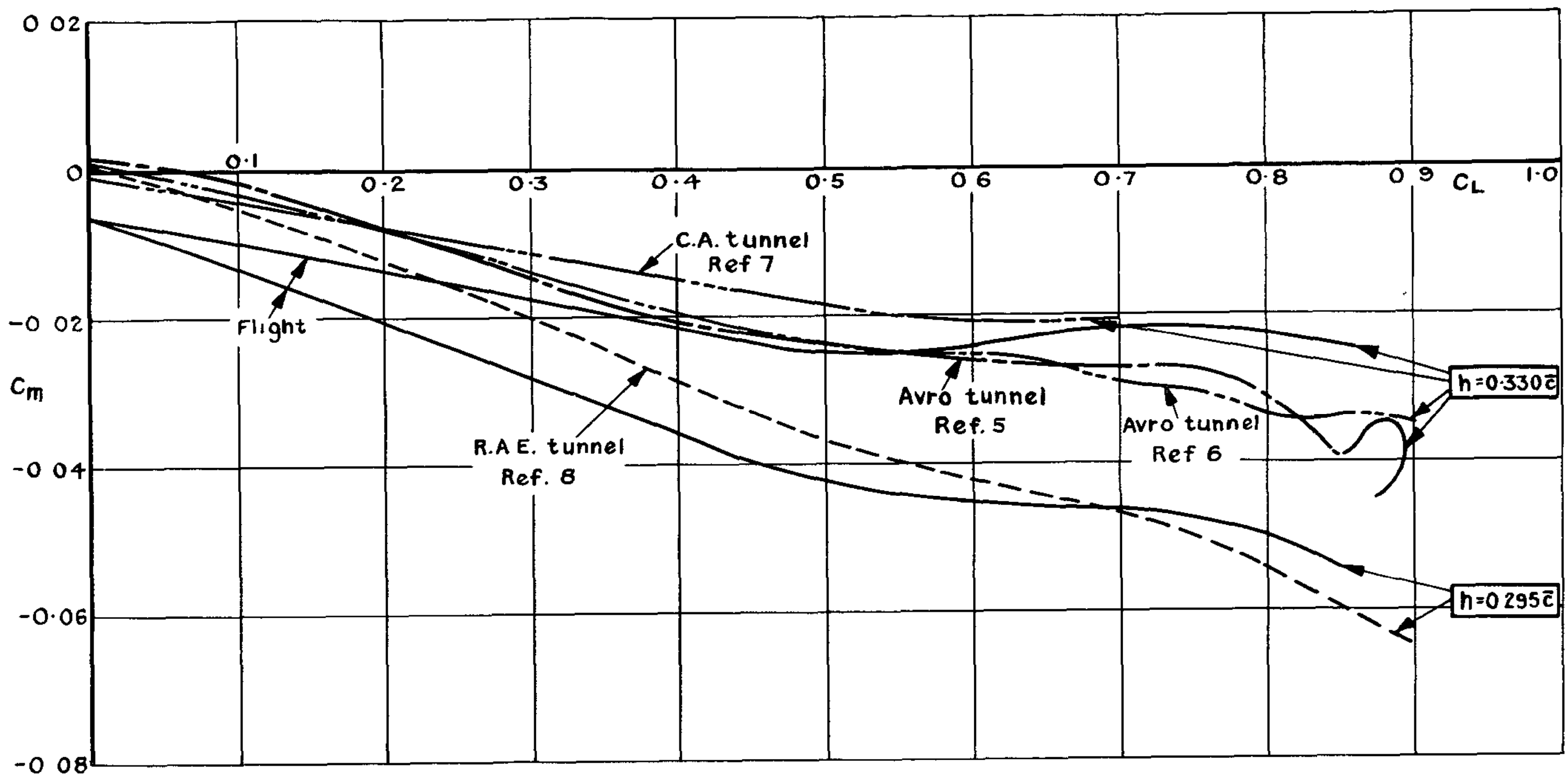


Fig. 32 Comparison of flight and tunnel results. Pitching moment coefficients-cruising configuration

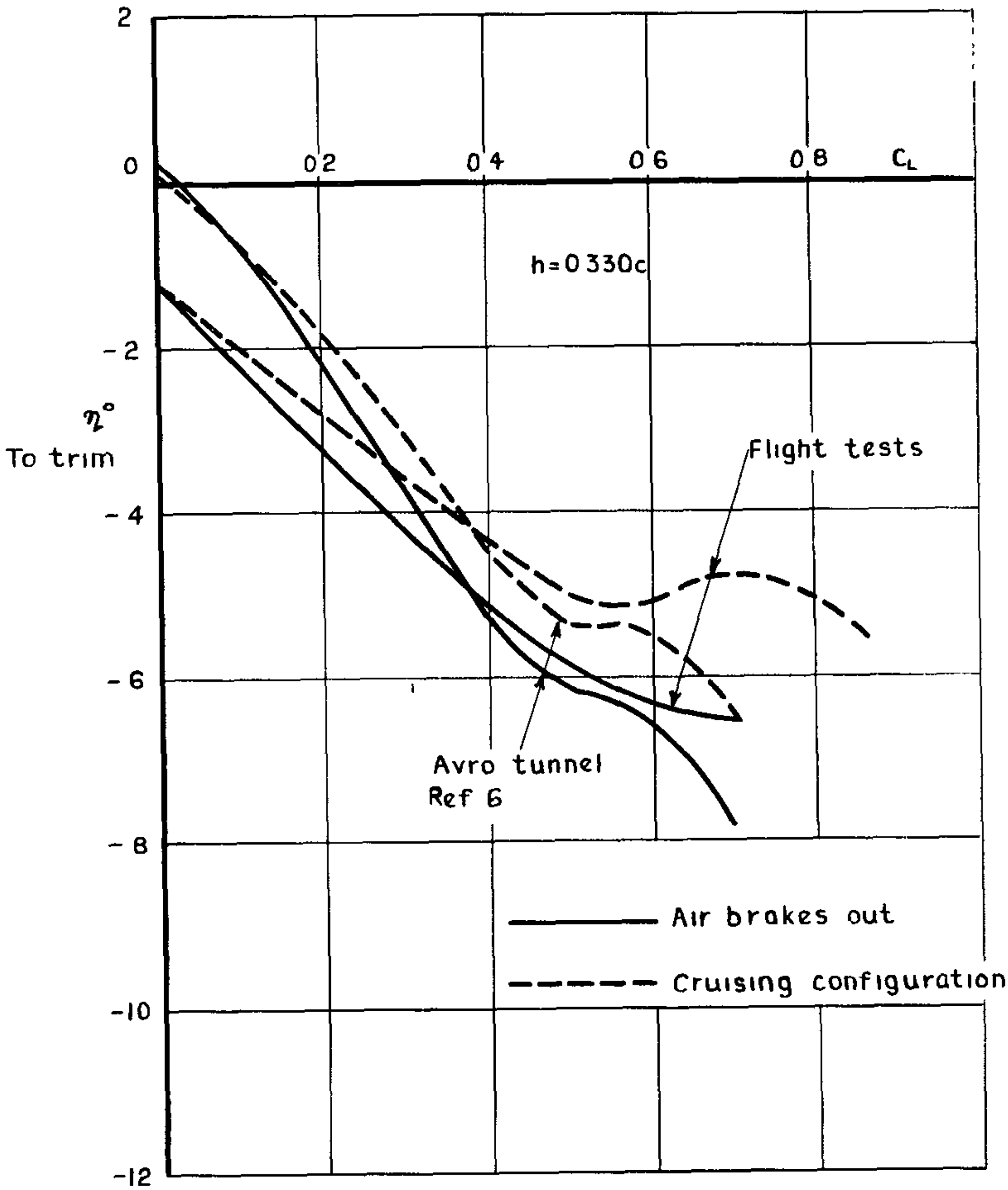


Fig 33 Comparison of flight and tunnel tests on the effect of air brakes on elevator angles to trim

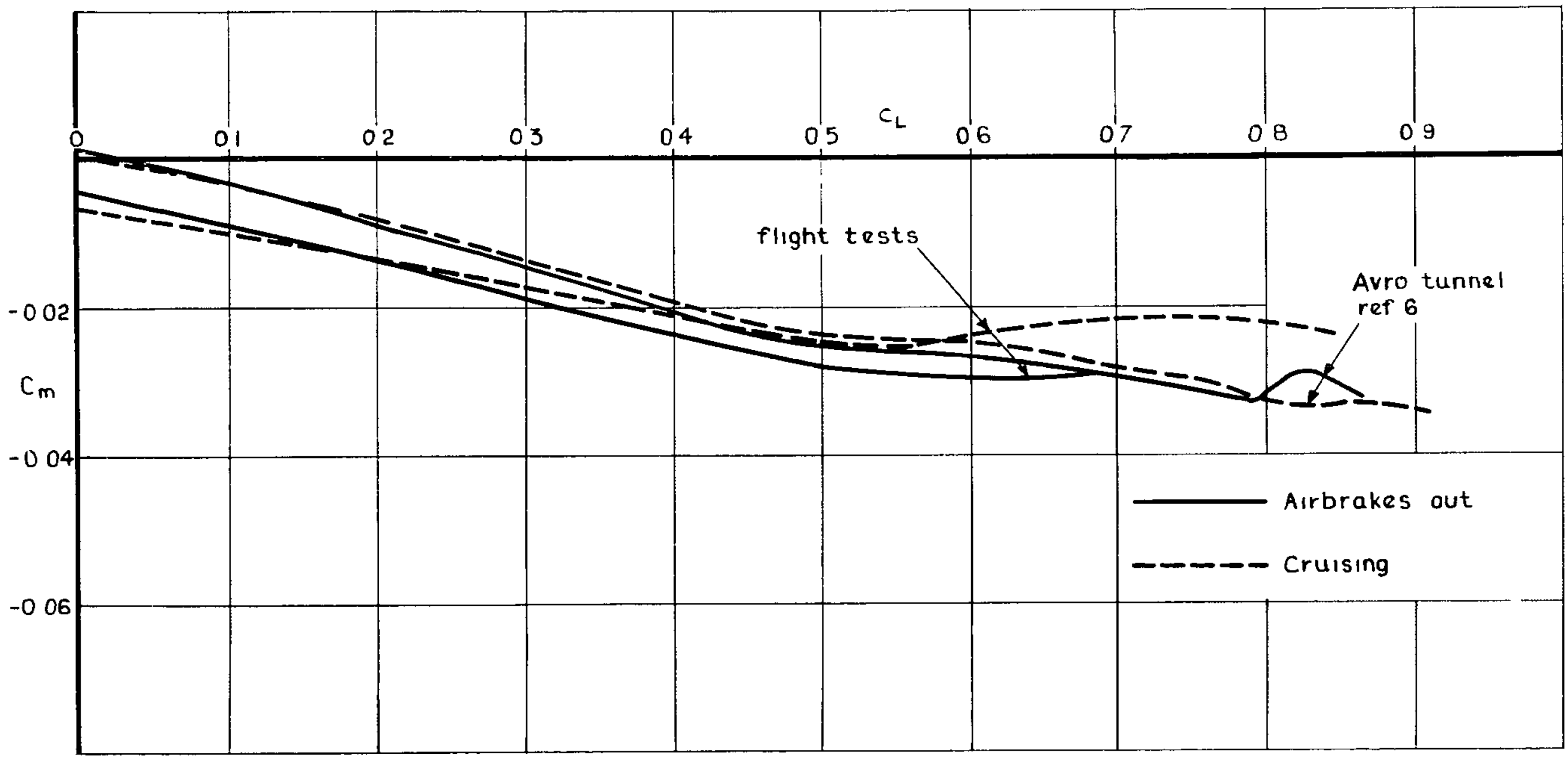


Fig 34 Comparison of flight and tunnel tests on the effect of air brakes on pitching moment coefficient

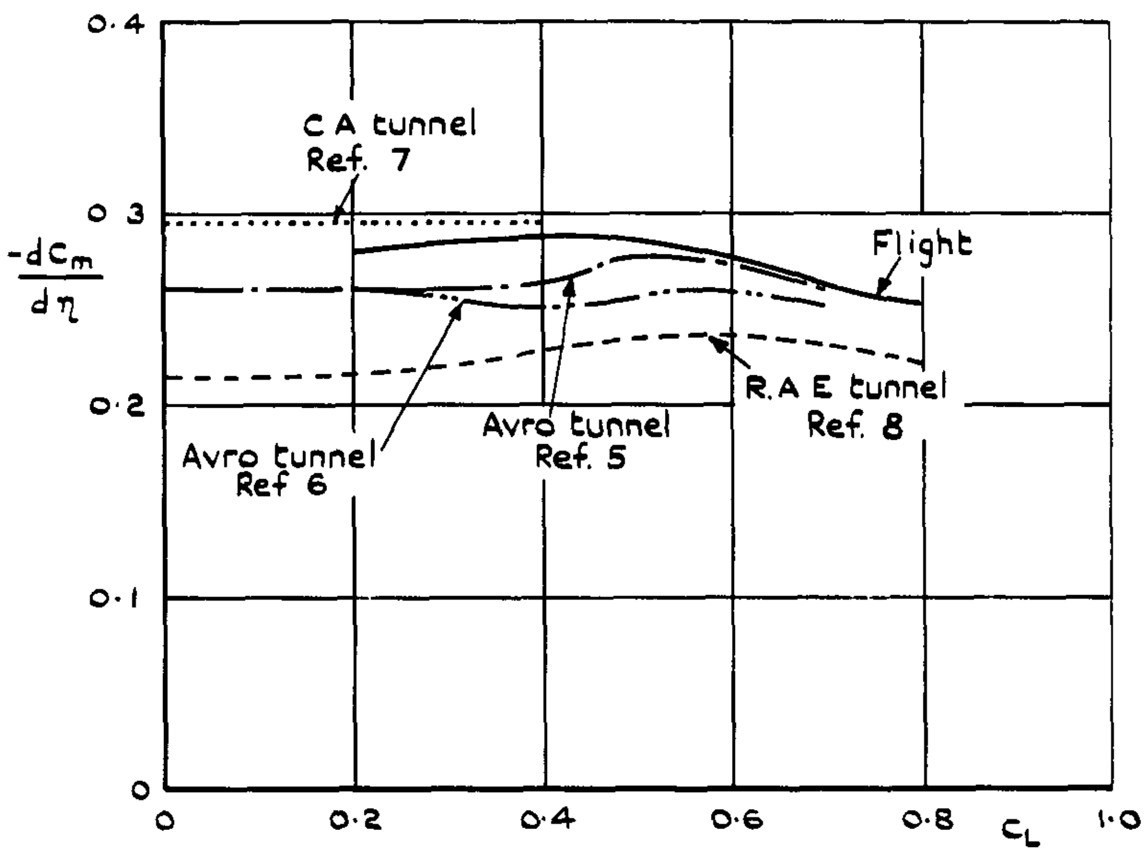


Fig. 35 Comparison of flight and tunnel tests on $\frac{\partial C_m}{\partial \eta}$ cruising configuration

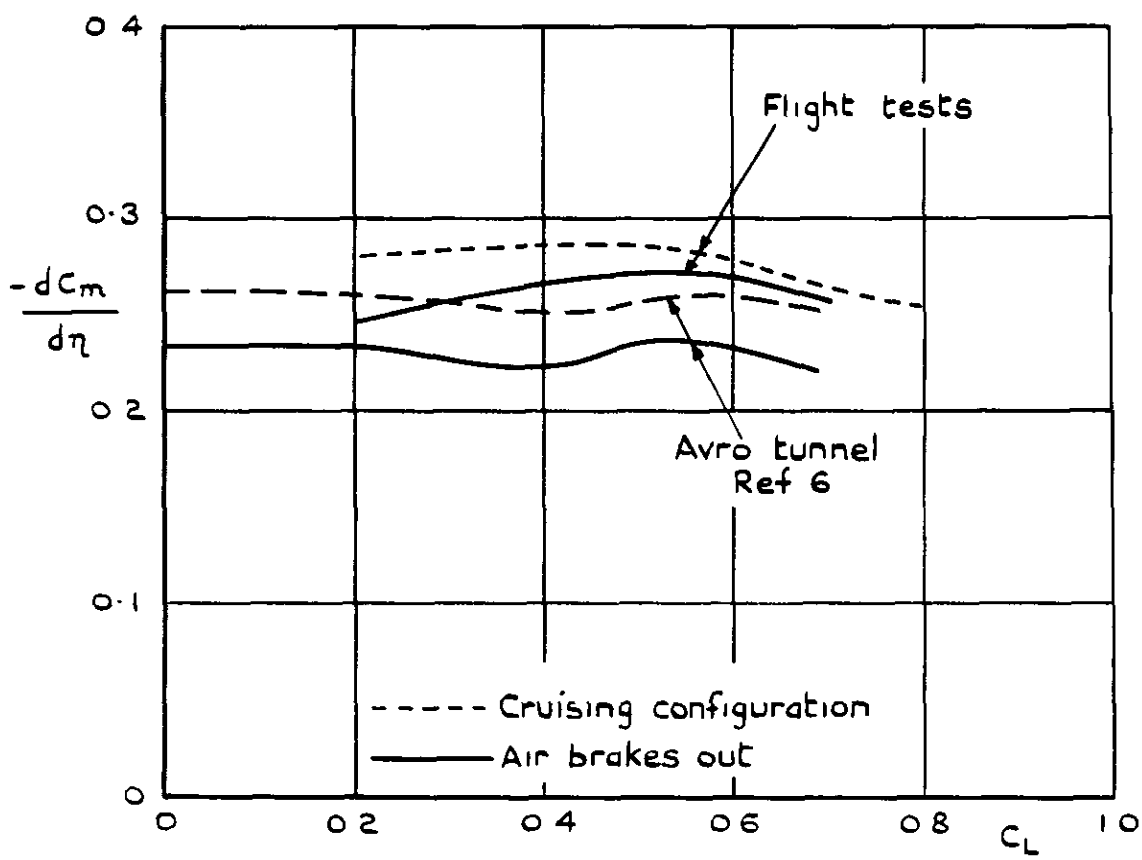


Fig. 36 Comparison of flight and tunnel tests on the effect of air brakes on $\frac{\partial C_m}{\partial \eta}$

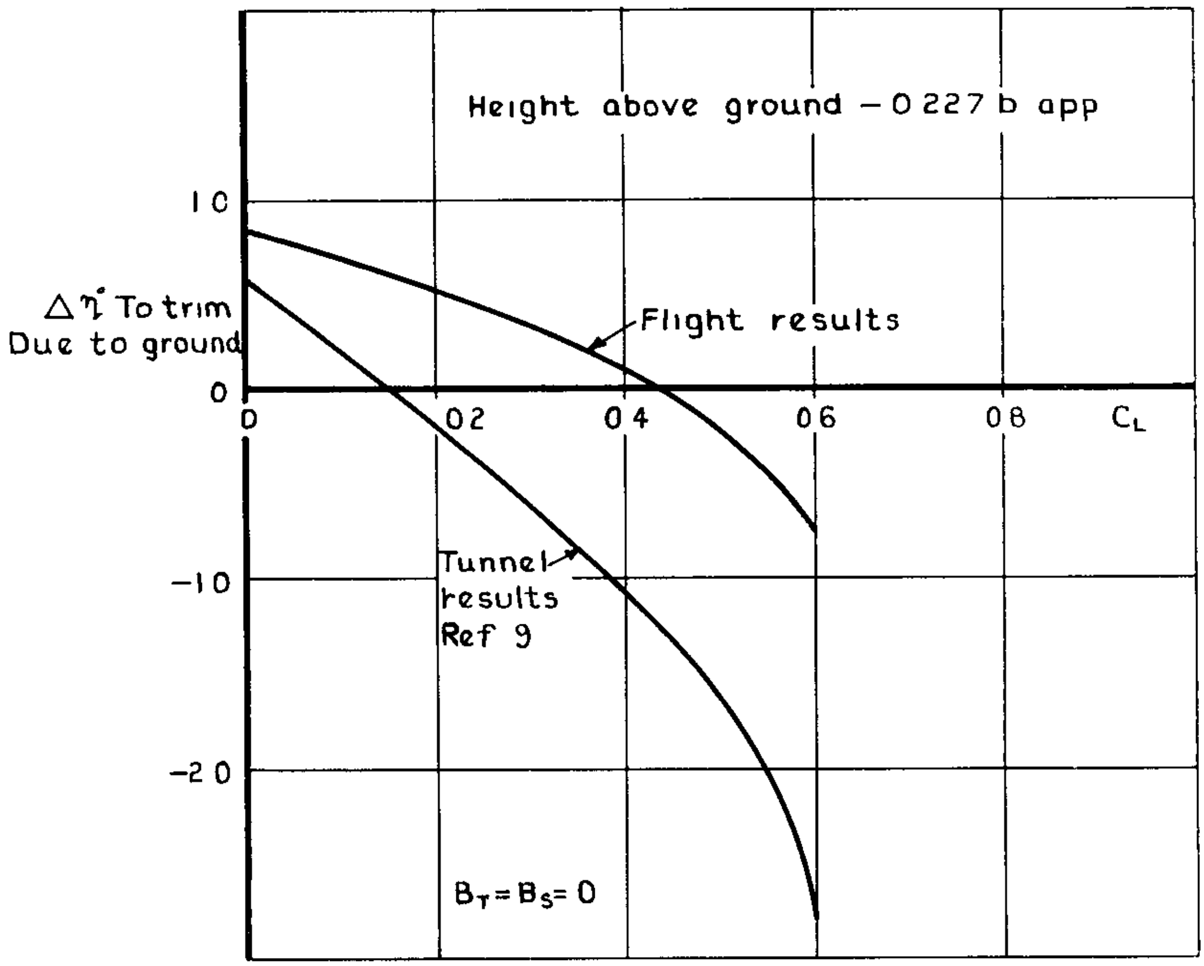


Fig 37 Comparison of flight and tunnel tests on change of elevator angles to trim due to ground-effect — cruising configuration

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There is a loss of static stability, stick fixed and free, above a lift coefficient of 0.5. Stick force/g at low speed is small particularly at the aft cg position, although no great difficulties were encountered due to this or the lack of static stability during the approach and landing.

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