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Ground Effect on a 55° Swept M-Wing of Aspect Ratio 5.0

by

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GROUND EFFECT ON A 55° SWEPT M-WING OF ASPECT RATIO 5.0

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SUMMARY

This Note presents the results of low-speed tunnel tests made to determine the effects of ground proximity on the lift, drag and pitching moment characteristics of a flat-plate M-wing. A few results are included to indicate how the presence of the ground modifies the effectiveness of an unswept tailplane mounted at varying heights relative to the wing chord plane.

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1 INTRODUCTION

As part of a general investigation of the low-speed characteristics of wings suitable for cruising at low supersonic speeds[1], a number of tests have been made in the 13 ft × 9 ft low-speed wind tunnel at R.A.E., Bedford, on a 55° swept M-wing of aspect ratio 5•0. This Note describes the effect of ground on the static longitudinal characteristics of this planform. The technique used for ground effect tests will be described separately in a later note.

2 MODEL GEOMETRY AND TEST PROCEDURE

Details of the model wing and tailplane are shown in Fig.1 and listed in Table 1. The wing had a flatplate section of constant thickness, with sharp bevelled leading and trailing edges.

A rectangular tailplane of aspect ratio 2•0 with a 10% thick R.A.E. 101 section was supported at several heights relative to the wing chord plane by means of a tubular sting and suitable packing blocks (see Fig.1). The tailplane was intended primarily for downwash measurements which will be presented in a subsequent note. Four tailplane positions were used, given by h/b = -0•05, 0, +0•05, +0•10. The tailplane setting angle was maintained zero during the present tests.

Using a wire rig, the model was supported in the inverted position on the tunnel centre-line, the ground board being supported above the model. The wing was tested with the mean quarter-chord point at two distances H from the ground board, H/b = 0•130 and 0•192.

In the presence of the ground board, the velocity past the model was deduced from the readings of a pitot-static rake placed ahead of and well to one side of the model. Lift, drag and pitching moment were measured at a wind speed of 150 ft/sec, giving a Reynolds number of $1{\cdot}8 \times 10^6$ based on the aerodynamic mean chord.

The induced incidence correction due to wall constraint was estimated for the ground tests from theoretical work by Brown[2] and Sanders[3], and found to be negligible, amounting to less than 10% of the correction needed without the ground present. A wake blockage correction of the form indicated by Maskell[4] has been applied throughout.

3 DISCUSSION OF RESULTS

In the presence of the ground, the lift-curve slope is increased by some 10% throughout the incidence range (see Fig.2), and a lift coefficient increment of 0•07 is produced at an incidence of 15° giving an overall C_L of 0•76. The favourable ground effect on lift does not increase steadily as the ground clearance is reduced, the increments being almost identical at the two H/b values tested. Simple considerations of the reflected trailing-vortex system of the M-wing suggest that, at small ground clearances, the induced upwash over the central portion of the wing will be replaced by an induced downwash, the downwash contribution from the images of the trailing vortices shed from the roots of the inner panels having exceeded the upwash contribution from the images of the weaker trailing vortices shed from the tips of the outer panels; this would account qualitatively for the observed levelling off of the ground effect on lift.

Although the lift increment is the same for the two wing heights, the distribution of lift on the wing differs and the longitudinal stability increases steadily as the ground is approached (Fig.2). At α = 15° and H/b = 0•192, the centre of pressure is moved aft by about 3% $\bar{c}$ and the ratio $\Delta C_m/\Delta C_L$ due to the ground is -0•14.

At low incidences, the drag is little changed and the lift/drag ratio is increased by about 10%, the maximum value of C_L/C_D rising from 11·0 to 12·5 (at $C_L = 0{\cdot}18$). This improvement gradually disappears as the incidence is raised, and the lift/drag ratio of 3·4 at 15° is unchanged by the presence of the ground (Fig.3). The plot of C_D as a function of $C_L{}^2$ (Fig.4) is non-linear; the induced drag factor is large and increases steadily with C_L. Near the ground the factor is reduced by a constant amount of order 1·0 (for example, from 6·3 to 5·3 at $C_L = 0{\cdot}7$).

Ground effect on the tailplane behaviour is illustrated in Fig.5. Away from the influence of the ground ($H/b = \infty$), the C_m curves for the lower tailplane positions (h/b = 0 and −0·05) do not show the pitch-up present on the wing alone i.e. the effectiveness of a tailplane mounted on or below the wing chord plane increases with increasing incidence as the tailplane moves down from the wing wake. Near the ground, the tailplane effectiveness is improved, presumably due to the decreased downwash. The tailplane effectiveness in the higher positions (h/b = 0·05 and 0·10) is reduced by the wing wake, and an appreciable pitch-up remains. The ground has a smaller effect on the pitching moments at these positions than with the lower tailplane mountings.

LIST OF SYMBOLS

C_L	overall lift coefficient
C_D	overall drag coefficient
C_m	overall pitching moment coefficient about the mean quarter chord point, based on the aerodynamic mean chord
ΔC_L, ΔC_m	lift and pitching moment coefficient increments due to ground effect.
$\bar{c}$	$= \int_0^{b/2} c^2\, dy \Big/ \int_0^{b/2} c\, dy$, aerodynamic mean chord.
b	wing span
c	local wing chord
y	spanwise co-ordinate
h	height of tailplane above wing chord plane
H	height of wing quarter chord point above ground
α	incidence
A	aspect ratio
η_T	tailplane setting angle relative to wing chord plane

LIST OF REFERENCES

Ref.No.	Author	Title, etc.
1	Bagley, J.	An aerodynamic outline of a transonic transport aeroplane. A.R.C. 19205. October, 1956.
2	Brown, W. S.	Wind tunnel corrections on ground effect. R & M No.1865. July, 1938.
3	Sanders, J.	Wind tunnel corrections in ground effect tests. N.R.C. Canada Aero. Report AR-5. 1948.
4	Maskell, E. C.	A theory of wind tunnel blockage effects on stalled flows. Unpublished M.O.A. Report.

ATTACHED:

Table 1
Figs. 1-5

TABLE 1

Details of wing and tailplane

Wing

Aspect ratio, A	5·02
Span, b	8·333 ft (100 in)
Gross area, S	13·84 sq ft
Aerodynamic mean chord, $\bar{\bar{c}}$	1·938 ft
Geometric mean chord, $\bar{c}$	1·660 ft
Distance of mean quarter chord point ahead of T.E. apex	3·689 ft
Flat-plate section	

Tailplane

Aspect ratio, A_T	2·00
Span, b_T	2·235 ft
Gross area, S_T	2·498 sq ft
Ratio of tailplane area/wing area, S_T/S	18·05%
Tail arm, l_T	4·625 ft
Tailplane volume coefficient, $\frac{S_T l_T}{S\bar{\bar{c}}}$	0·43
Tailplane volume coefficient, $\frac{S_T l_T}{S\bar{c}}$	0·50
10% R.A.E. 101 section	
Tailplane heights/wing span, h/b	-0·05, 0, +0·05, +0·10

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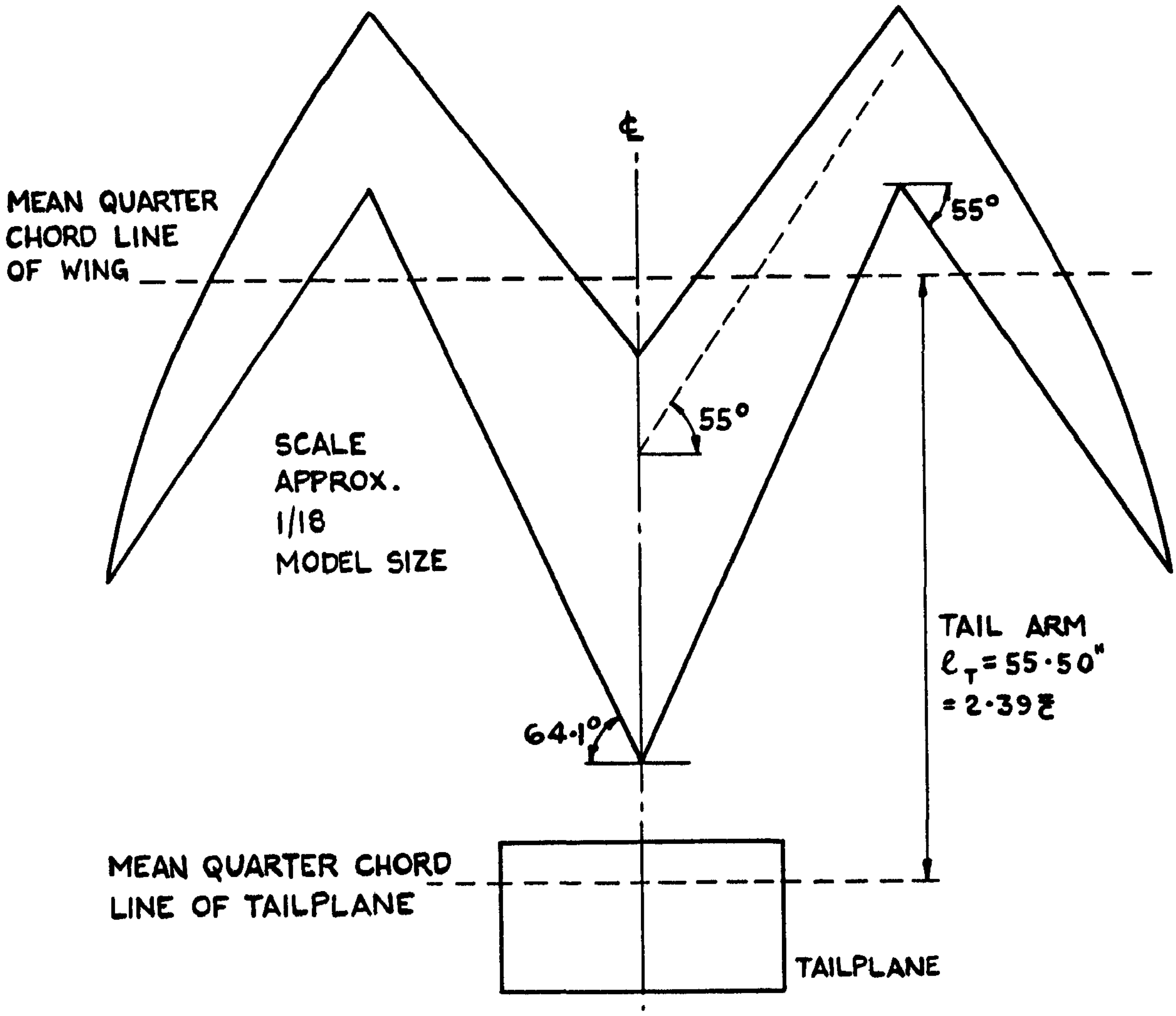

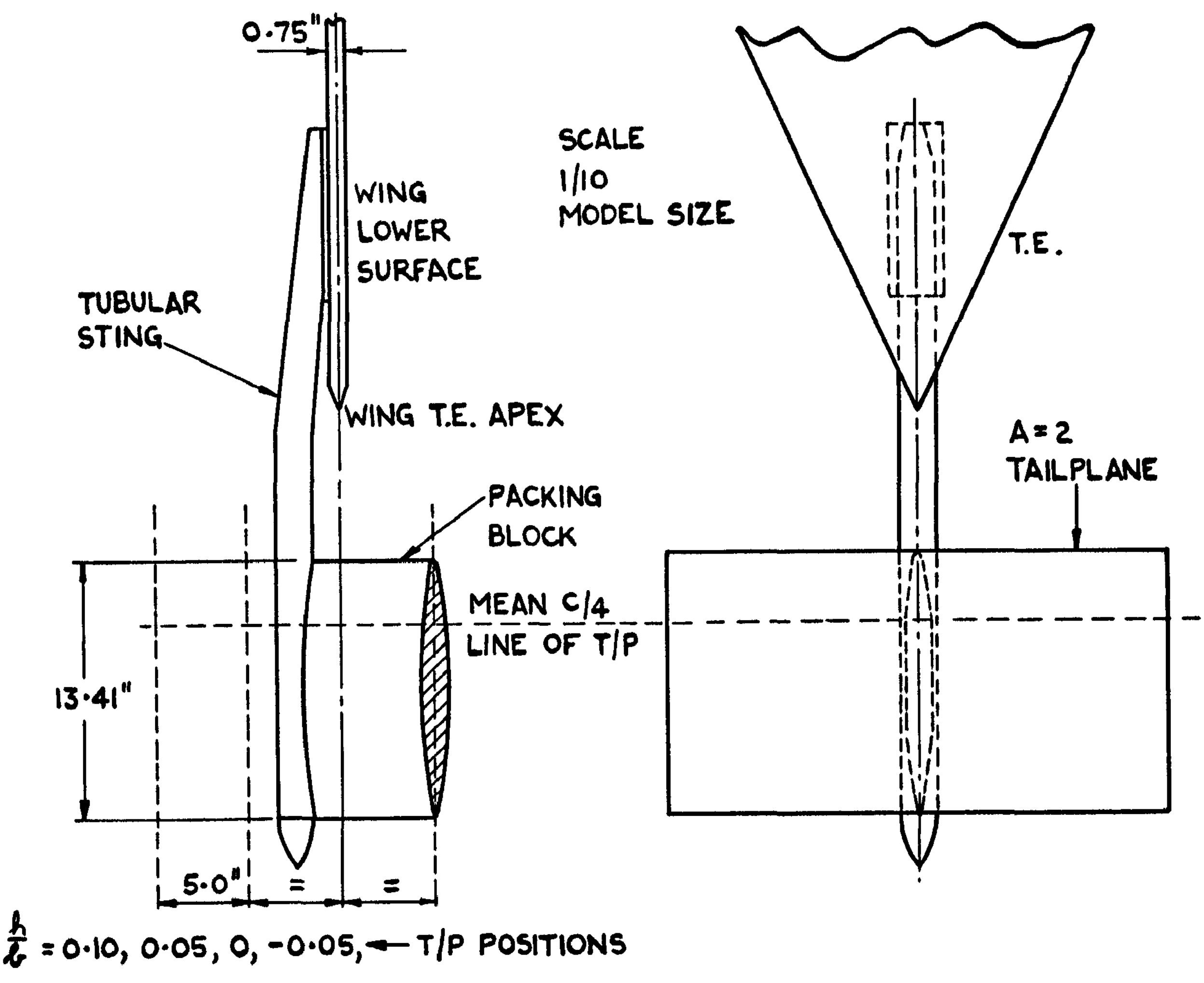

FIG.1 G.A. OF M-WING AND TAILPLANE ASSEMBLY

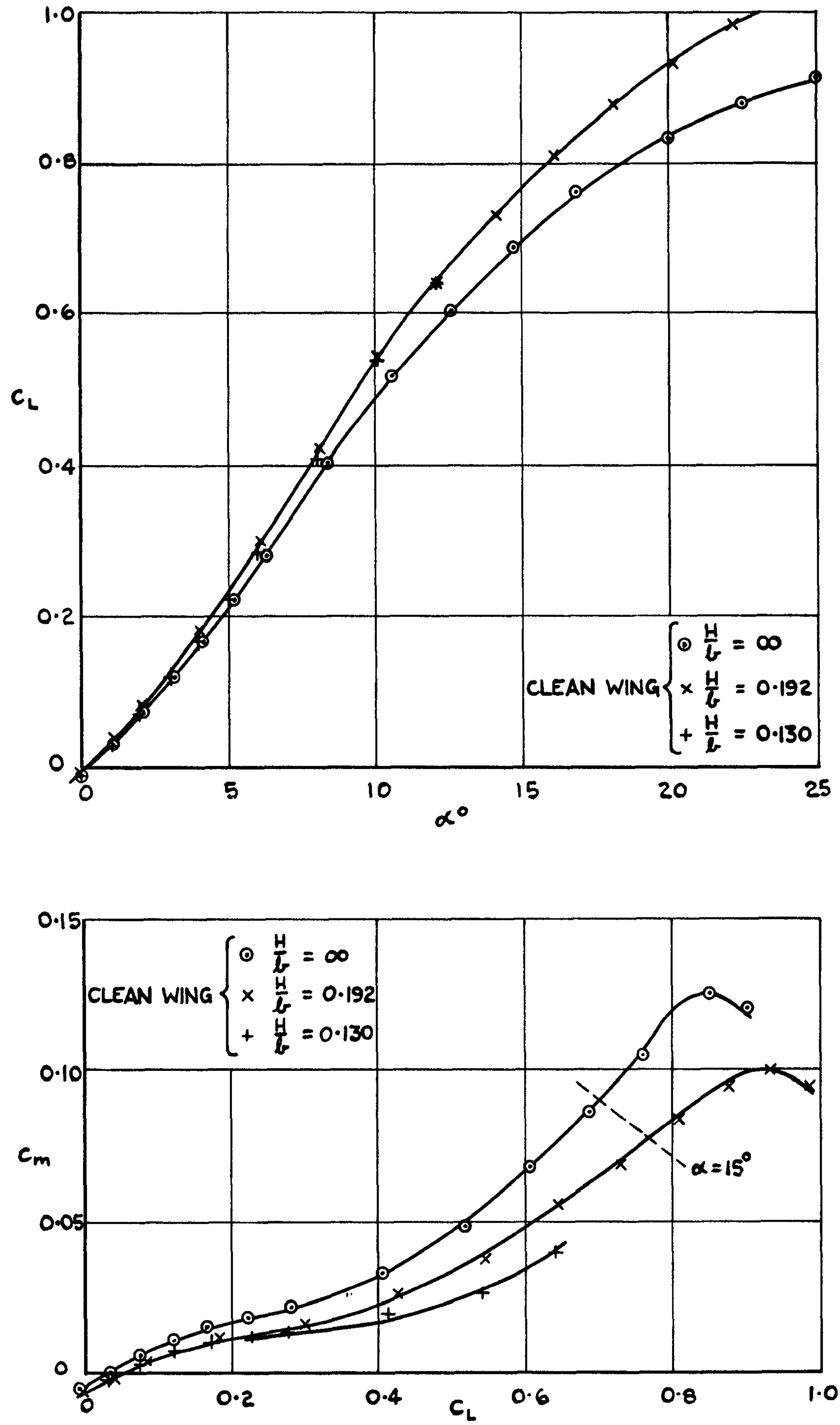

FIG.2 EFFECT OF GROUND ON LIFT AND PITCHING MOMENT CHARACTERISTICS OF A = 5 M-WING

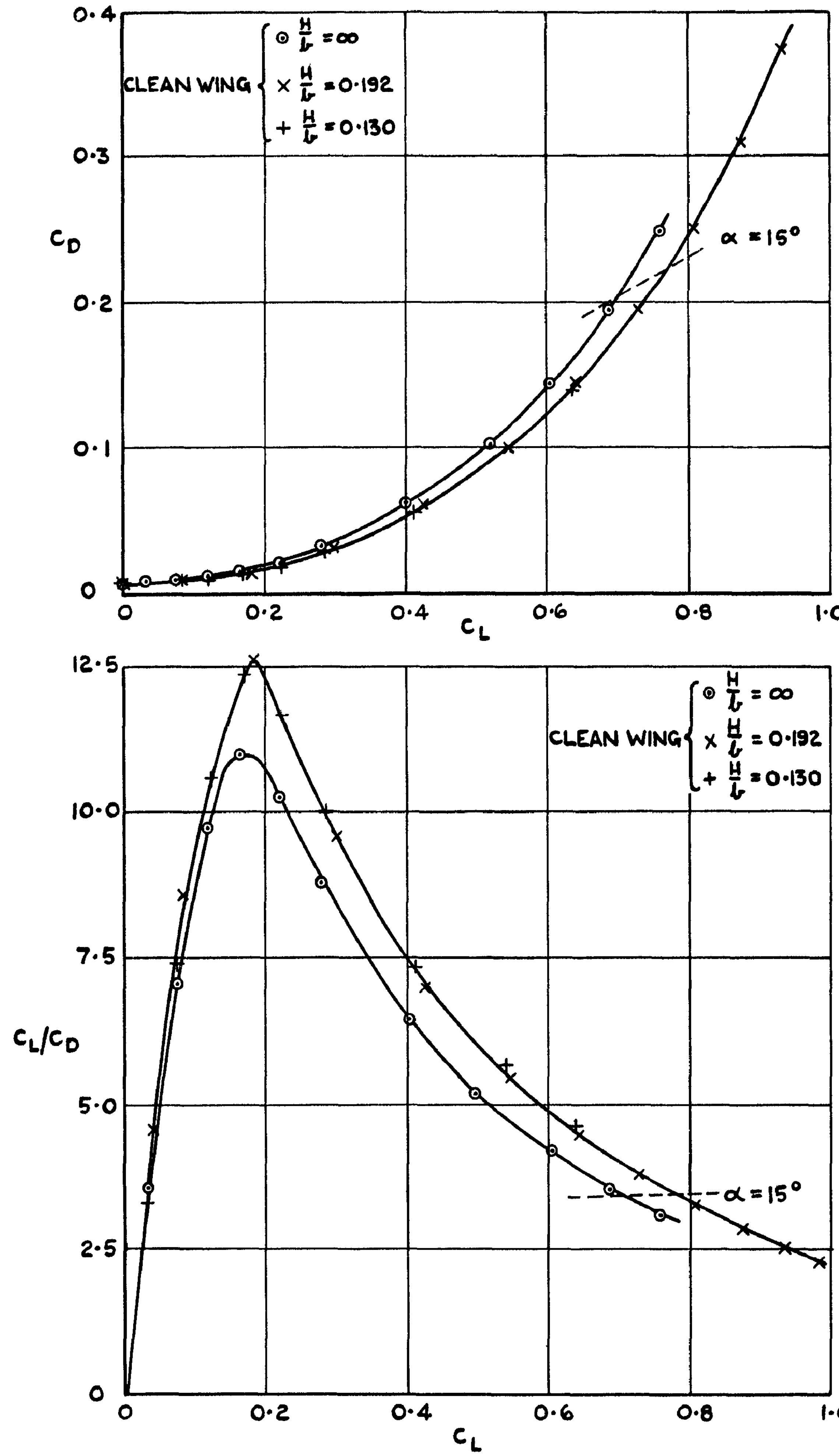

FIG.3 EFFECT OF GROUND ON DRAG CHARACTERISTICS AND LIFT/DRAG RATIO OF A = 5 M-WING

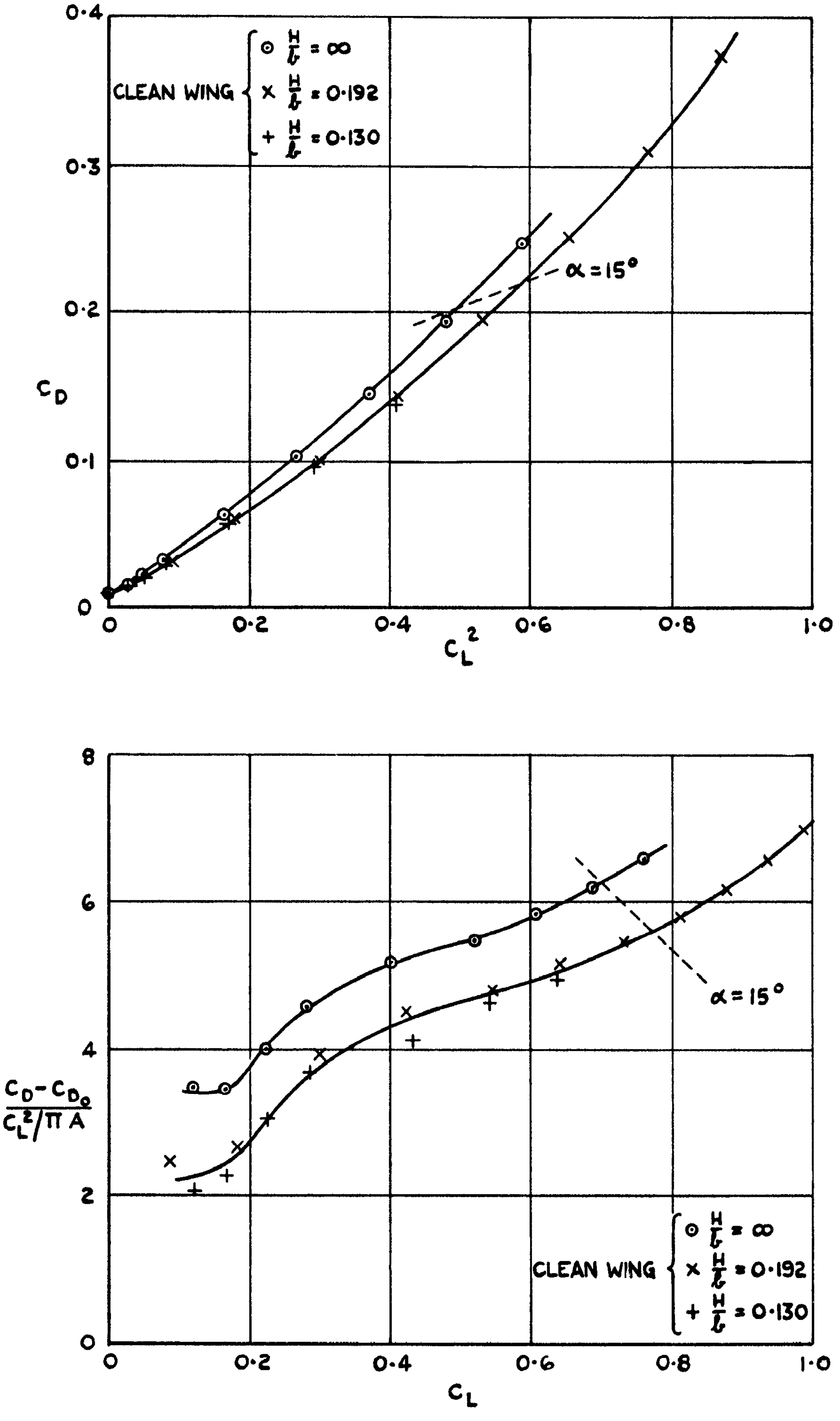

FIG.4 EFFECT OF GROUND ON INDUCED DRAG CHARACTERISTICS OF A=5 M-WING

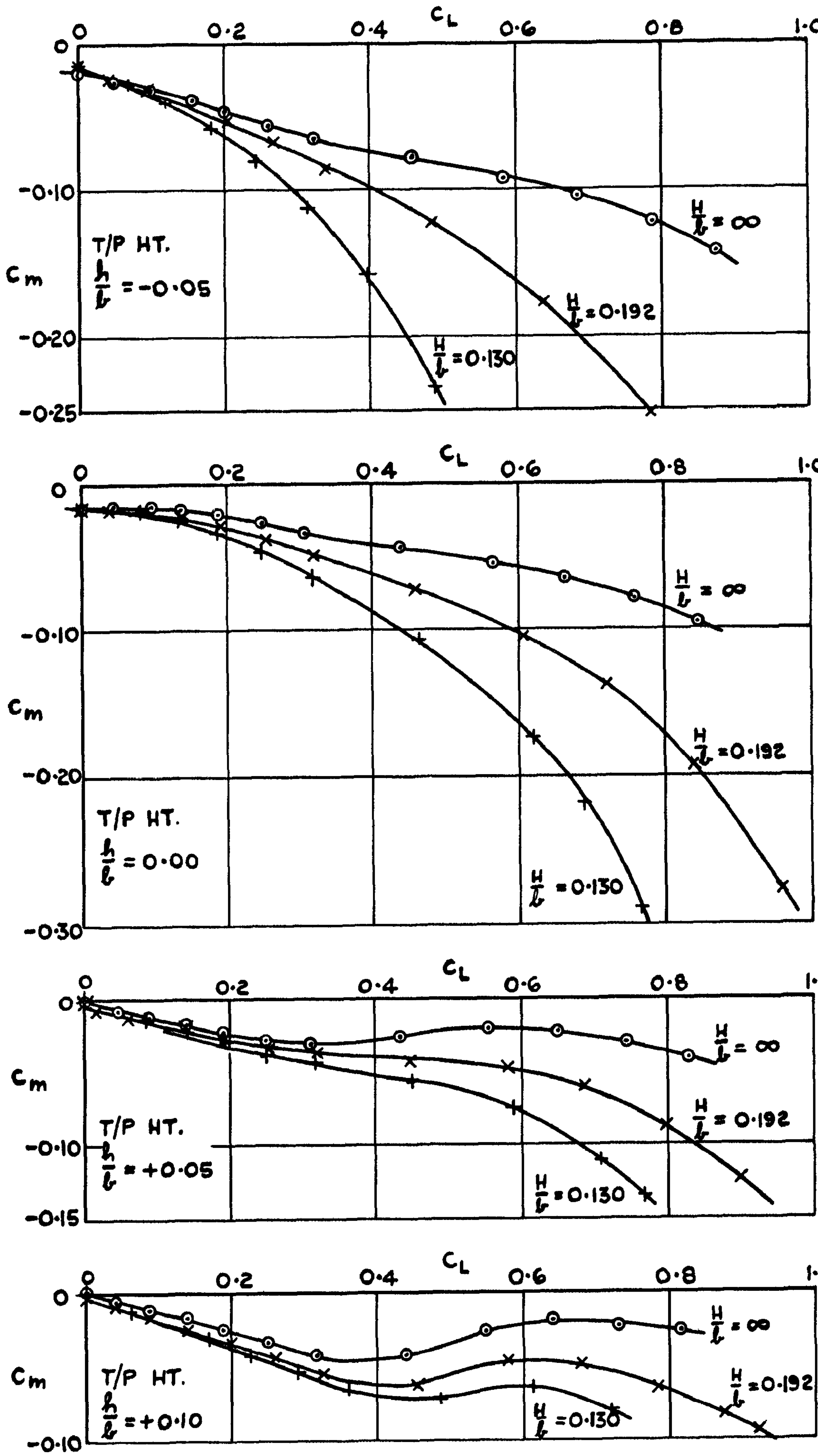

FIG. 5 EFFECT OF GROUND ON PITCHING MOMENT CHARACTERISTICS OF A=5 M-WING WITH A=2 RECTANGULAR TAILPLANE AT VARIOUS HEIGHTS, $\eta_T = 0°$

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GROUND EFFECT ON A 55° SWEPT M-WING OF ASPECT RATIO 5.0. 1.2.2.2.3
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