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Systematic Wind-Tunnel Tests with Slats on a 10 per cent Thick Symmetrical Wing Section (EQ 1040 Profile)

By

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Summary.—It was thought that present rules for the design of Handley Page slats might be inadequate for modern high-speed aerofoil sections. These tests were made on the EQ 1040 wing section to determine the optimum slat setting for this type of wing profile.

Three slats were tested whose chords were 10 per cent, 20 per cent and 30 per cent of the wing chord, over a wide range of positions. Lift coefficients were measured over the stall in each case. Some tests were made with a split flap.

Best results for the 10 per cent chord slat are obtained with very small gap and large dip. Zero gap, *i.e.*, using the slat as a nose flap, may in fact give the optimum. Optimum positions for the larger chord slats are more conventional, but require larger forward extensions than are given by the old rules.

1. *Introduction.*—The rules which are at present in use for the design of Handley Page slats were compiled from the results of a considerable number of *ad hoc* tests. These are quoted in the appendix to this report. Most of the tests were made on thick cambered aerofoil sections with considerable upper surface curvature towards the leading edge and were confined to slats of the order of $12\frac{1}{2}$ per cent wing chord. It was considered that the old rules might be inadequate (a) for modern thin symmetrical wing sections and (b) for slats of large chord. This report describes the results of some systematic tests with slats on a wing section representative of the type employed at the present day.

2. *Details of Tests.*—The tests were made during March and April, 1948, in a 5-ft open-jet, wind-tunnel. The wing section was a 10 per cent thick ellipto-quartic section with the maximum thickness at 40 per cent chord. Ordinates of the section are given in Table 1. The model had an aspect ratio of $3 \cdot 0$, but was fitted with elliptical end-plates (*see* Fig. 1*a*) which effectively increased the aspect ratio to $4 \cdot 6$ (estimated from Ref. 1 on the basis of the measured lift curve slope).

The chords of the slats used were 10 per cent, 20 per cent and 30 per cent wing chord. The wing was cut away to accommodate a 23 per cent chord slat. This cut-away section was satisfactory for the 20 per cent and 30 per cent slats, but leaves some doubt as to the interpretation of results with the 10 per cent slat (*see* section 3.1). Further details are given in

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Table 1 and Fig. 1b. The slats could be fixed in any desired position by means of clamps at the end plates and at the small mid-span plate (shown in Fig. 1a). The position of the slat relative to the wing was determined in terms of the ' forward extension ', the ' dip ' and the ' gap.' These quantities are defined in Fig. 1b.

Measurements of lift coefficient were made at a wind speed of 180 ft/sec giving a Reynolds number of $0 \cdot 94 \times 10^6$ based on wing chord, but tests were also made on the datum wing section at speeds of 120 ft/sec and 160 ft/sec ($R = 0 \cdot 62 \times 10^6$ and $0 \cdot 83 \times 10^6$, respectively,) to check the scale effect. The majority of the tests were made without flap, but some measurements with a 60 deg split flap were made for each slat in a few representative positions.

3. *Results and Discussion.*—3.1. *Flaps* 0 *deg.*—The scale effect on lift coefficient for the datum wing section is shown in Fig. 2. With the split flap there is little effect on maximum lift coefficient due to an increase of Reynolds number from $0 \cdot 62 \times 10^6$ to $0 \cdot 94 \times 10^6$, but with the flap closed there is a considerable increase which is almost linear with Reynolds number. Tests at higher Reynolds numbers could not be made owing to structural limitations.

If the slats are automatic and open independently, it is undesirable to have much change of lift when the slat opens, since near the stall it is possible to have one open and the other closed. Typical lift curves for the three slats are given in Figs. 3, 4 and 5 which show that a compromise must be made between the maximum lift coefficient and the loss of lift at constant incidence below the stall. $\alpha = 12$ deg has been taken as the reference incidence at which the variation in lift due to the slat is specified, since this is about the top of the linear part of the lift curve.

The results are summarised in Tables 2, 3 and 4 and also in Figs. 6 to 23 where contours of maximum lift coefficient and stalling incidence are given together with the corresponding loss of lift at an incidence of 12 deg. Each illustration has been drawn for a constant forward extension.

As regards maximum lift the best forward extension of those tested was $15 \cdot 3$ per cent chord for the 20 per cent chord slat and 23 per cent chord for the 30 per cent chord slat. Reduction of the forward extension in both cases gave inferior maximum lift. In the case of the 10 per cent chord slat, however, as the forward extension was reduced, an additional region of high maximum lift appeared at a forward extension of 3 per cent chord. This high lift occurred at large values of the slat dip and with small gaps. Further tests with still smaller forward extensions gave the results presented in Fig. 3. The gap became zero, and the highest maximum lift coefficient for this slat was given by a nose flap ($C_{L\max} = 1 \cdot 355$). It must be noted that the Reynolds number of the 10 per cent chord slat considered as a separate aerofoil was as low as $0 \cdot 94 \times 10^5$. Previous work[2,3], however, has shown good agreement between low Reynolds number tunnel tests and flight tests on a highly cambered wing section with slat (tunnel Reynolds number of slat $= 1 \cdot 6 \times 10^5$).

The optimum positions for the three slats are given in Table 5. These may be compared with the conventional slat designs, given in the Appendix, obtained using the rules at present in use. No provision is made in the rules for slat chords other than $12\frac{1}{2}$ per cent chord with a wing of this thickness, but in practice the rules governing dip and forward extension have been taken to apply to slats of larger chord, and the gap has been increased to some extent. It will be seen that the present tests indicate:

(a) With 20 per cent and 30 per cent chord slats, the optimum forward extension is greater than was found on old-type wing sections—about 80 per cent slat chord compared with 60 per cent.

(b) With a 10 per cent chord slat, optimum results require a bigger dip and smaller gap than are given by the old rules. The best result actually obtained was by using the slat as a nose flap, *i.e.*, with zero gap. This direct comparison of slat and nose flap must be accepted with caution, because the use of a wrong cutaway shape on the wing (section 2) may have been detrimental to the slat results.

It would appear that on the symmetrical thin wing a big advantage can be gained by using the small chord slat as a turned-down nose to give the equivalent of camber. This has the disadvantage of moving the no-lift angle to a more positive value, and so decreasing the lift at a given pre-stall incidence. With the larger slats, in order to get a good gap shape on the flatter wing surface, the slat must be at a more shallow angle than is the case with more cambered sections; this makes the forward extension greater.

3.2. *Effect of Split Flap*.—Only a few slat positions were tested with the split flap, but in general the increase in maximum lift coefficient due to the flap with the slat extended is greater with the 10 per cent slat than with the slats of larger chord. The results at three representative positions are plotted in Fig. 33 and all the positions tested are given in Table A.

TABLE A

per cent chord slat	Forward Extension	Dip	Increase in highest $C_{L\,max}$ due to flap 60 deg
*10 (nose flap)	2·7%c	7·1%c	0·91
10	5·2	2·3	0·77
10	5·0	4·8	0·82
10	7·1	4·8	0·81
20	11·1	2·3	0·74
20	15·1	2·2	0·66
20	19·1	2·3	0·68
*20	19·1	7·3	0·80
20	19·5	−2·6	0·68
*30	23·0	9·7	0·68
30	23·1	2·4	0·62

* The positions plotted in Fig. 33.

The effect of the split flap on the value of the optimum gap is shown in Fig. 34. In most of the positions tested a small increase of gap (about 0·5 per cent wing chord) is indicated with the flap.

4. *Slat Design*.—4.1. *Untapered Slats*.—The highest value of the maximum lift coefficient for the three slats is plotted in Figs. 24 and 25 and the corresponding slat positions are given in Table 5. A compromise has to be made between the maximum lift and the loss of lift on opening. Owing to the peculiar nature of the $C_{L\,max}$ contour field for the 10 per cent chord slat discussed in section 3, it would appear to be impossible to interpolate the optimum slat settings for slats of between 10 per cent and 20 per cent chord.

4.2. *Tapered Slats*.—In the design of a tapered slat, the angle of rotation on opening must be identical at both ends. This angle of dip, ϕ, has been determined graphically for each slat setting tested and is included in all the tables. The design in any particular case will involve a compromise between the optimum angles of dip at both ends, and for this purpose Fig. 26 has been prepared. The highest maximum lift coefficient is shown for various values of ϕ at fixed losses of lift due to the slat. The corresponding slat positions are given in Table 6.

4.3. *Automatic Slats*.—Here the loss of lift on opening the slat is of great importance for reasons detailed in section 3.1. In Figs. 27 to 32 contours of maximum lift and stalling incidence have been drawn for the design of automatic slats. For the 10 per cent chord slat, the condition of zero loss of lift at $\alpha = 12$ deg is too extreme for contours to be drawn, so a loss of lift of $\Delta C_L = -0 \cdot 02$ has been assumed. For the 20 per cent and 30 per cent chord slats, zero loss of lift at $\alpha = 12$ deg has been used.

5. *Conclusions.*—The highest increments of maximum lift coefficient are 0·43, 0·70 and 0·99 respectively for the 10 per cent, 20 per cent and 30 per cent chord slats. This result is achieved in the case of the 10 per cent chord slat with zero gap, *i.e.*, with the slat used as a nose flap. With a small gap the lift obtained is still high for this slat, but the slat has to be dipped down much more than is indicated in the old rules.

The results in general should prove useful in the design of slats on high speed wing sections.

REFERENCES

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APPENDIX

The Rules for Slat Design at present in use

(1) *Slat chord:* 12½ per cent wing chord for wing thickness ratios up to 10 per cent and equal to the thickness ratio plus 2½ per cent for wings of greater thickness.

(2) *Forward extension:* at least 60 per cent slat chord.

(3) *Dip:* 25 per cent of forward extension.

(4) *Gap:* 2·4 per cent wing chord for wing thickness ratios up to 6 per cent increasing by 0·3 per cent for every 2 per cent increase in wing thickness.

(5) *W* (*see* Fig. 1b): 2 per cent wing chord, increasing slightly for thick wings.

Applying these rules to the EQ 1040 wing section for slat chords of 10 per cent, 20 per cent and 30 per cent wing chord as well as for the 12½ per cent chord slat recommended above, we have:—

Slat chord—per cent c	12½ *per cent*	10 *per cent*	20 *per cent*	30 *per cent*
Forward extension—per cent *c* ..	7·5	6	12	18
Dip—per cent *c*	1·9	1·5	3	4·5
Gap—per cent *c*	3	3	—	—

These values may be compared with the optimum designs given in Table 5.

TABLE 1

Model Details and Data

Wing:	section		EQ 1040 symmetrical
	span	b	2·5 ft
	chord	c	0·833 ft
	area	S	2·083 sq ft

End plates: ellipse of semi-axes = 0·375 and 0·542 ft
(slight modification of ellipse shape at leading edge, *see* Fig. 1).
Distance from leading edge of complete wing section to that of end plate = 0·229 ft.

Split flap:	full span	
	chord	20%c = 0·167 ft
	angle	60 deg
	area	0·417 sq ft

Slat Ordinates

Distance from leading edge (% wing chord)	10%c Slat (y%c)		20%c Slat (y%c)		30%c Slat (y%c)	
	Upper surface	Lower surface	Upper surface	Lower surface	Upper surface	Lower surface
0·5	0·77	− 0·77	0·77	− 0·77	0·77	− 0·77
1·0	1·12	− 1·12	1·12	− 1·12	1·12	− 1·12
1·5	1·35	− 1·35	1·35	− 1·35	1·35	− 1·35
2·0	1·58	− 1·58	1·58	− 1·58	1·58	− 1·58
2·5	1·73	− 1·73	1·73	− 1·73	1·73	− 1·73
5·0	2·42	1·25	2·42	0·60	2·42	0·60
7·5	2·92	2·42	2·92	1·60	2·92	1·60
10·0	3·31	3·31	3·31	2·23	3·31	2·23
15·0			3·92	3·42	3·92	3·22
20·0			4·35	4·35	4·35	3·92
25·0					4·62	4·40
30·0					4·85	4·85

Leading edge radius = 0·62 per cent c

N.B. y gives distance above wing chord line when slat is closed (per cent wing chord).

Table 1—*continued*

Wing Ordinates

EQ 1040 Symmetrical Section

Distance from leading edge %c	Complete section half ordinate y%c	Cut away section used with slats y%c	
		Lower surface	Upper surface
0·5	0·77	—	(y is + ve above the chord line)
1·0	1·12	—	
1·5	1·35	—	
2·0	1·58	—	—
2·5	1·73	As for complete section	− 1·73
5·0	2·42		+ 0·60
7·5	2·12		1·70
10·0	3·31		2·35
15	3·92		3·40
20	4·35		4·15
25	4·62		4·62
30	4·85		4·85
35	4·96		4·96
40	5·00		5·00
50	4·85		4·85
60	4·31		4·31
70	3·46		3·46
80	2·42		2·42
85	1·85		1·85
90	1·23		1·23
95	0·62		0·62
100	0		0

Leading edge radius = 0·62 per cent *c*

TABLE 2

10% *Chord Slat: Summary of Results* (Figs. 6 to 13)

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	9·9	0	4	− 8·4	1·040	20·4	− 0·03
0	9·7	0	5	− 0·4	1·058	17·9	− 0·03
0	9·3	− 0·1	6·5	10·7	0·895	18·6	− 0·095
0	9·7	2·5	3	− 3·0	0·989	18·95	− 0·025
0	9·5	2·4	4	4·1	1·131	18·25	− 0·06
0	9·3	2·3	5	11·6	1·067	19·4	− 0·11
0	9·6	5·1	2·6	1·5	0·856	16·95	− 0·05
0	9·5	5·0	3	5·1	1·031	17·1	− 0·06
0	9·2	4·8	4	14·0	0·934	16·9	− 0·125
0	7·7	0	3	− 3·9	1·020	20·0	− 0·01
0	7·4	0	4	3·0	1·087	17·5	− 0·035
0	7·3	− 0·1	5	8·8	1·119	19·8	− 0·075
0	7·1	− 0·2	6	15·5	0·825	21·6	− 0·175
0	7·5	2·5	2	1·4	0·986	18·75	− 0·03
0	7·3	2·4	3	8·1	1·163	19·2	− 0·065
0	7·1	2·3	4	15·5	1·166	23·1	− 0·125
0	6·9	2·2	5	22·3	0·757	28(?)	− 0·225
0	7·4	4·9	1	4·9	0·984	15·85	− 0·055
0	7·2	4·8	2	13·1	1·223	20·85	− 0·075
0	7·0	4·7	3	20·4	1·093	22·35	− 0·235
60	7·2	4·8	2	13·1	1·920	16·65	− 0·03
60	7·0	4·7	3	20·4	2·035	19·7	− 0·03
60	6·8	4·6	4	27·5	1·498	11·45	− 0·055
0	7·1	7·2	2	18·1	1·012	19·6	− 0·115
0	6·9	7·1	3	27·9	0·675	13·4	− 0·455
0	5·5	0	3	2·2	1·048	17·25	− 0·03
0	5·3	− 0·1	4	9·3	1·142	19·4	− 0·085
0	5·1	− 0·2	5	16·1	0·933	25·0	− 0·195
0	5·5	2·4	1	3·1	0·974	16·5	− 0·035
0	5·3	2·3	2	10·1	1·222	19·45	− 0·055
0	5·1	2·2	3	17·1	1·197	24·2	− 0·115
0	4·9	2·1	4	24·1	0·745	18·15(?)	− 0·19
60	5·3	2·3	2	10·1	1·838	15·2	− 0·02
60	5·1	2·2	3	17·1	1·996	19·1	− 0·04
60	4·9	2·1	4	24·1	1·679	15·2	− 0·045
0	5·2	4·8	0·5	13·6	1·222	19·65	− 0·03
0	5·1	4·8	1	16·1	1·285	21·35	− 0·045
0	4·9	4·7	2	24·1	1·130	23·15	− 0·10
0	4·7	4·6	3	31·6	0·717	14·9	− 0·16
60	5·1	4·8	1	16·1	1·986	18·0	− 0·015
60	4·9	4·7	2	24·1	2·100	20·1	− 0·03
60	4·7	4·6	3	31·6	1·693	14·5	− 0·04

TABLE 2—*continued*

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	5·0	7·2	0	20·3	1·234	19·5	− 0·015
0	4·9	7·2	0·5	23·7	1·234	20·45	− 0·055
0	4·8	7·1	1·0	26·7	1·116	19·9	− 0·075
0	4·7	6·9	2·0	34·7	0·868	17·35	− 0·16
0	3·5	0	2	1·2	0·929	18·4	− 0·045
0	3·2	− 0·1	3	8·3	1·076	19·25	− 0·115
0	3·1	− 0·2	4	15·9	0·972	22·85	− 0·195
0	3·3	2·4	0·5	7·4	1·033	16·8	− 0·055
0	3·2	2·3	1	10·5	1·171	19·7	− 0·095
0	3·0	2·2	2	19·2	1·038	23·0	− 0·125
0	3·0	4·8	0	18·9	1·205	19·45	− 0·015
0	2·9	4·7	0·5	23·1	1·165	20·6	− 0·05
0	2·8	4·7	1	26·1	0·895	22·6	− 0·12
0	2·7	4·5	2	33·6	0·820	15·85	− 0·14
0	2·7	7·1	0	32·5	1·341	21·15	− 0·03
0	2·6	6·9	0·5	36·2	1·154	19·85	+ 0·005
0	2·5	6·8	1	40·1	0·933	17·5	− 0·12
60	2·7	7·1	0	32·5	2·247	22·25	− 0·06
60	2·6	6·9	0·5	36·2	2·135	20·95	− 0·05
0	0·7	8·6	0	50·6	1·355	21·75	− 0·05
0	− 1·7	8·5	0	67·1	1·288	21·8	− 0·08

TABLE 3

20% Chord Slat: Summary of Results (Figs. 14 to 19)

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	20·1	− 2·4	3	− 19·3	0·760	16·2	− 0·14
0	19·9	− 2·4	5	− 10·0	1·055	19·2	0
0	19·7	− 2·5	6·5	− 4·6	1·275	22·0	0·065
0	19·6	− 2·5	8	0·6	1·380	23·0	0·025
0	19·4	− 2·6	10	7·1	1·345	20·9	− 0·035
60	19·6	− 2·5	8	0·6	1·970	19·35	0
60	19·4	− 2·6	10	7·1	1·990	18·1	− 0·03
60	19·3	− 2·6	11	10·5	2·060	19·9	− 0·075
60	19·2	− 2·7	12	13·6	1·890	17·9	− 0·075
0	19·9	0·1	3	− 11·3	0·896	18·0	− 0·105
0	19·7	0	5	− 2·9	1·223	21·7	0·04
0	19·7	2·5	3	− 4·1	1·053	21·2	0·03
0	19·4	2·5	5	3·6	1·363	23·3	0·025
0	19·3	2·4	6·5	8·7	1·430	22·4	− 0·025
0	19·1	2·3	8	13·6	1·474	24·75	− 0·110
0	19·0	2·2	10	20·4	1·065	29·5	− 0·290
60	19·3	2·4	6·5	8·7	2·035	19·1	− 0·070
60	19·1	2·3	8	13·6	2·155	21·0	− 0·055
60	19·0	2·2	10	20·4	1·562	15·6	− 0·108
0	19·5	5·0	3	1·5	1·140	19·35	0·035
0	19·3	4·9	5	9·4	1·435	21·5	− 0·035
0	19·4	7·4	3	5·2	1·275	19·1	− 0·040
0	19·1	7·3	5	14·6	1·410	22·9	− 0·125
0	19·0	7·2	6·5	19·7	1·105	25·1	− 0·255
60	19·4	7·4	3	5·2	1·910	16·0	− 0·010
60	19·1	7·3	5	14·6	2·208	20·85	− 0·055
60	19·0	7·2	6·5	19·7	1·953	19·5	− 0·095
0	15·8	− 2·4	3	− 9·4	0·860	17·3	− 0·075
0	15·7	− 2·5	5	− 3·0	1·145	19·6	0·045
0	15·6	− 2·5	6·5	1·3	1·336	23·0	0·03
0	15·4	− 2·6	8	6·1	1·390	22·3	− 0·015
0	15·2	− 2·7	10	12·6	1·325	24·0	− 0·115
0	15·6	0	3	− 2·4	1·016	19·0	0·05
0	15·4	0	5	4·1	1·320	23·0	0·035
0	15·5	2·4	3	5·1	1·260	18·1	0·035
0	15·3	2·3	5	11·1	1·505	23·9	− 0·04
0	15·1	2·2	6·5	16·4	1·520	25·85	− 0·12
0	15·0	2·1	8	20·7	1·110	27·0	− 0·29
60	15·3	2·3	5	11·1	2·100	21·1	− 0·025
60	15·1	2·2	6·5	16·4	2·183	22·1	− 0·045
60	15·0	2·1	8	20·7	1·805	17·7	− 0·095
0	15·2	4·8	3	11·8	1·465	22·3	− 0·035
0	15·0	4·7	5	18·1	1·470	27·65	− 0·13

TABLE 3—*continued*

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	15·1	7·3	1·5	13·6	1·514	22·9	− 0·05
0	15·0	7·3	3	18·5	1·588	26·0	− 0·11
0	14·9	7·1	5	24·7	1·204	25·1	− 0·265
0	14·9	9·6	3	23·6	1·425	31·3	− 0·16
0	14·8	12·1	3	28·0	0·998	26·9	− 0·245
0	14·7	11·9	5	34·7	0·890	37·0	− 0·455
0	11·7	− 2·5	3	− 5·4	0·878	16·3	0·005
0	11·5	− 2·5	5	0·8	1·167	20·1	0·045
0	11·4	− 2·6	6·5	5·6	1·313	21·0	− 0·005
0	11·3	− 2·6	8	10·4	1·282	23·0	− 0·095
0	11·5	0	3	2·2	1·138	16·9	0·040
0	11·3	− 0·1	5	8·6	1·355	22·0	− 0·020
0	11·3	2·4	1·5	5·4	1·170	17·95	0·035
0	11·3	2·4	3	9·8	1·335	20·4	0
0	11·1	2·3	5	16·1	1·360	26·0	− 0·13
0	11·0	2·3	6·5	21·1	1·295	28·3	− 0·225
60	11·3	2·4	3	9·8	1·929	16·8	− 0·02
60	11·1	2·3	5	16·1	2·104	21·65	− 0·05
60	11·0	2·3	6·5	21·1	1·833	19·0	− 0·075
0	11·1	4·7	3	17·3	1·365	27·0	− 0·23
0	10·9	4·6	5	24·0	1·318	30·1	− 0·235
0	10·9	7·2	1	18·9	1·458	25·3	− 0·11
0	10·9	7·2	2	21·7	1·425	28·9	− 0·18
0	10·8	7·1	3	25·1	1·210	33·1	− 0·195
0	10·6	11·9	3	38·8	0·950	37·5	− 0·505

TABLE 4

30% Chord Slat: Summary of Results (Figs. 20 to 33)

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	27·3	2·45	6·5	8·0	1·550	25·3	0·045
0	27·2	2·4	8	11·1	1·650	27·4	0
0	27·1	2·4	10	15·1	1·675	26·0	− 0·08
0	23·5	− 2·6	6·5	2·1	1·314	21·4	0·095
0	23·4	− 2·6	8	5·2	1·455	23·4	0·08
0	23·25	− 2·65	10	9·1	1·525	23·3	0
0	23·2	− 2·65	11	11·1	1·570	24·3	− 0·05
0	23·3	0	6·5	6·7	1·460	23·9	0·05
0	23·4	2·5	4	6·5	1·360	19·2	0·075
0	23·3	2·5	5	8·4	1·460	23·3	0·055
0	23·2	2·45	6·5	11·5	1·607	25·75	0·005
0	23·1	2·4	8	14·5	1·670	26·7	− 0·065
60	23·3	2·5	5	8·4	2·130	21·35	0·025
60	23·2	2·45	6·5	11·5	2·238	23·3	− 0·005
60	23·1	2·4	8	14·5	2·280	23·25	− 0·05
60	23·0	2·35	10	18·7	2·293	24·0	− 0·05
60	22·9	2·3	11	20·7	1·999	20·95	− 0·075
0	23·2	4·85	5	13·2	1·635	23·75	0
0	23·1	4·8	6·5	16·2	1·715	27·7	− 0·055
0	23·2	7·4	2	11·7	1·588	22·0	0
0	23·1	7·4	3	13·7	1·655	23·25	− 0·01
0	23·1	7·35	4	15·7	1·727	25·0	− 0·075
0	23·1	9·8	2	16·2	1·705	24·5	− 0·05
0	23·1	9·75	3	18·2	1·772	26·15	− 0·075
0	23·0	9·75	4	20·3	1·830	29·6	− 0·115
0	23·0	9·7	5	22·3	1·562	26·6	− 0·155
60	23·1	9·75	3	18·2	2·402	24·25	− 0·01
60	23·0	9·75	4	20·3	2·470	26·1	− 0·025
60	22·9	9·7	5	22·3	2·509	27·1	− 0·05
60	22·8	9·65	6·5	25·3	2·268	24·7	− 0·075
0	23·0	12·8	2	21·2	1·835	27·6	− 0·105
0	22·9	12·7	3	23·3	1·884	31·45	− 0·165
0	22·8	12·65	4	25·3	1·680	32·95	—
0	22·8	12·6	5	27·4	1·548	30·3	− 0·29
0	19·5	− 2·5	6·5	3·9	1·318	22·0	0·08
0	19·4	− 2·6	8	7·0	1·450	23·9	0·05
0	19·3	− 2·6	10	11·0	1·512	24·85	− 0·025
0	19·3	0	6·5	9·0	1·481	21·85	0·03
0	19·2	2·4	5	11·0	1·500	22·5	0·02
0	19·1	2·4	6·5	14·0	1·607	25·75	− 0·035
0	19·0	2·4	8	17·1	1·615	27·0	− 0·115

(22742) A2*

TABLE 4—*continued*

Flap deg	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	$C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$ (flaps 0°) $\alpha = 9°$ (flaps 60°)
0	19·1	4·9	4	13·9	1·602	23·75	− 0·005
0	19·0	4·8	5	15·9	1·605	25·95	− 0·055
0	18·9	4·75	6·5	19·0	1·618	28·25	− 0·135
0	19·1	7·5	0	10·7	1·330	20·0	0·015
0	19·0	7·4	2	14·7	1·615	23·5	− 0·025
0	19·0	7·35	3	16·7	1·700	25·7	− 0·055
0	18·9	7·3	4	18·7	1·709	28·7	− 0·105
0	18·9	7·25	5	20·8	1·548	29·8	− 0·16
0	18·8	7·2	6·5	23·9	1·525	30·8	− 0·265
0	18·7	7·1	8	27·0	1·218	32·0	− 0·405
0	18·9	9·8	2	19·7	1·732	26·4	− 0·165
0	18·8	9·7	3	21·7	1·740	30·0	− 0·235
0	18·7	14·6	3	31·2	1·535	38·1	− 0·465
0	15·4	− 2·5	6·5	5·7	1·345	19·95	0·05
0	15·3	− 2·5	8	8·7	1·455	22·9	0·01
0	15·2	− 2·6	10	12·7	1·447	24·4	− 0·095
0	15·2	0	6·5	10·7	1·475	22·85	− 0·015

TABLE 5

(Figs. 30 and 31)

Highest $C_{L\,max}$ obtained for various values of ΔC_L at $\alpha = 12$ deg (Flap 0 deg)

	Slat Chord %c	Forward Extension %c	Dip %c	Gap %c	Angle of Dip ϕ deg	Highest $C_{L\,max}$	$\alpha°$ for $C_{L\,max}$	ΔC_L at $\alpha = 12°$
Highest $C_{L\,max}$ for $\Delta C_L = 0$ at $\alpha = 12°$	10	3·0	7·25	0·4	35·9	1·25	20	0
	20	15·3	1·0	5·0	7·5	1·44	23	0
	30	23·8	5·75	4·0	13·1	1·66	23	0
Highest $C_{L\,max}$ for $\Delta C_L = -0·02$ at $\alpha = 12°$	10	5·0	6·7	0	18·4	1·32	20	− 0·02
	20	16·5	1·2	6·0	9·4	1·47	23·2	− 0·02
	30	26·5	4·5	6·8	12·4	1·68	26	− 0·02
Highest $C_{L\,max}$ for $\Delta C_L = -0·05$ at $\alpha = 12°$	10	0·7	8·6	0	50·6	1·355	21·8	− 0·05
	20	16·0	3	5·0	12·5	1·51	24	− 0·05
	30	23·0	6·0	5·0	15·6	1·72	26·5	− 0·05
Highest $C_{L\,max}$ for $\Delta C_L = -0·10$	10	4·1	2·2	2·0	14·4	1·21	21	− 0·10
	20	15·3	7·5	2·6	17·0	1·62	26	− 0·10
	30	23·0	11·0	3·1	20·4	1·85	28·5	− 0·10
Highest $C_{L\,max}$ measured	10	0·7	8·6	0	50·6	1·355	21·8	− 0·05
	20	15·3	7·5	2·4	17·0	1·62	25·2	− 0·095
	30	23·0	12·7	2·7	22·1	1·91	30·3	− 0·15

TABLE 6

(Fig. 32)

Highest $C_{L\,max}$ obtained for various values of Angle of Dip, ϕ deg, at fixed values of ΔC_L at $\alpha = 12$ deg (Flap 0 deg)

ΔC_L at $\alpha = 12$ deg	Slat Chord %c	Angle of Dip ϕ deg	Forward Extension %c	Dip %c	Gap %c	Highest $C_{L\,max}$	$\alpha°$ $C_{L\,max}$
0	20	5	16·0	− 2·5	7·6	1·4	22·5
		7·5	15·3	1·0	5·0	1·44	23
		9·3	13·5	4·0	2·0	1·33	20
	30	10·6	27·5	1·0	9·0	1·65	26
		12·3	25·0	3·5	6·6	1·65	26
		13·1	23·8	5·75	4·0	1·66	23
− 0·02	10						
		5·4	6·5	5·0	0·2	1·05	19
	(nose flap)	9·4	5·6	6·0	0	1·2	20
	(nose flap)	18·4	5·0	6·7	0	1·32	20
		26·6	4·5	7·1	0·2	1·2	19·4
	20	5	19·5	− 3·0	9·8	1·35	21
		7·5	16·5	− 0·5	7·0	1·45	23·2
		9·4	16·5	1·2	6·0	1·47	23·2
		10	15·3	2·25	4·7	1·45	23
		12	12·5	5·0	1·7	1·35	21
	30	12·4	26·5	4·5	6·8	1·68	26
		13·6	24·0	5·0	5·5	1·66	25·5
		14·2	22·0	6·0	4·0	1·64	24·5
− 0·05	10	− 0·6	9·5	5·0	2·4	0·9	18
		2·2	7·5	3·0	1·8	1·1	19
		4·4	7·0	2·9	1·8	1·13	19
		9·4	6·2	5·0	0·8	1·21	20·4
		16·4	5·2	5·0	0·7	1·31	21
		24·4	4·0	6·0	0·5	1·24	21·1
	(nose flap)	50·6	0·7	8·6	0	1·355	21·8
	20	7·5	14·0	− 3·0	8·4	1·36	23·0
		10	16·5	− 0·3	7·5	1·45	23·8
		12·5	16·0	3·0	5·0	1·51	24·0
		15	13·0	6·0	1·8	1·45	21·8
	30	13·5	27·0	3·0	8·7	1·7	26·5
		14·6	25·0	4·0	7·5	1·71	27·0
		15·6	23·0	6·0	5·0	1·72	26·5
		16·85	21·0	9·0	2·0	1·69	24·0
+ 0·02	20	2·5	21·0	2·5	5·9	1·35	22·5
		5·0	15·5	0	5·2	1·37	22·7
		7·5	13·0	1·5	3·8	1·33	21·2

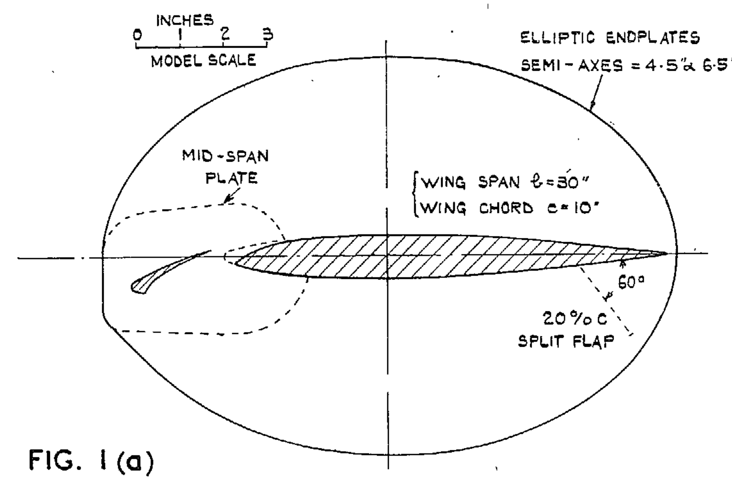


FIG. 1 (a)

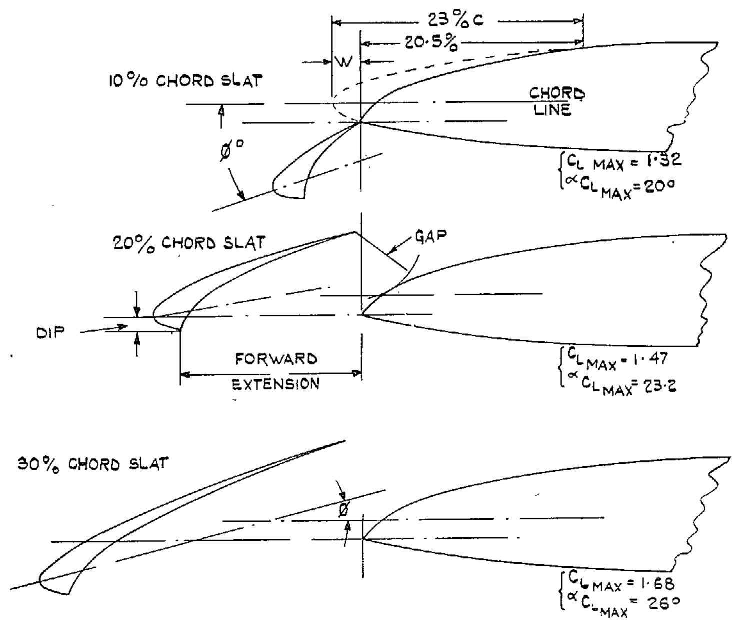


FIG. 1 (b)

FIG. 1. General arrangement of wing and slats. The slat positions shown are those giving highest $C_{L\,max}$ for $\Delta C_L = -0{\cdot}02$ on opening at $\alpha = 12$ deg (see Table 5).

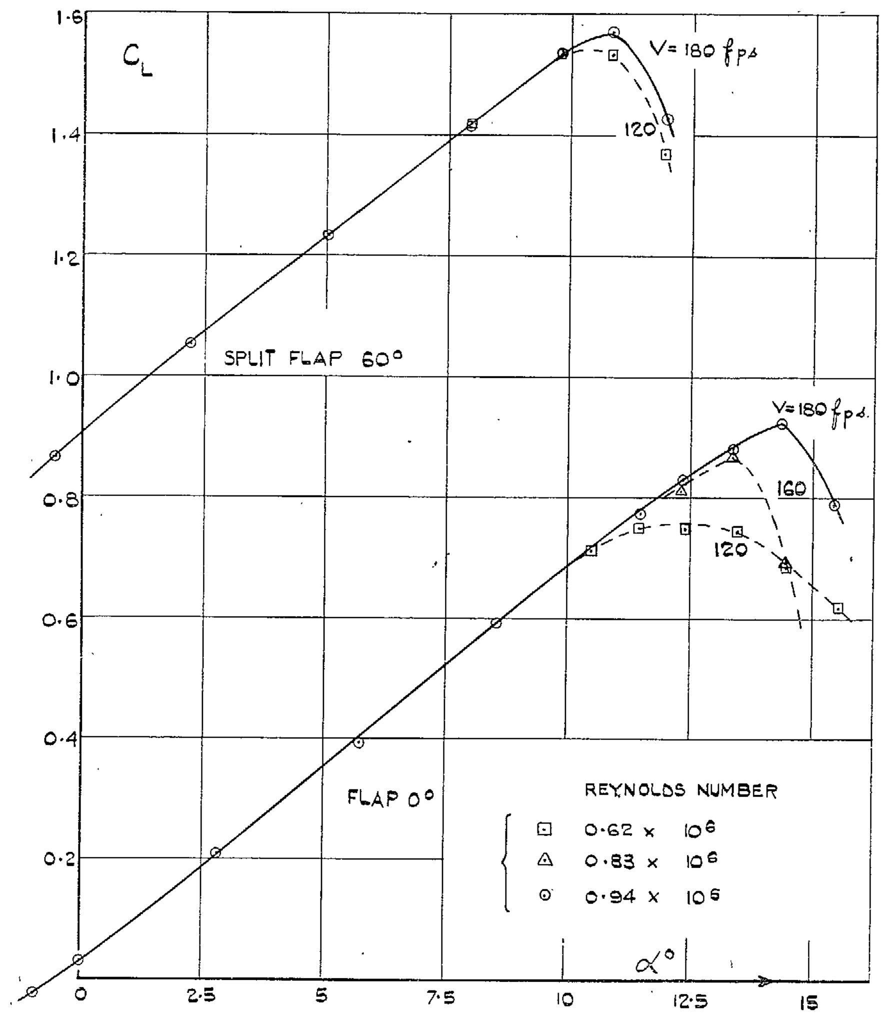


FIG. 2. Lift coefficients without slats.

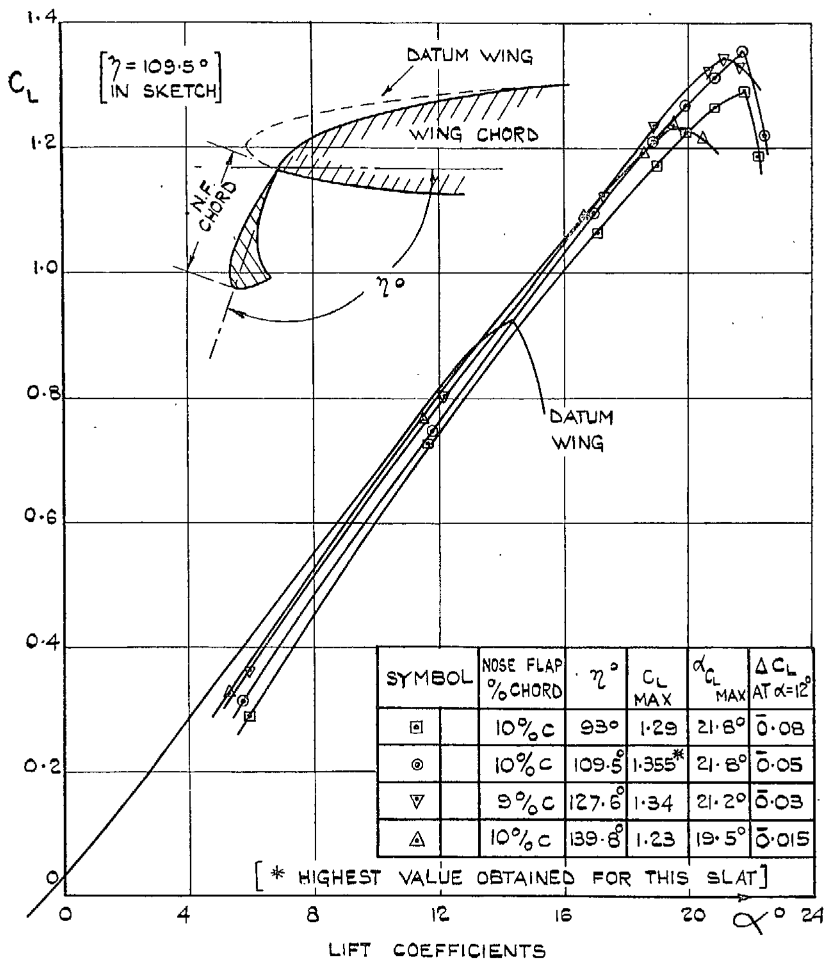


FIG. 3. 10 per cent chord slat used as a nose flap.

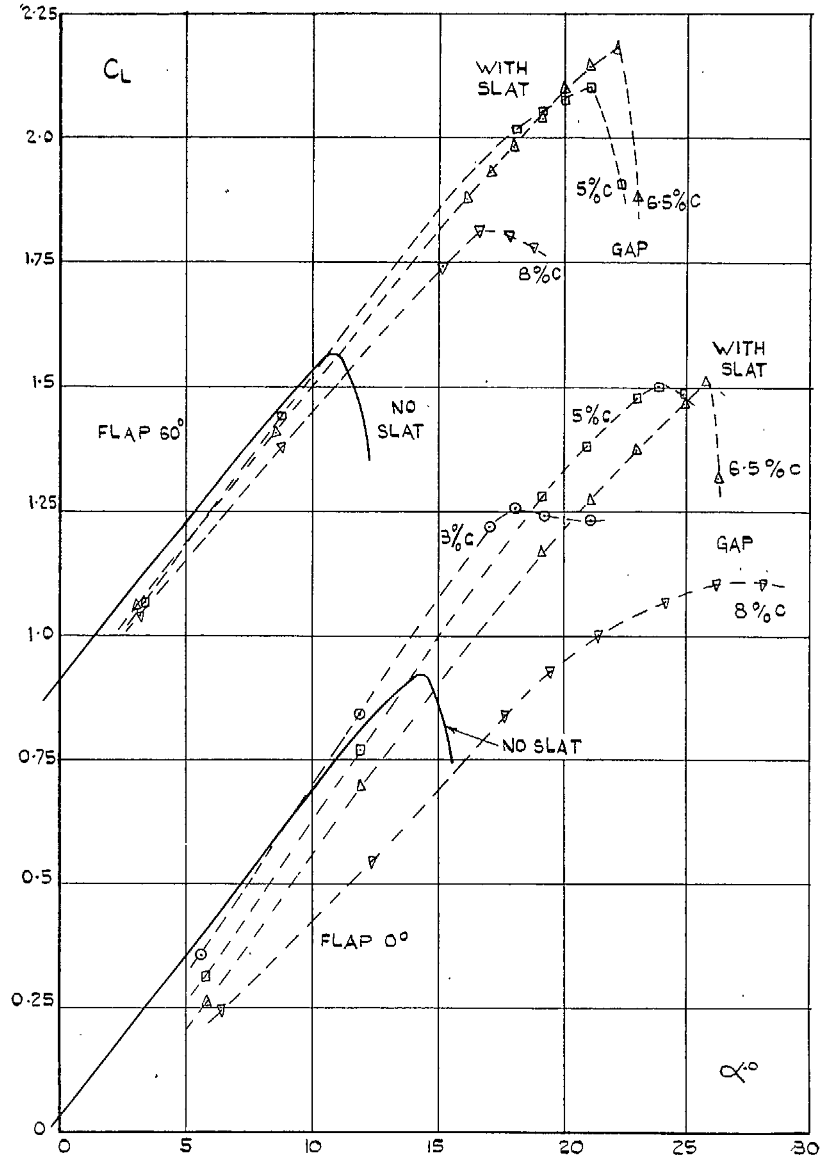


FIG. 4. 20 per cent chord slat: typical lift curves
(Dip = 2·2 per cent c, forward extension = 15·3 per cent c).

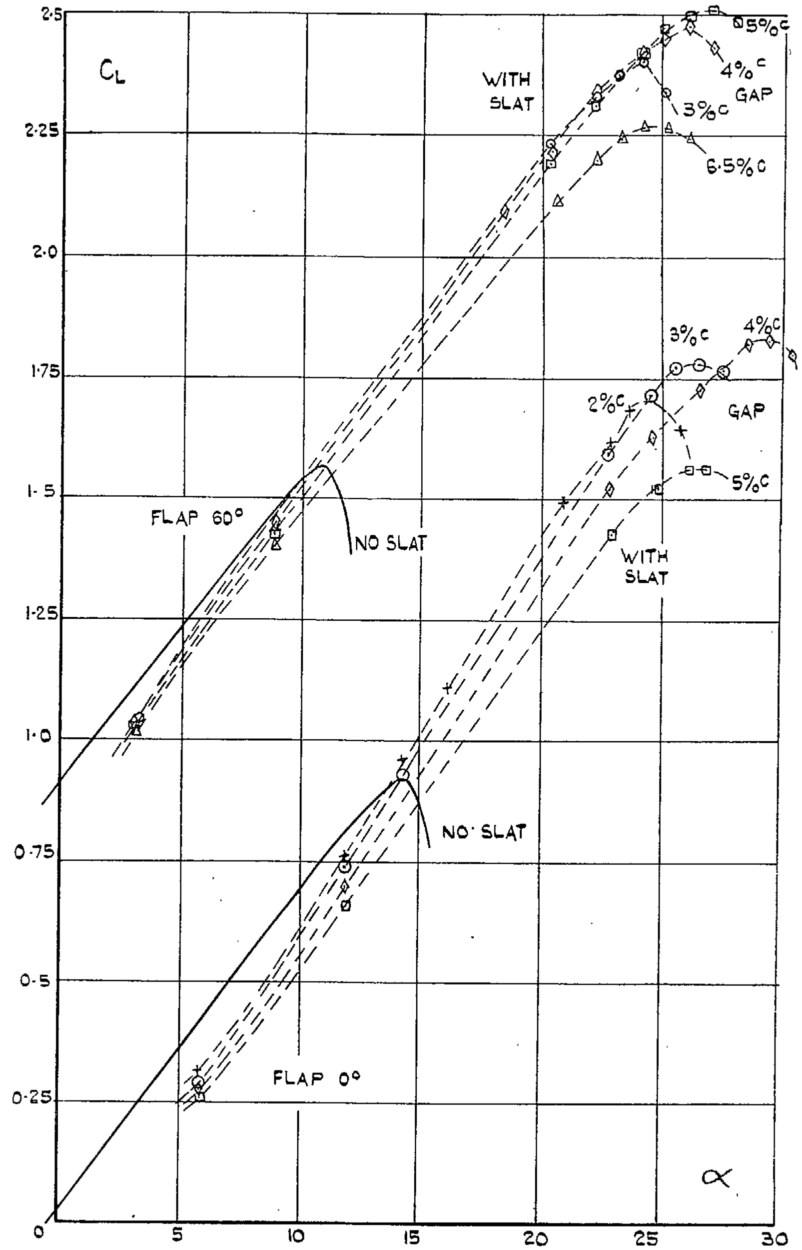
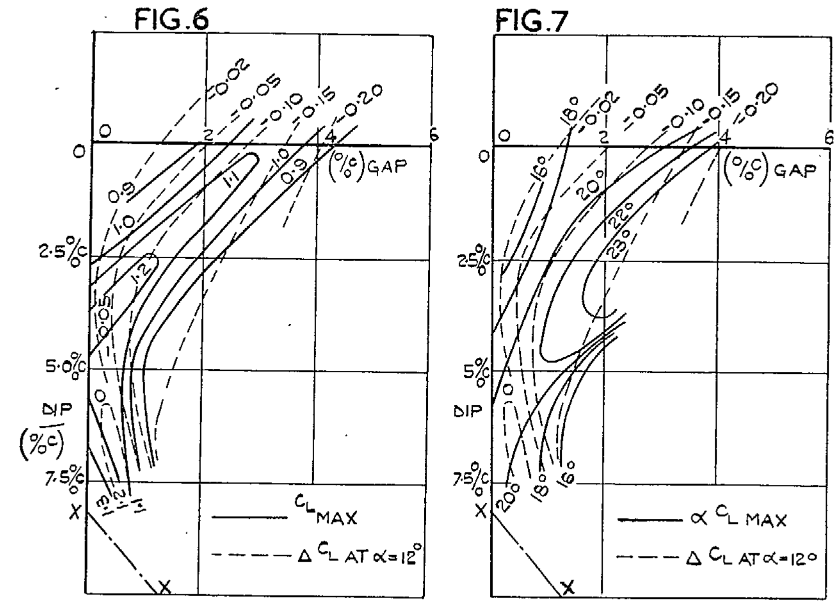
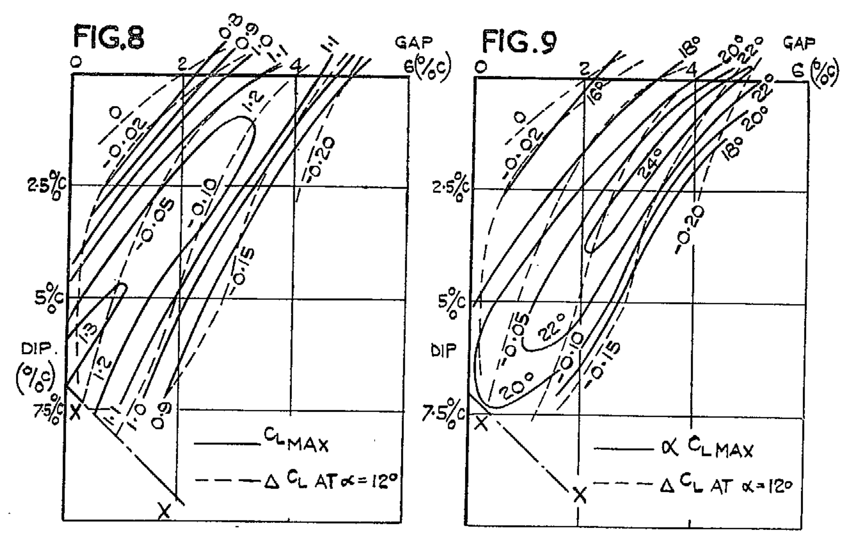


FIG. 5. 30 per cent chord slat: typical lift curves (Dip = 9·8 per cent c, forward extension = 23 per cent c).



FIGS. 6 and 7. 10 per cent chord slat: forward extension = 3·0 per cent c.



FIGS. 8 and 9. 10 per cent chord slat: forward extension = 5·2 per cent c (N.B. X-X line marks the minimum gap possible for a given dip).

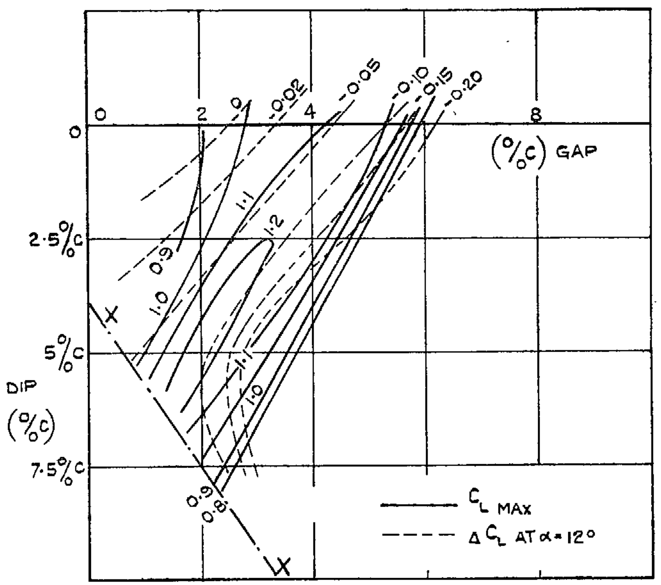
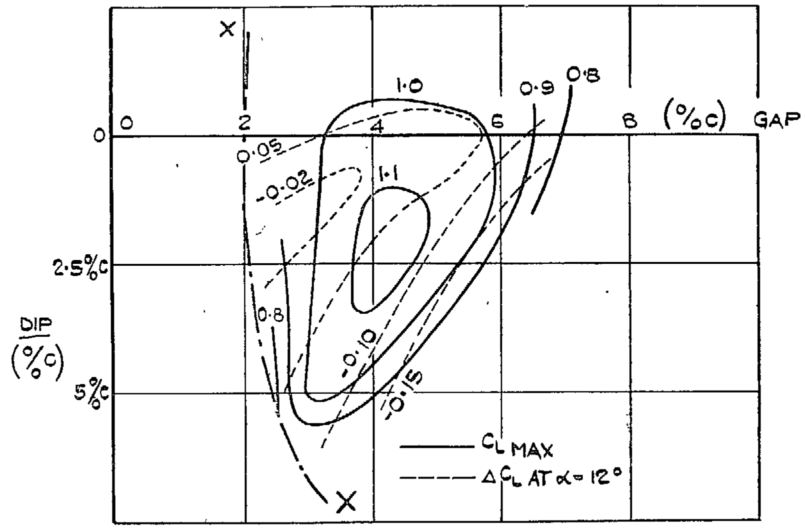


FIG. 10.



C_L MAX

FIG. 12.

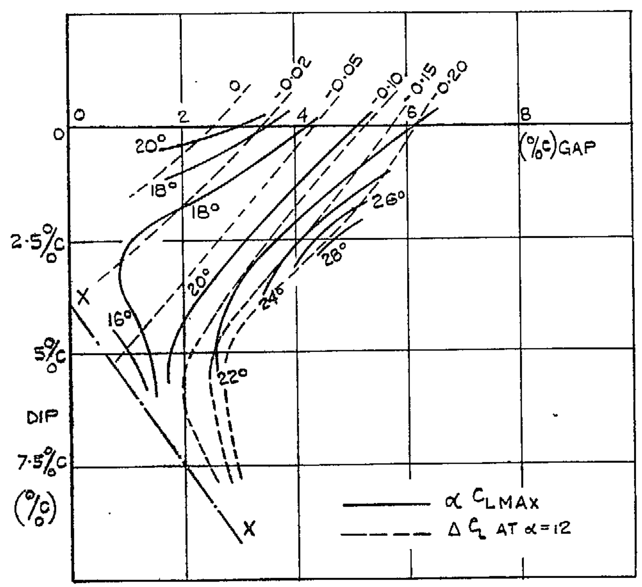
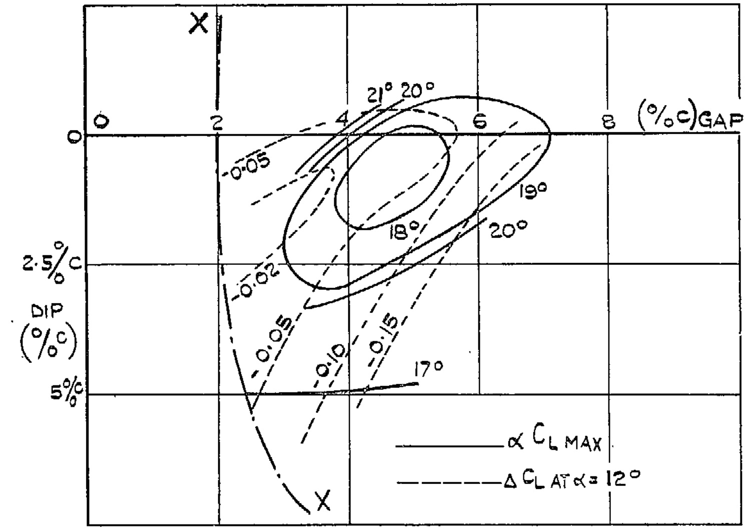


FIG 11.

FIGS. 10 and 11. 10 per cent chord slat: forward extension = 7·3 per cent chord.



α C_L MAX

FIG. 13.

FIGS. 12 and 13. 10 per cent chord slat: forward extension 9·6 per cent c. (N.B. X-X line marks the minimum gap possible for a given dip).

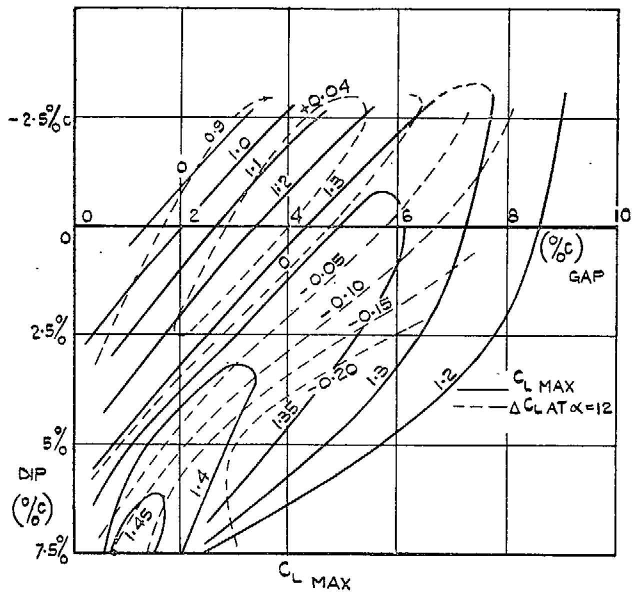


FIG. 14.

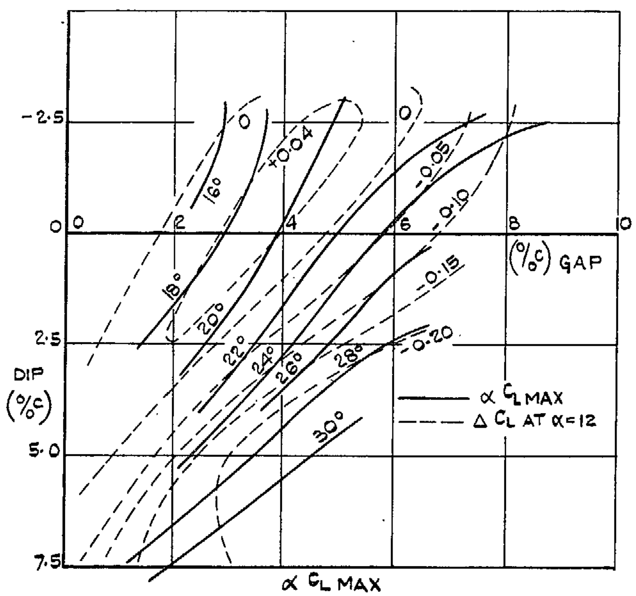


FIG. 15.

FIGS. 14 and 15. 20 per cent chord slat: forward extension 11·2 per cent c.

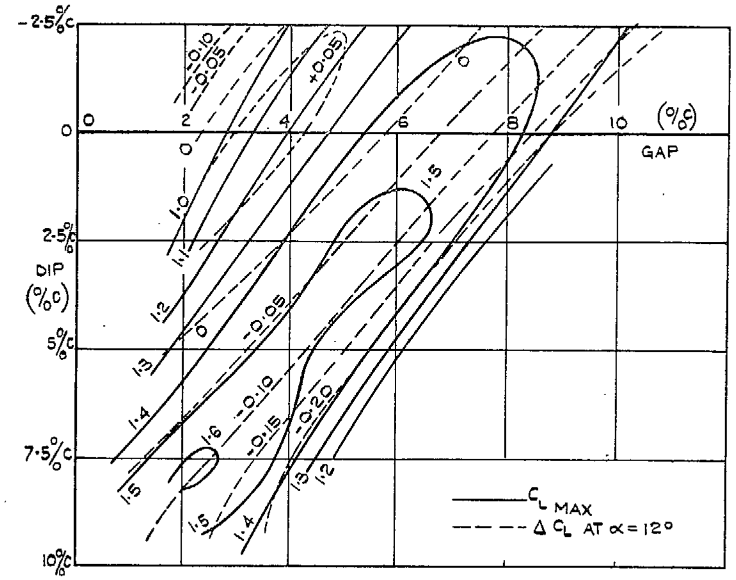


FIG. 16.

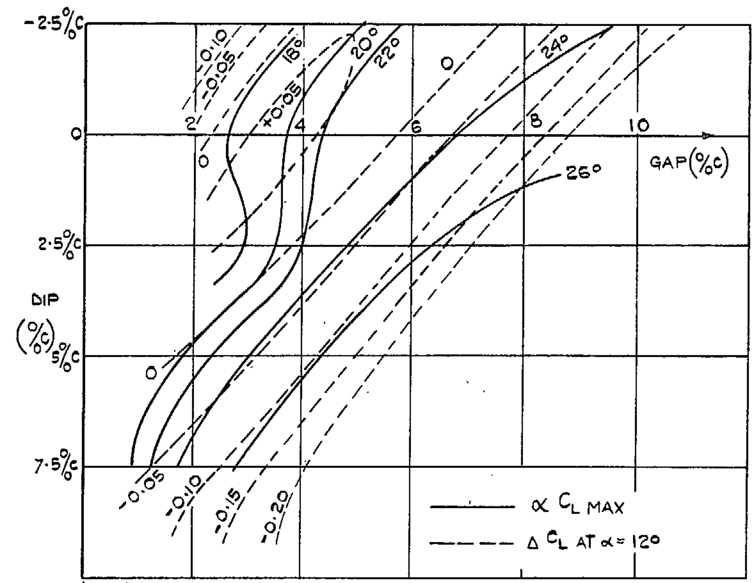


FIG. 17.

FIGS. 16 and 17. 20 per cent chord slat: forward extension 15·3 per cent c.

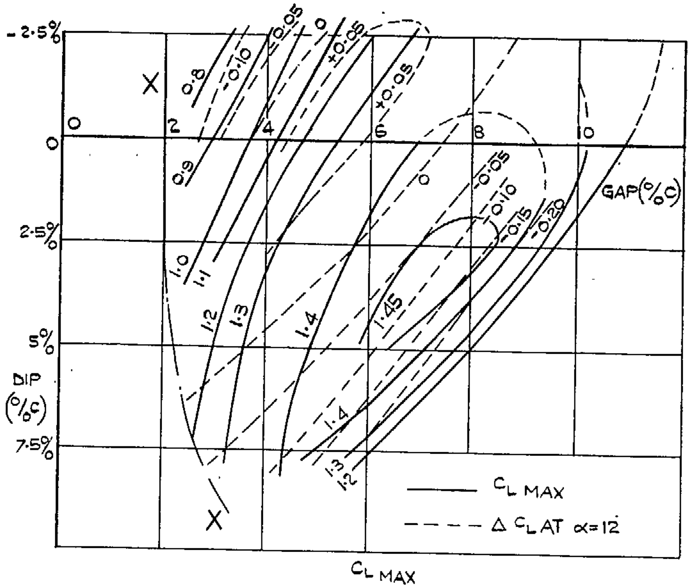


FIG. 18.

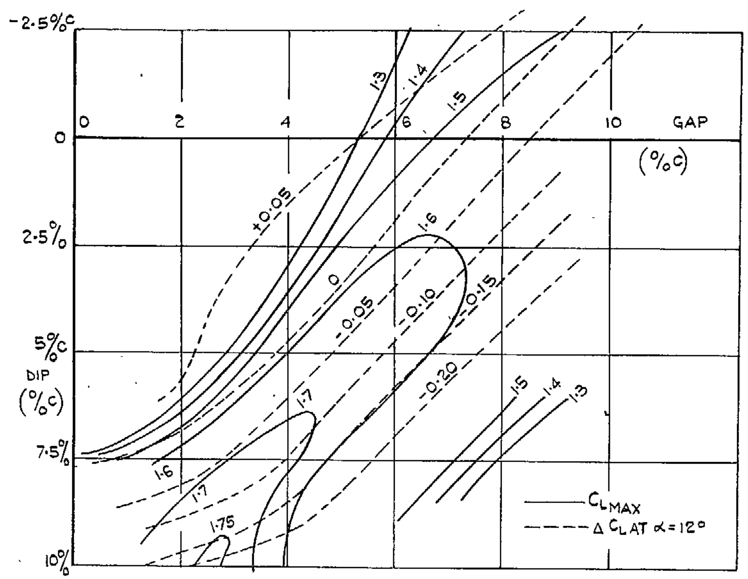


FIG. 20.

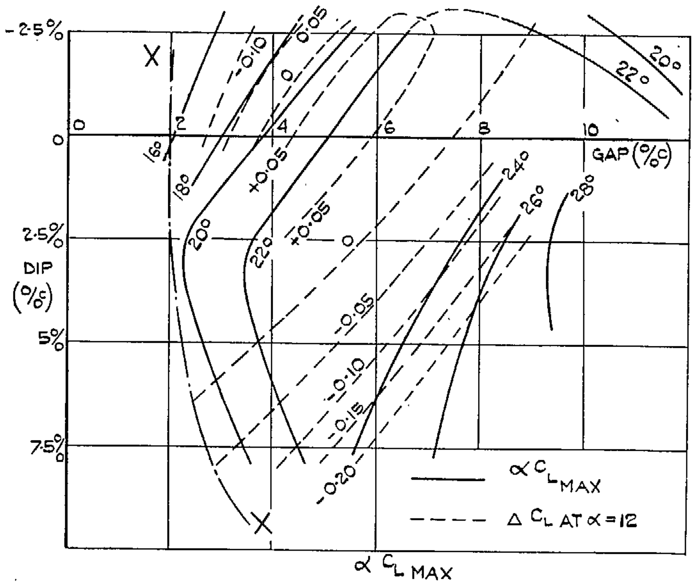


FIG. 19.

FIGS. 18 and 19. 20 per cent chord slat: forward extension = 19·5 per cent c. (N.B. X-X line marks the minimum gap for a given dip).

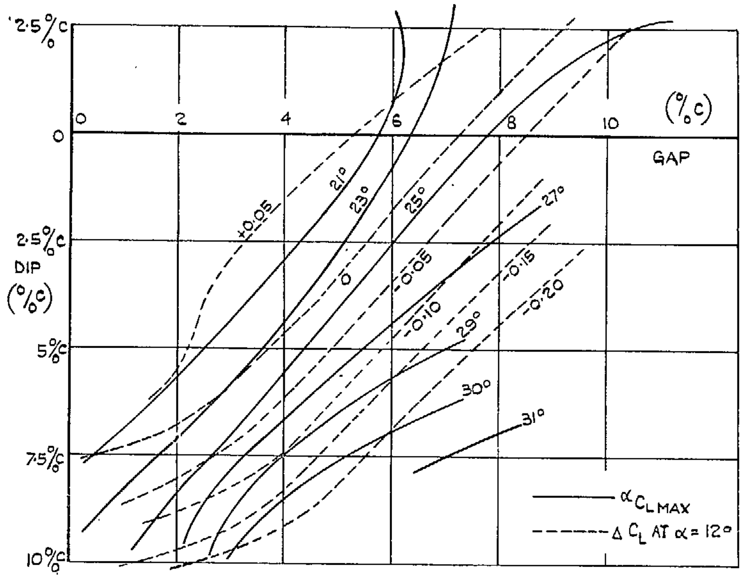


FIG. 21.

FIGS. 20 and 21. 30 per cent chord slat: forward extension = 19 per cent c.

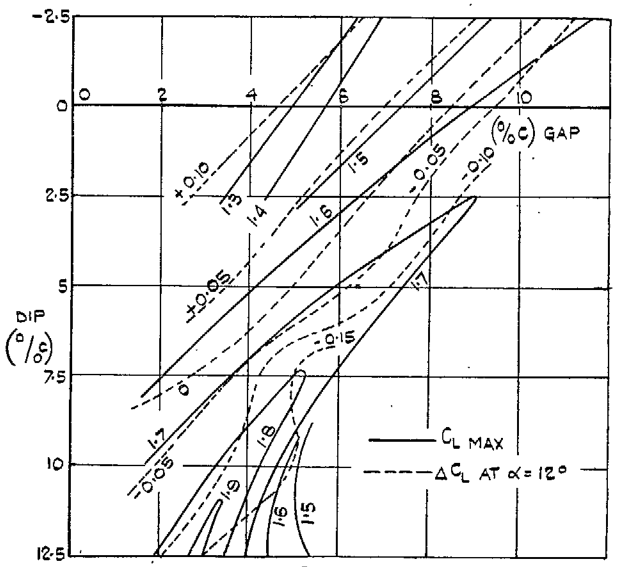


FIG. 22.

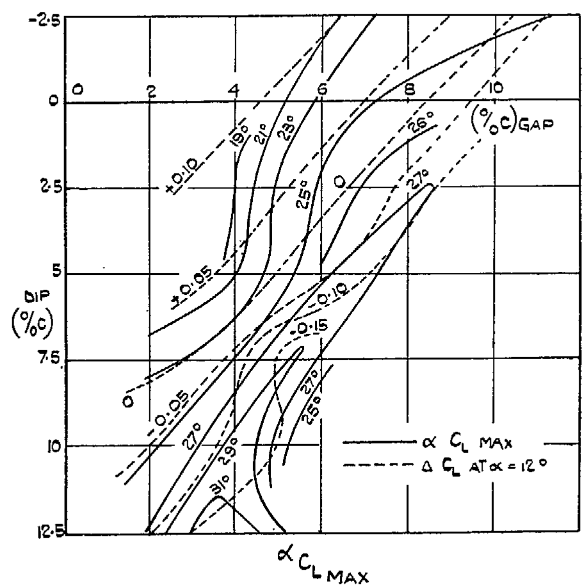


FIG. 23.

FIGS. 22 and 23. 30 per cent chord slat: forward extension = 23 per cent c.

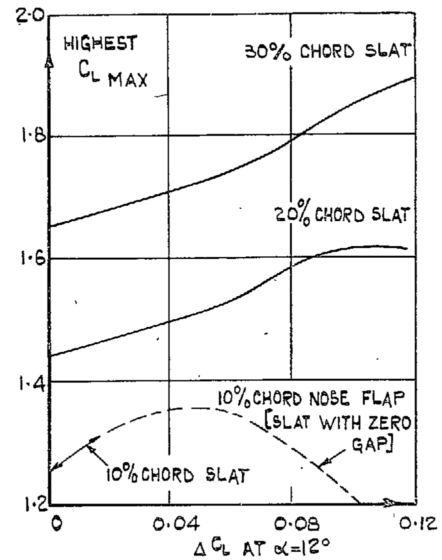


FIG. 24.

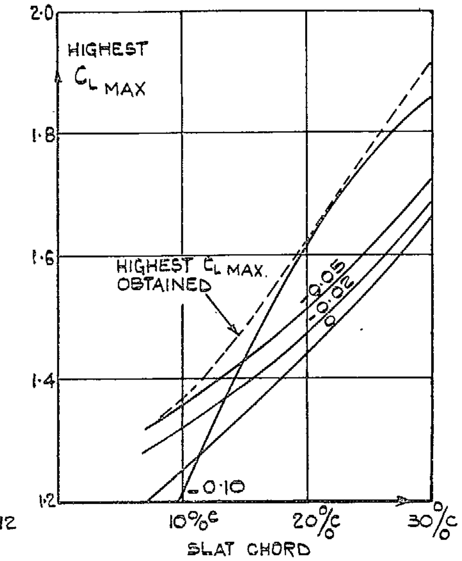


FIG. 25.

FIGS. 24 and 25. Highest $C_{L\,\max}$ obtained and the associated ΔC_L at $\alpha = 12$.

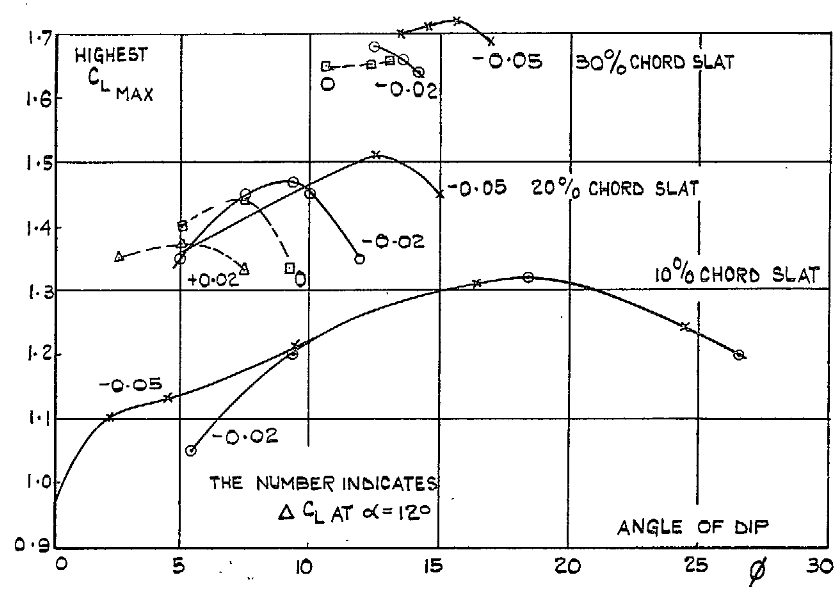


FIG. 26. Highest $C_{L\,\max}$ for a given angle of dip.

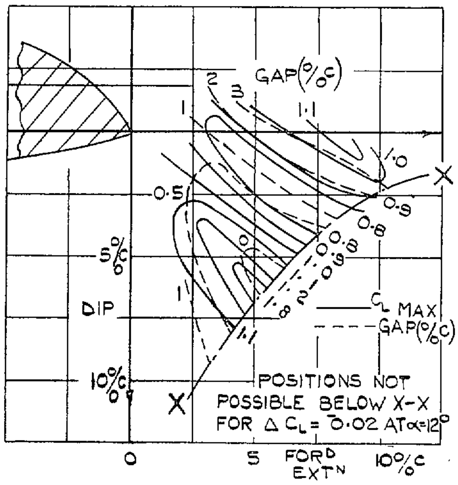


FIG 27.

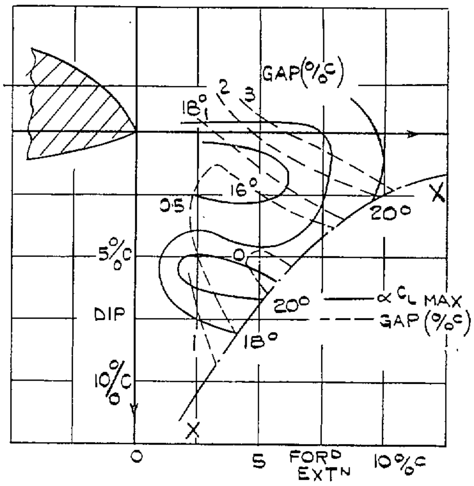


FIG. 28.

FIGS. 27 and 28. 10 per cent chord slat: $C_{L\,max}$, $\alpha C_{L\,max}$, and gap required for a loss of lift, $\Delta C_L = -0 \cdot 02$, on opening at $\alpha = 12$ deg.

(N.B. For 10 per cent c slat, the condition of zero loss of lift at $\alpha = 12$ deg is too extreme for contours to be drawn).

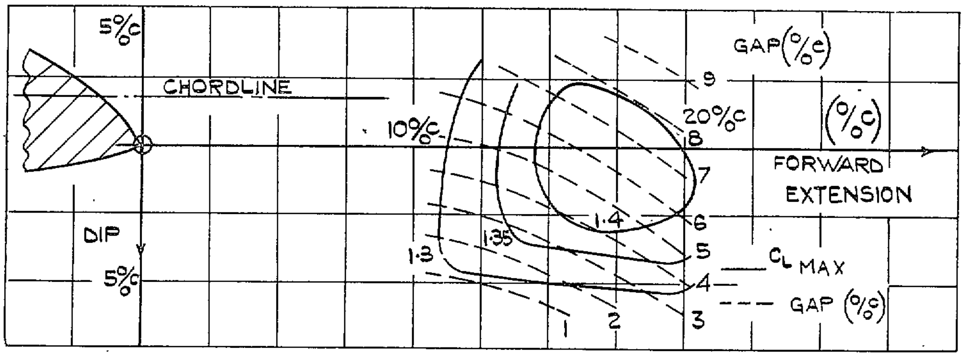


FIG. 29.

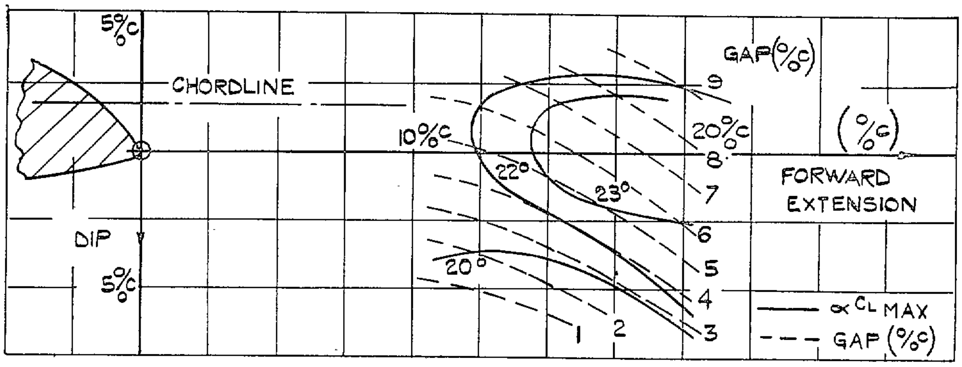


FIG. 30.

FIGS. 29 and 30. 20 per cent chord slat: $C_{L\,max}$, $\alpha C_{L\,max}$ and gap required for zero loss of lift on opening at $\alpha = 12$ deg.

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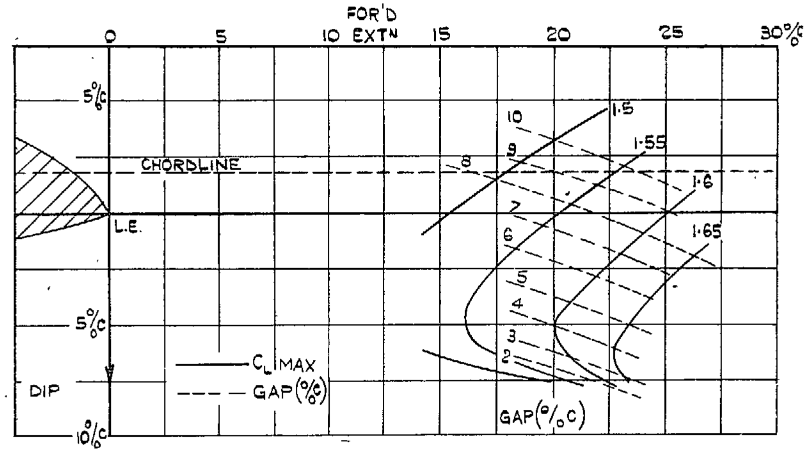


FIG. 31.

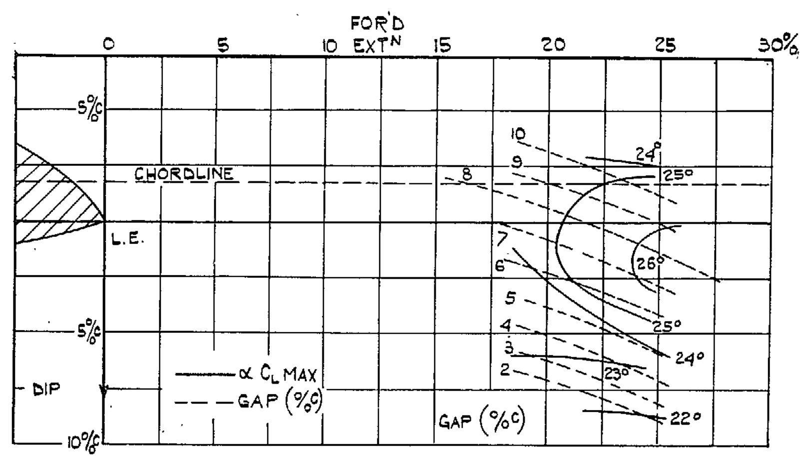
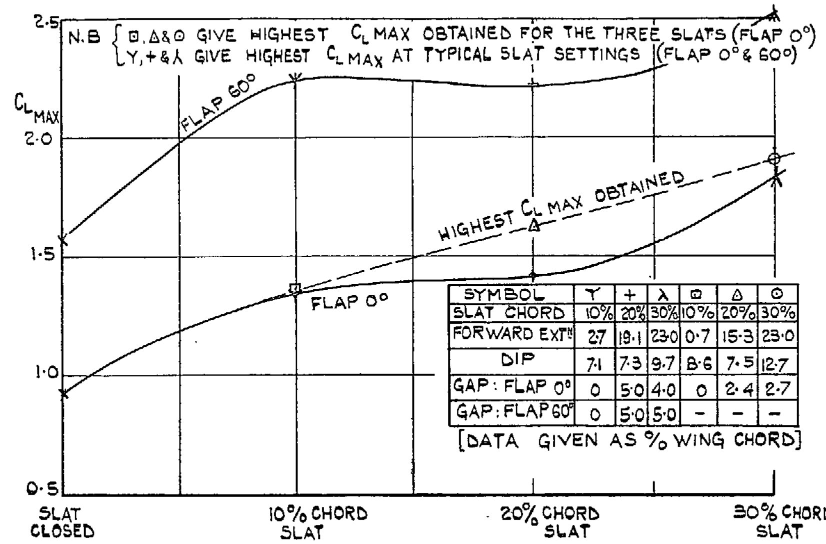


FIG. 32.

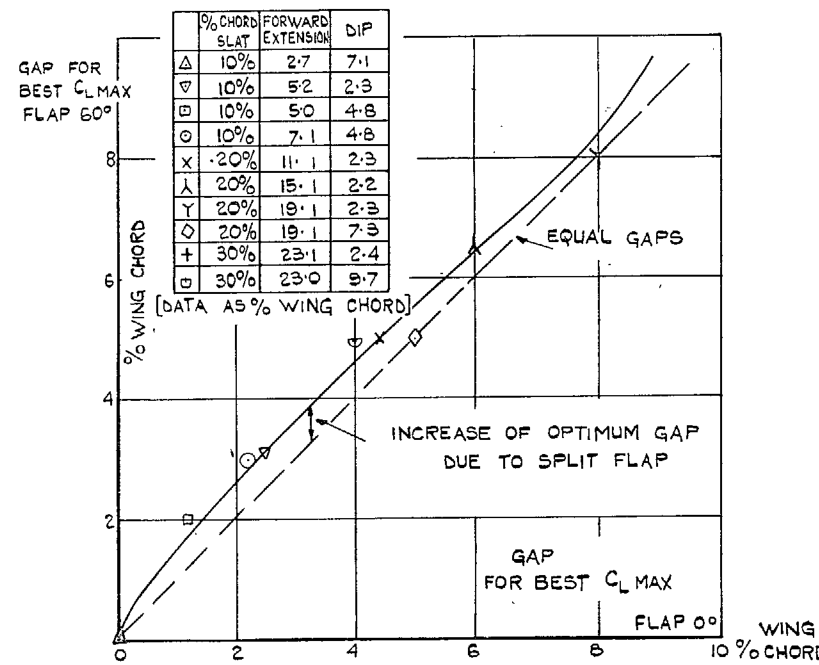
FIGS. 31 and 32. 30 per cent chord slat: $C_{L\,\max}$, $\alpha C_{L\,\max}$ and gap required for zero loss of lift on opening at α = 12 deg.



SYMBOL	Y	+	λ	⊡	Δ	⊙
SLAT CHORD	10%	20%	30%	10%	20%	30%
FORWARD EXTN	2·7	19·1	23·0	0·7	15·3	23·0
DIP	7·1	7·3	9·7	8·6	7·5	12·7
GAP: FLAP 0°	0	5·0	4·0	0	2·4	2·7
GAP: FLAP 60°	0	5·0	5·0	–	–	–

[DATA GIVEN AS % WING CHORD]

FIG. 33. Variation of the highest $C_{L\,\max}$ obtained at typical slat settings with and without split flap 60 deg.



	% CHORD SLAT	FORWARD EXTENSION	DIP
Δ	10%	2·7	7·1
∇	10%	5·2	2·3
⊡	10%	5·0	4·8
⊙	10%	7·1	4·8
×	·20%	11·1	2·3
λ	20%	15·1	2·2
Y	20%	19·1	2·3
◇	20%	19·1	7·3
+	30%	23·1	2·4
⊔	30%	23·0	9·7

[DATA AS % WING CHORD]

FIG. 34. Effect of split flap 60 deg on optimum gap.

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