ELLIOTT G. REID

459

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 459

WIND-TUNNEL TESTS ON MODEL WING WITH FOWLER FLAP AND SPECIALLY DEVELOPED LEADING-EDGE SLOT

By Fred E. Weick and Robert C. Platt
Langley Memorial Aeronautical Laboratory

Washington
May, 1933

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 459

WIND-TUNNEL TESTS ON MODEL WING WITH FOWLER FLAP AND SPECIALLY DEVELOPED LEADING-EDGE SLOT

By Fred E. Weick and Robert C. Platt

SUMMARY

An investigation was made in the N.A.C.A. 7 by 10 foot wind tunnel to find the increase in maximum lift coefficient which could be obtained by providing a model wing with both a Fowler trailing-edge extension flap and a Handley Page type leading-edge slot. A conventional Handley Page slot proportioned to operate on the plain wing without a flap gave but a slight increase with the flap; so a special form of slot was developed to work more effectively with the flap. With the best combined arrangement the maximum lift coefficient based on the original area was increased from 3.17, for the Fowler wing, to 3.62. The minimum drag coefficient with both devices retracted was increased in approximately the same proportion. Tests were also made with the special-type slot on the plain wing without the flap. The special slot, used either with or without the Fowler flap, gave definitely higher values of the maximum lift coefficient than the slots of conventional form, with an increase of the same order in the minimum drag coefficient.

INTRODUCTION

The purpose of the present investigation was to determine the maximum lift coefficient obtainable by combining the best retractable trailing-edge and leading-edge devices found to date in the general wind-tunnel investigation of high-lift devices now being carried on by the National Advisory Committee for Aeronautics. The retractable devices that have given the largest increases in lift are the Fowler slotted extension flap (reference 1) and the Handley Page leading-edge slot (reference 2).

The first step of the present investigation was to test an airfoil based on the Clark Y section, incorporating the Fowler flap and Handley Page slot, in the optimum arrangement separately determined for each (references 1 and 2). The maximum lift coefficient obtained with this combination was only slightly higher than that for the Fowler wing alone, which was ascribed to the unsatisfactory location and action of the leading-edge slot on the wing with the Fowler flap. A modified form of slot was therefore developed and tested with the slat in a number of different positions, with the Fowler flap both extended and retracted.

APPARATUS

The tests were made in the N.A.C.A. 7 by 10 foot wind tunnel, which is described in detail, together with the balances and standard test procedure, in reference 3. Because of the high lift obtained with the special devices the model was supported by a fine wire at each wing tip in addition to the usual center support. The tests were made at an air speed of 80 m.p.h. which corresponds to a Reynolds Number of 609,000 for the basic wing chord of 10 inches. No corrections were made for tunnel-wall interference.

The wing model was the same one used in the previous tests on the Fowler wing, as shown in figure 1, but the nose was cut off to the contour of the Handley Page slotted wing and the slat was located in the position previously found best for the plain slotted wing (fig. 2). Both the original investigations (references 1 and 2) were made with models having the Clark Y as the basic section, the chord being 10 inches and the span 60 inches.

TESTS AND RESULTS

The maximum lift coefficient (based on the original area of 600 square inches) for the model with both the Fowler flap and the Handley Page slot in the individually obtained optimum positions was found to be 3.36, which is only slightly greater than the value of 3.17 found for the Fowler wing alone. In order to determine whether the Fowler flap, set at a different location or angle, would function more favorably in the presence of the slot, the tests were repeated with these factors varied throughout a small range. The highest value obtained, 3.37, was found with the same nose location but with the flap deflected 45° instead of the original 40°. It was concluded that the slot has no substantial influence on the best position of the Fowler flap, and the final tests on this arrangement were made with a flap setting of 45°. It was thought probable, however, that the action of the leading-edge slot was adversely affected to an appreciable extent by the presence of the Fowler flap, and a program was undertaken to improve the slot when operating in conjunction with the flap. It seemed likely that a better slat position could be found for this condition, and in addition a comparison of the results of reference 2 with those of reference 4 indicated that an improvement might be expected if the slat were changed to have a better airfoil form. The section used in reference 4, later designated N.A.C.A. No. 22, was chosen. (The ordinates are given in table I.) With the slot closed the section of the wing was that shown in figure 3 and, as this arrangement was obviously not favorable for minimum drag, the first test made was a measurement of the drag with the slot closed and the Fowler flap retracted. After the tests had shown that the minimum drag coefficient had increased from 0.0156 to 0.0224, the nose of the main airfoil was rounded as shown in figure 4. With this condition the value of the minimum drag coefficient was reduced to 0.0182, which was considered reasonably satisfactory. A complete test of C_L, C_D, and c.p. for various angles of attack was then made with the wing model as illustrated in figure 4. The results are given in figure 5.

The model was then given a series of tests to find the maximum lift coefficients with the Fowler flap extended and the N.A.C.A. 22 slat held by metal clips in the various positions shown in figure 6. The trailing edge of the slat was located at eight different positions, giving a series of intersecting straight lines forming a convenient basis for a contour chart. The slat was tested at three different angles for each of the trailing-edge locations shown. During this survey the angle of the Fowler flap was varied throughout a sufficient range to enclose the optimum angle for each trailing-edge location of the slat. The optimum angle in all cases was 35°, giving increases in C_{Lmax} of 2 to 4 percent over the C_{Lmax} found for a flap angle of 40°, the optimum angle for the original Fowler wing. The results, given in figure 7 and table II, show that the highest value of the maximum lift coefficient obtained was 3.58 for which the slat was in position F, the angle between the chords of slat and main wing being 40°.

The center fitting supporting the slat was made rather thick for convenience in permitting adjustment of angle and position and it was thought that this fitting might disturb the flow, particularly near the stall, and cause a somewhat low value of the maximum lift coefficient. Another test was therefore made with the slat in the best position but with the center fitting replaced by a smaller thinner one. With the smaller fitting the interference with the flow between the slat and the wing at the center of the span was reduced and the value of the maximum lift coefficient was raised to 3.62. The characteristics of the wing in this condition are given in table IV and figure 9.

After these tests had been completed it was decided that the special form of slot which had been developed was of sufficient interest to warrant another series of tests to find the best slat position with the Fowler flap retracted, making the model a plain slotted wing. The results of these tests are given in figure 8 and table III. The best position found was with the trailing edge of the slat at point H and the slat at an angle of 45°. With the small center fitting holding the slat in this position a maximum lift coefficient of 2.08 was obtained. (See fig. 9 and table IV.)

DISCUSSION

The extended Fowler flap and the leading-edge slat provide additional area which involves additional complication and weight. From one viewpoint, if lift-increasing devices are to be considered effective they should increase the actual surface loading, rather than produce lift only in proportion to the additional area. In order to facilitate a comparison of the various models on this basis, values of the maximum lift coefficients based on the total extended area are given in the last column of table IV. Either of the slots alone, it will be noticed, gives a substantial increase in the surface loading, that for the special slot being definitely higher than that for the conventional type. The Fowler flap alone gives a further increase of the same order. The combined Fowler flap and conventional leading-edge slot give a slightly lower value than the Fowler wing alone, but the combination with the special slot gives a somewhat higher value. In the latter case the increase in the maximum lift coefficient is accompanied by a proportional increase in the minimum drag coefficient, however, and it is somewhat doubtful whether any possible increase in performance or the decrease in wing size obtained by adding even the special slot to the Fowler wing would warrant the increase in complication and cost.

The unfavorable effect of the high drag on the rate of climb of an airplane is indicated by the value of L/D for a lift coefficient of 0.7 given in the third column of table IV.

One interesting feature of the wing having both the Fowler flap and the special leading-edge slot is the flat peak of the lift curve as shown in figure 9. The maximum value of the lift coefficient was obtained at an angle of attack of 21° and the same value maintained up to 25°.

CONCLUSIONS

1. By the addition of a special retractable leading-edge slot to the Fowler wing arrangement, the maximum lift coefficient based on the original area was increased from 3.17 to 3.62 and was accompanied by an increase of approximately the same relative amount in the minimum drag coefficient with the devices retracted.

2. By the application of the same slot arrangement to a plain Clark Y wing the maximum lift coefficient was increased from 1.27 to 2.08 with an increase in the minimum drag coefficient from 0.0156 to 0.0182.

3. The special slot, used either with or without the Fowler flap, gave definitely higher values of the maximum lift coefficient than the slot of conventional form, with proportionate increases in the values of minimum drag coefficient.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 4, 1933.

REFERENCES

1. Weick, Fred E., and Platt, Robert C.: Wind-Tunnel Tests of the Fowler Variable-Area Wing. T.N. No. 419, N.A.C.A., 1932.

2. Wenzinger, Carl J., and Shortal, Joseph A.: The Aerodynamic Characteristics of a Slotted Clark Y Wing as Affected by the Auxiliary Airfoil Position. T.R. No. 400, N.A.C.A., 1931.

3. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

4. Weick, Fred E., and Bamber, Millard J.: Wind-Tunnel Tests of a Clark Y Wing with a Narrow Auxiliary Airfoil in Different Positions. T.R. No. 428, N.A.C.A., 1932.

TABLE I

AIRFOIL ORDINATES

(Values in percent of chord)

	Clark Y		N.A.C.A. 22	
Station	Ordinate upper	Ordinate lower	Ordinate upper	Ordinate lower
0	3.50	3.50	2.88	2.88
1.25	5.45	1.93	5.40	1.09
2.5	6.50	1.47	6.48	.65
5	7.90	.93	8.02	.28
7.5	8.85	.63	9.11	.08
10	9.60	.42	9.96	.00
15	10.69	.15	11.34	.12
20	11.36	.03	12.29	.44
30	11.70	0	13.35	1.46
40	11.40	0	13.42	3.08
50	10.52	0	12.60	4.78
60	9.15	0	11.12	5.63
70	7.35	0	9.15	5.79
80	5.22	0	6.68	4.68
90	2.80	0	3.95	2.67
95	1.49	0	2.51	1.32
100	.12	0	1.13	.00
L.E. Rad.	1.50		1.50	

TABLE II

VARIATION OF $C_{L_{max}}$ WITH SLAT ANGLE ON

FOWLER WING WITH SPECIAL SLOT

Slat angle	Trailing-edge positions						
	A	C	D	E	F	G	H
25°							
27.5°	3.490						
30°	3.540						
32.5°	3.460		3.520				
35°		3.445	3.540	3.525		3.460	
37.5°		3.475	3.530	3.570	3.520	3.520	
40°		3.450		3.515	3.580	3.490	
42.5°					3.560		
45°							3.520
47.5°							3.550
50°							3.540

TABLE III

VARIATION OF $C_{L_{max}}$ WITH SLAT ANGLE ON

PLAIN WING WITH SPECIAL SLOT

	Trailing-edge positions								
Slat angle	A	C	D	E	F	G	H	I	J
20°	1.922								
22.5°	1.952								
25°	1.754		1.990						
27.5°		1.860	2.005	2.000					
30°		1.890		2.045	1.985	1.750			
32.5°			1.770	1.835	2.020	1.755			
35°		1.765			1.975	1.745			
37.5°									
40°									
42.5°							2.030		
45°							2.059		1.975
47.5°							2.030		
50°								1.953	2.040
52.5°									1.820
55°								1.992	
57.5°								1.985	

TABLE IV

SUMMARY OF CHARACTERISTICS OF LIFT

INCREASING DEVICES TESTED

Arrangement	$C_{L_{max}}$ (original area)	$C_{D_{min}}$[1] (original area)	L/D at[1] C_L=0.7	$C_{L_{max}}$ (actual surface area)
Plain wing	1.27	0.0156	17.5	1.27
Plain wing with Handley page slot	1.84	[2].0156	[2]17.5	1.63
Plain wing with special slot	2.08	.0182	14.3	1.87
Fowler wing	3.17	.0156	17.5	2.26
Fowler wing with Handley Page slot	3.37	[2].0156	[2]17.5	2.21
Fowler wing with special slot	3.62	.0182	14.3	2.40

[1]Based on data with slat and flap retracted.

[2]Wing profile is assumed perfect with Handley Page slot closed. This condition is not attained in practice, which would make the actual drag difference between the Handley Page and special slots less than the above figures indicate.

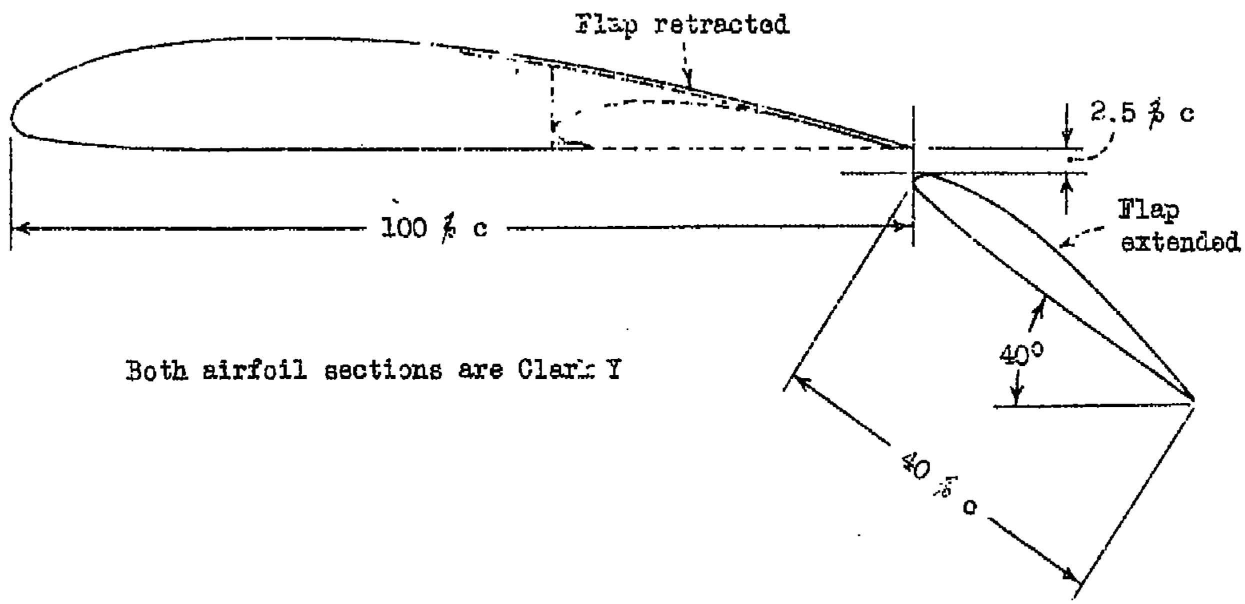

Figure 1.-Section of Fowler wing.

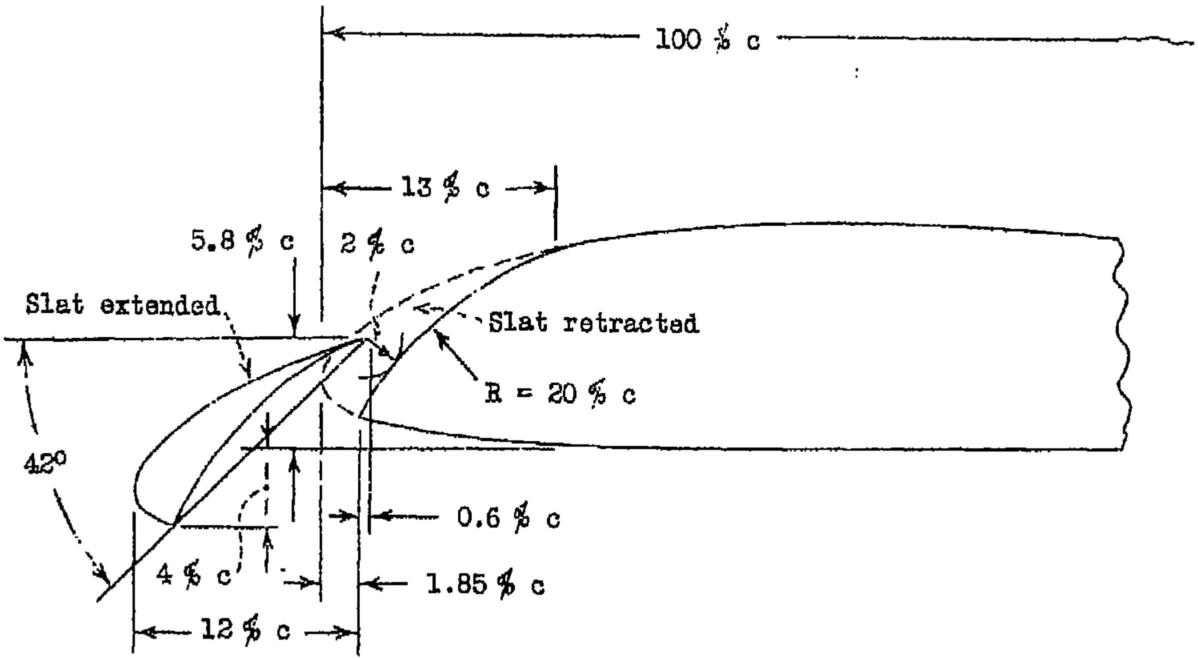

Figure 2.-Section showing dimensions of Handley Page slot on leading edge of Fowler wing.

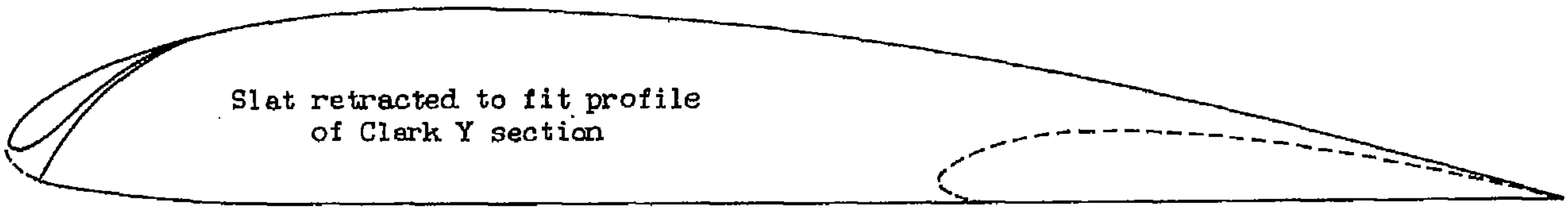

Figure 3.-Section showing special slat and Fowler flap retracted.

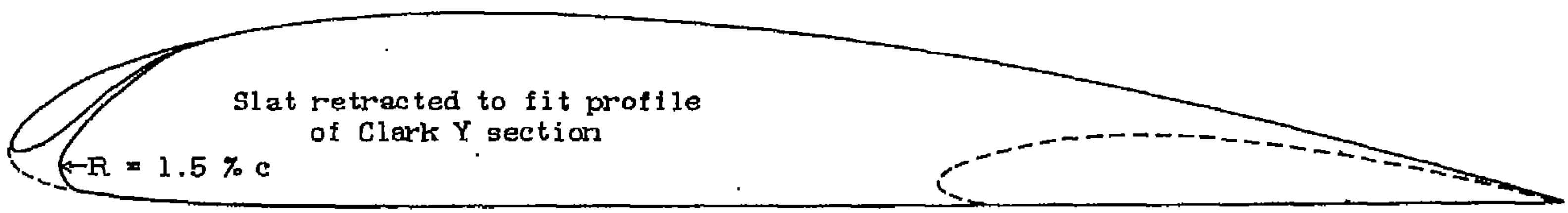

Figure.4.-Section showing special slat and Fowler flap retracted and nose rounded 1.5 percent chord.

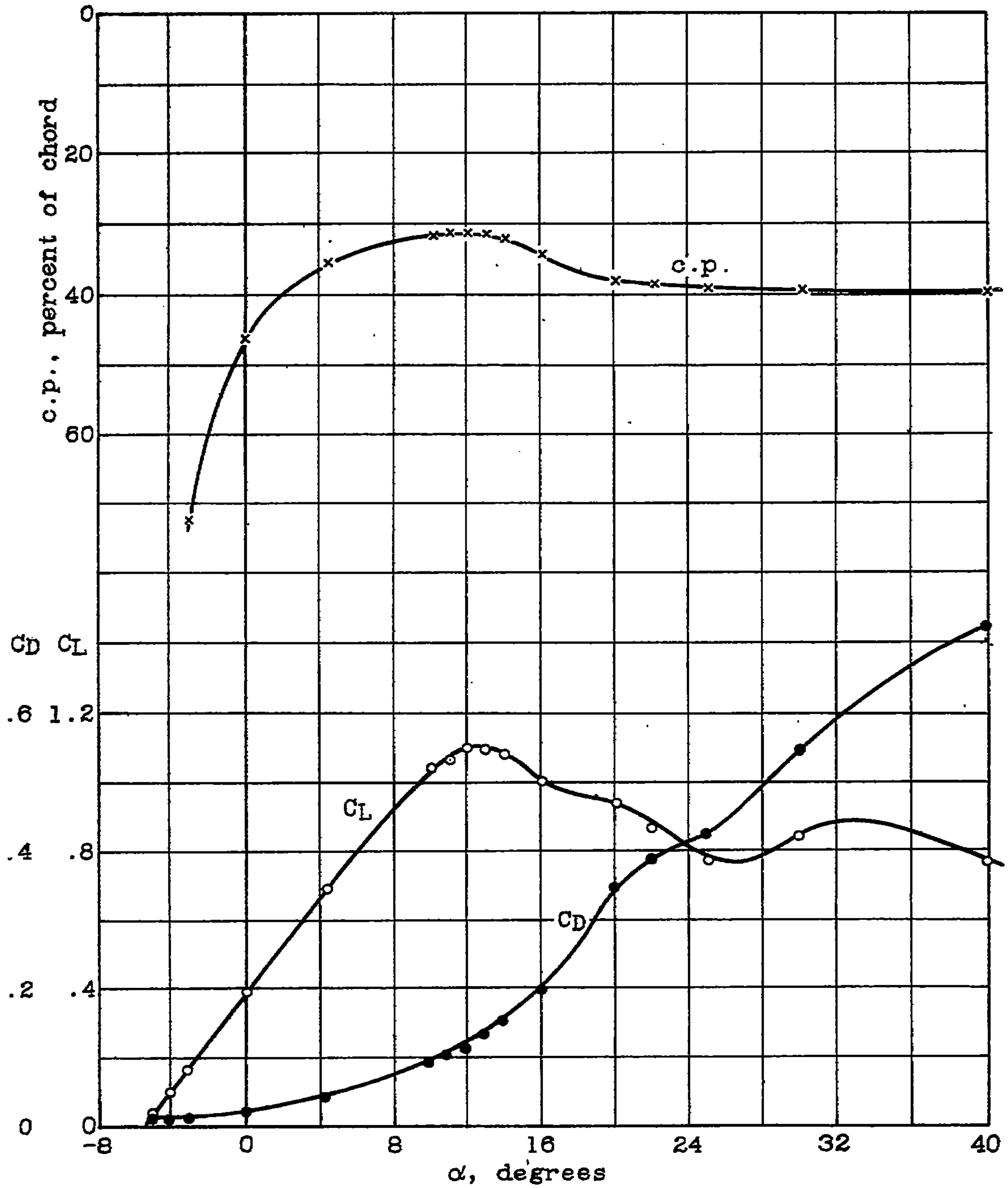

Figure 5.- Characteristic curves for wing with special slat retracted as applied to plain wing or Fowler wing with flap retracted.

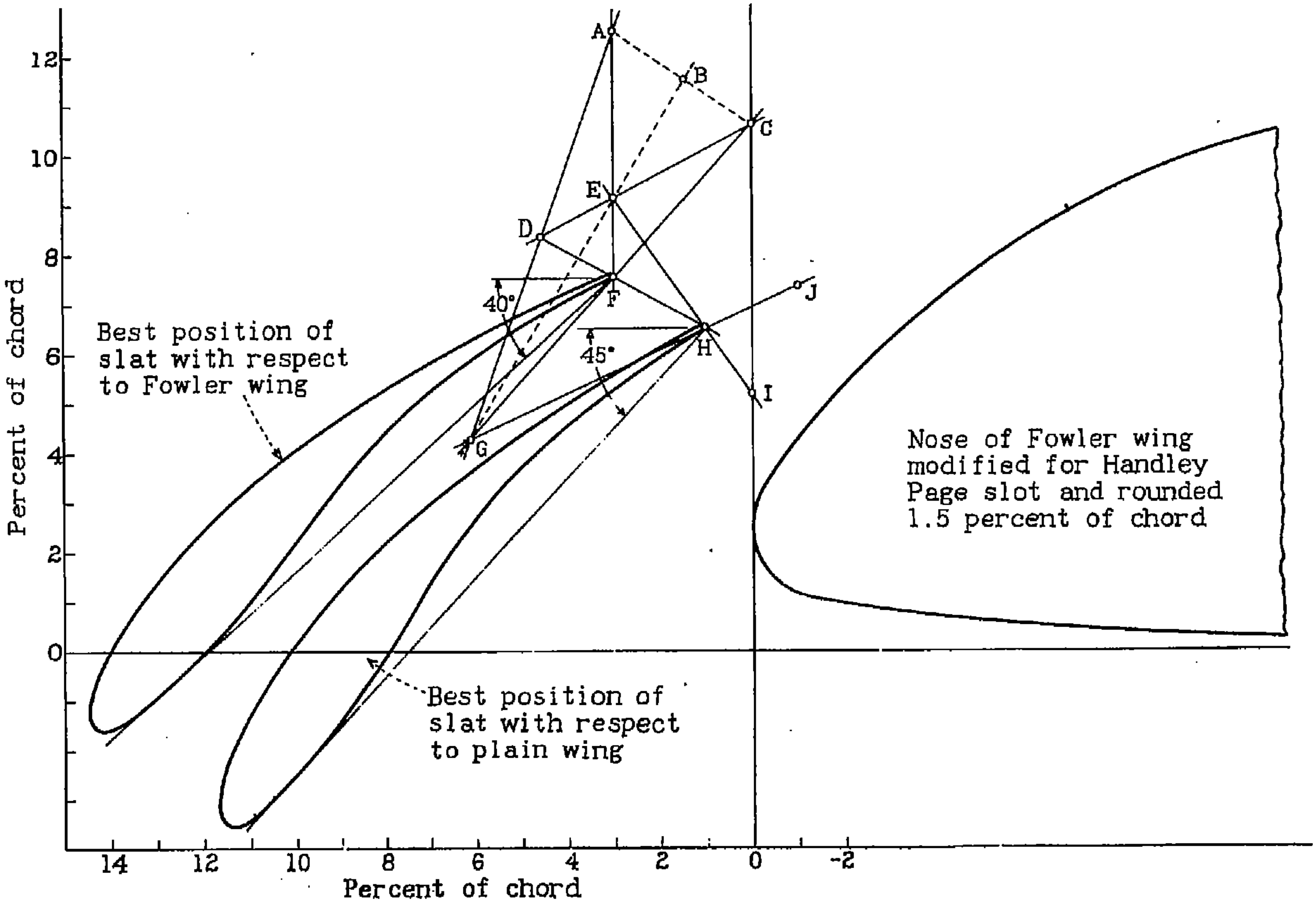

Figure 6.- Diagram showing trailing edge locations used in making surveys to find best position of slat.

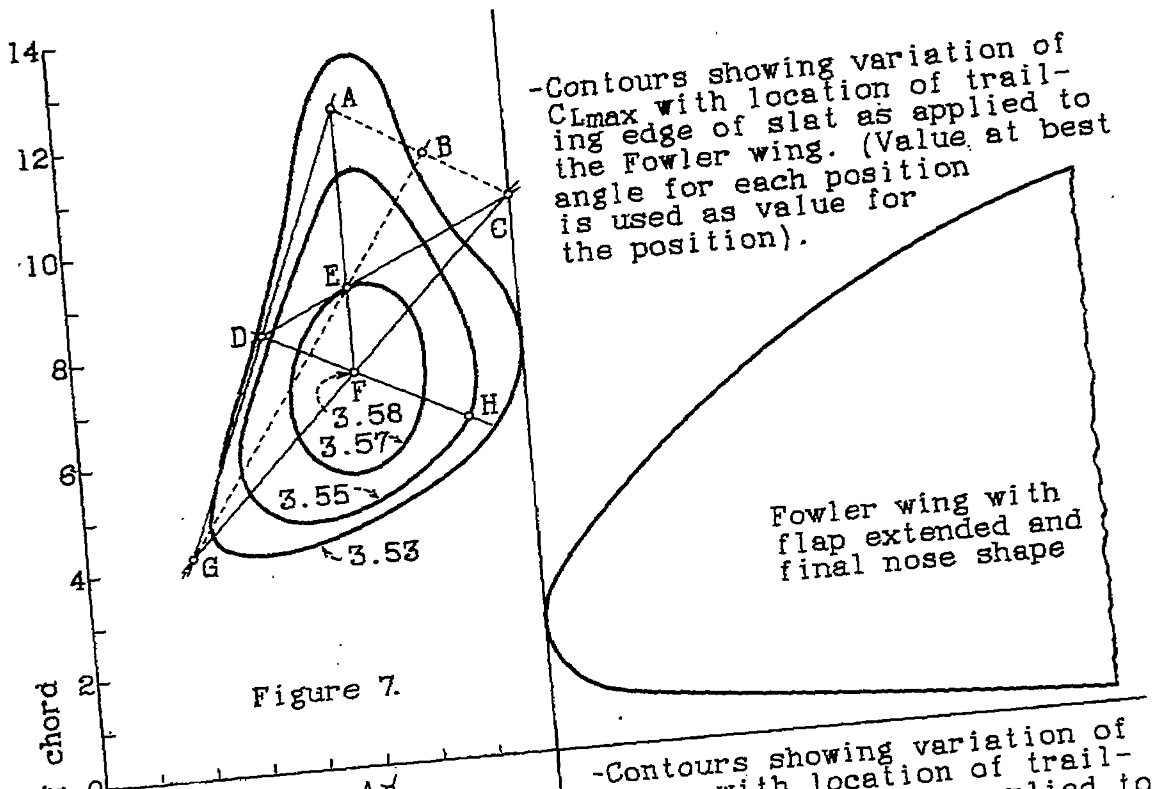

Figure 7.-Contours showing variation of $C_{L_{max}}$ with location of trailing edge of slat as applied to the Fowler wing. (Value at best angle for each position is used as value for the position).

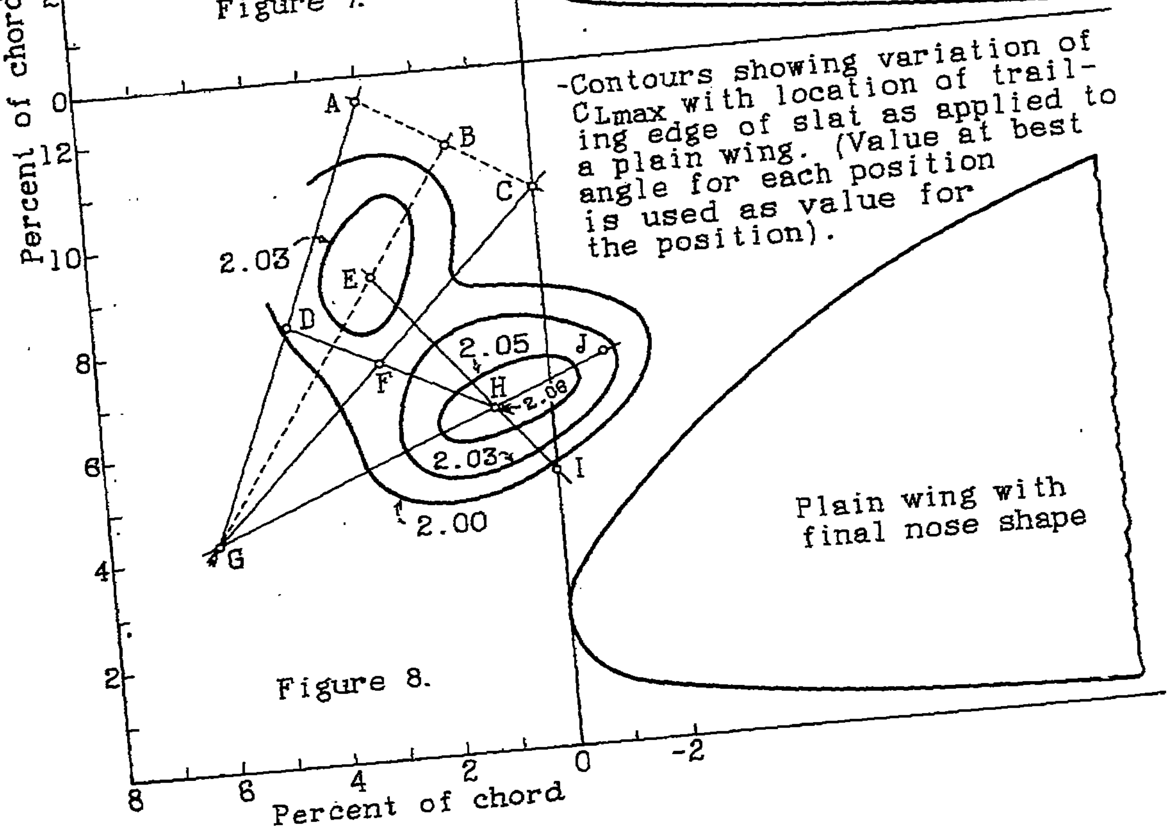

Figure 8.-Contours showing variation of $C_{L_{max}}$ with location of trailing edge of slat as applied to a plain wing. (Value at best angle for each position is used as value for the position).

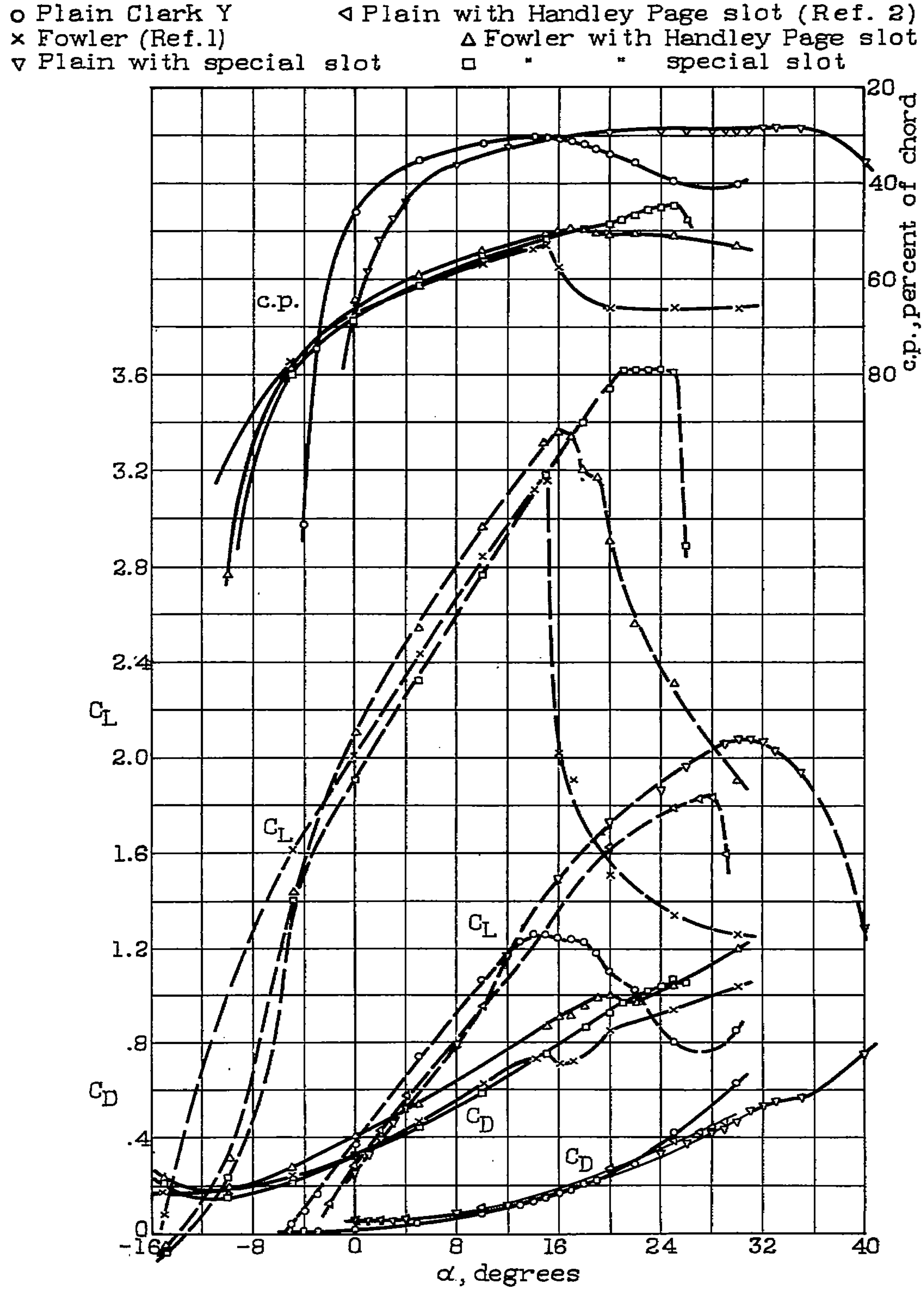

Figure 9-Characteristic curves for wings equipped with various lift increasing devices.