TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 416

CHARACTERISTICS OF TWO SHARP-NOSED AIRFOILS HAVING REDUCED SPINNING TENDENCIES

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CHARACTERISTICS OF TWO SHARP-NOSED AIRFOILS HAVING REDUCED SPINNING TENDENCIES

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SUMMARY

According to Mr. L. D. Bell, of the Consolidated Aircraft Corporation, certain undesirable spinning characteristics of a commercial airplane were eliminated by the addition of a filler to the forward part of the wing to give it a sharp leading edge. To ascertain what aerodynamic effects result from such a change of section, two airfoils having sharp leading edges were tested in the variable-density wind tunnel. Both sections were derived by modifying the Gött. 398. The tests, which were made at a large value of the Reynolds Number, were carried to very large angles of attack to provide data for application to flight at angles of attack well beyond the stall.

The characteristics of the sharp-nosed airfoils are compared with those of the normal Gött. 398 airfoil. Both of the sharp-nosed airfoils, which differ in the angle between the upper and lower surfaces at the leading edge, have about the same characteristics. As compared with the normal airfoil, the maximum lift is reduced by approximately 26 per cent, but the objectionable rapidly decreasing lift with angle of attack beyond the stall is eliminated; the profile drag of the section is slightly reduced in the range of the lift coefficient between 0.2 and 0.85, but at higher and lower lift coefficients the drag is increased.

INTRODUCTION

According to Mr. L. D. Bell of the Consolidated Aircraft Corporation, certain undesirable spinning characteristics of a commercial plane were eliminated by the addition of a filler to the forward part of the wing to give it a sharp leading edge, the modification having been first suggested to him by the effects of a deposit of ice. Accordingly, Lt. Comdr. Diehl, through the Bureau of Aeronautics, Navy Department, requested the National Advisory Committee for Aeronautics to investigate, by tests in the variable-density wind tunnel, the characteristics of two such modifications of the Gött. 398 airfoil. The tests were made in November, 1931. The results are presented in this note together with the results of a test of the normal Gött. 398 airfoil for comparison.

Attention is also called to another investigation of the effects of nose shape, the results of which have recently been published (reference 3), consisting of tests in the variable-density wind tunnel of nine symmetrical airfoils having different leading edge radii.

Models caps.

The section Gött. 398-A was derived from the Gött. 398 section by fairing new upper and lower surface curves from a point 1 per cent of the chord forward of the original leading edge into the original surface curves. The Gött 398-B was similarily derived except that the leading-edge point was taken 2 per cent of the chord forward of the original leading edge. The resulting nose forms are shown in Figure 1 after the sections have been scaled back to the same chord. The profile forms and tables of ordinates are also given in Figures 3 and 4. The models that were built for the tests were the usual 5 by 30 inch duralumin airfoils made as described in reference 1.

Tests caps

The airfoils were tested in the usual manner as described in reference 1 except that the angle of attack range was extended to 60° in order to investigate the characteristics of the airfoils beyond the stall. The tests were made at a Reynolds Number of approximately 3,000,000, which is roughly the value reached in flight by the usual airplane flying near its minimum speed.

Results and Discussion caps.

The results are presented in the standard graphical form by means of two plots for each airfoil. (See figs. 2

to 7.) In the first plot the lift coefficient C_L, drag coefficient C_D, the L/D ratio, and the center of pressure are plotted against angle of attack α. These results have been corrected for the effects of the tunnel walls by the method described in reference 2 so that they represent the characteristics of rectangular wings of aspect ratio 6. The second, the infinite-aspect-ratio plot, presents the results reduced by the method described in reference 2 to infinite aspect ratio. The profile-drag coefficient C_{D_0}, the angle of attack for infinite aspect ratio α_0, and the coefficient of moment about a point one-quarter of the chord behind the leading edge $C_{m\ c/4}$, are plotted against the lift coefficient as the independent variable.

Effects of the nose modification. - Referring to Figure 8, it may be seen that the modifications have little effect on the slope of the lift curve or on the lift in the angle-of-attack range corresponding to low profile-drag coefficients. However, the lift curves for the sharp-nosed airfoils remain straight over a smaller range of angles of attack. The maximum lift coefficient is reduced by approximately 26 per cent by either modification, and the rapid loss of lift beyond the maximum is eliminated.

The effects of the modifications on the profile-drag coefficient may be seen from Figure 9. The effect of changing to either form of sharp nose is to reduce the minimum profile-drag coefficient by approximately 8 per cent, and to cause the minimum profile drag to occur at a higher value of the lift coefficient. The section having the finest nose, however, shows a particularly rapid increase of drag for lift coefficients below that for minimum profile drag. If a Gött. 398 wing were replaced by one of this type some loss of high speed might result, particularly if a larger wing were used to compensate for the lower maximum-lift coefficient. It should be noted that these results could have been predicted in a general way from the earlier investigation of the effects of nose shape reported in reference 3.

The effects of the nose modifications on the pitching-moment characteristics may be studied by referring to the c.p. and moment curves in Figures 2 to 7 or to the following table:

Airfoil	Gött.398	Gött.398-A	Gött.398-B
Most forward c.p. (per cent chord)	30	31	31
c.p. at 1/4 $C_{L\,max}$ (per cent chord)	46	55	55
c.p. travel (per cent. chord) chord	16	24	24
C_{m_0}	-0.083	-0.087	-0.090

Spinning tendencies. - Curves of normal-force coefficient against angle of attack have been used (reference 4) to indicate the spinning tendencies of a wing. Such curves for the two sharp-nosed airfoils are compared with the corresponding curve for the Gött. 398 airfoil in Figure 10. It is evident from these that, as compared with the normal airfoil, the sharp-nosed airfoils have characteristics that give the normal-force curves a smaller negative slope and a smaller total drop for angles of attack beyond the first maximum, indicating a smaller degree of instability in roll about the longitudinal axis in the plane of symmetry and a reduced tendency to develop a violent or dangerous spin.

CONCLUSIONS

Both sharp-nosed airfoils have about the same characteristics. As compared with the normal airfoil, the maximum lift is reduced by approximately 26 per cent, but the objectionable rapidly decreasing lift with angle of attack beyond the stall is eliminated; the profile drag is slightly reduced in the range of the lift coefficient between 0.2 and 0.85, but at higher and lower lift coefficients the drag is increased. For practical purposes the Gött. 398-A, the section having the blunter angle at the nose, is probably preferable to the Gött. 398-B because the profile drag increases less rapidly as the angle of attack departs from that for minimum profile drag.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 25, 1931.

References copy -

1. Jacobs, Eastman N.: Tests of Six Symmetrical Airfoils in the Variable-Density Wind Tunnel. T.N. No. 385, N.A.C.A., 1931.

2. Jacobs, Eastman N., and Anderson, Raymond F.: Large-Scale Aerodynamic Characteristics of Airfoils as Tested in the Variable-Density Wind Tunnel. T.R. No. 352, N.A.C.A., 1930.

3. Pinkerton, Robert M.: Effect of Nose Shape on the Characteristics of Symmetrical Airfoils. T.N., No. 386, N.A.C.A., 1931.

4. Fuchs, Richard, and Schmidt, Wilhelm: Air Forces and Air Force Moments at Large Angles of Attack and How they are Affected by the Shape of the Wing. T.M. No. 573, N.A.C.A., 1930.

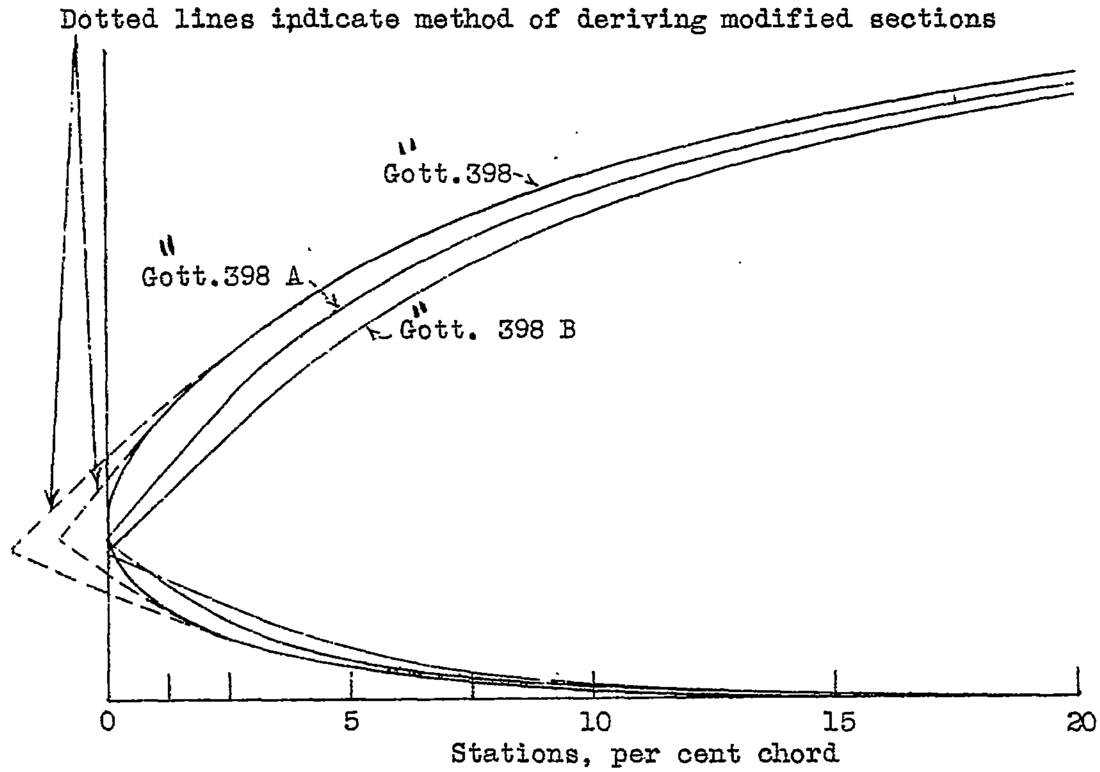
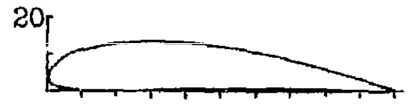


Fig. 1 Nose forms for normal and sharp-nosed airfoils

Name of section: Gött. 398 Size 5" x 30"
R.N. 3,090,000 Vel.: 70.0 ft./sec. 3/18/31
Press. stand. atm.: 20.3 V.D.T. 524
Results corrected to A.R. 6 in free air



Sta.	Up'r	Lw'r	Sta.	Up'r	Lw'r
0	3.74	3.74	40	13.34	.17
1.25	6.20	1.89	50	12.27	.27
2.50	7.40	1.28	60	10.63	.33
5.0	9.17	.69	70	8.53	.35
7.5	10.37	.35	80	6.12	.27
10	11.25	.18	90	3.40	.13
15	12.53	.03	95	1.92	.06
20	13.34	.00	100	.40	.00
30	13.80	.05			

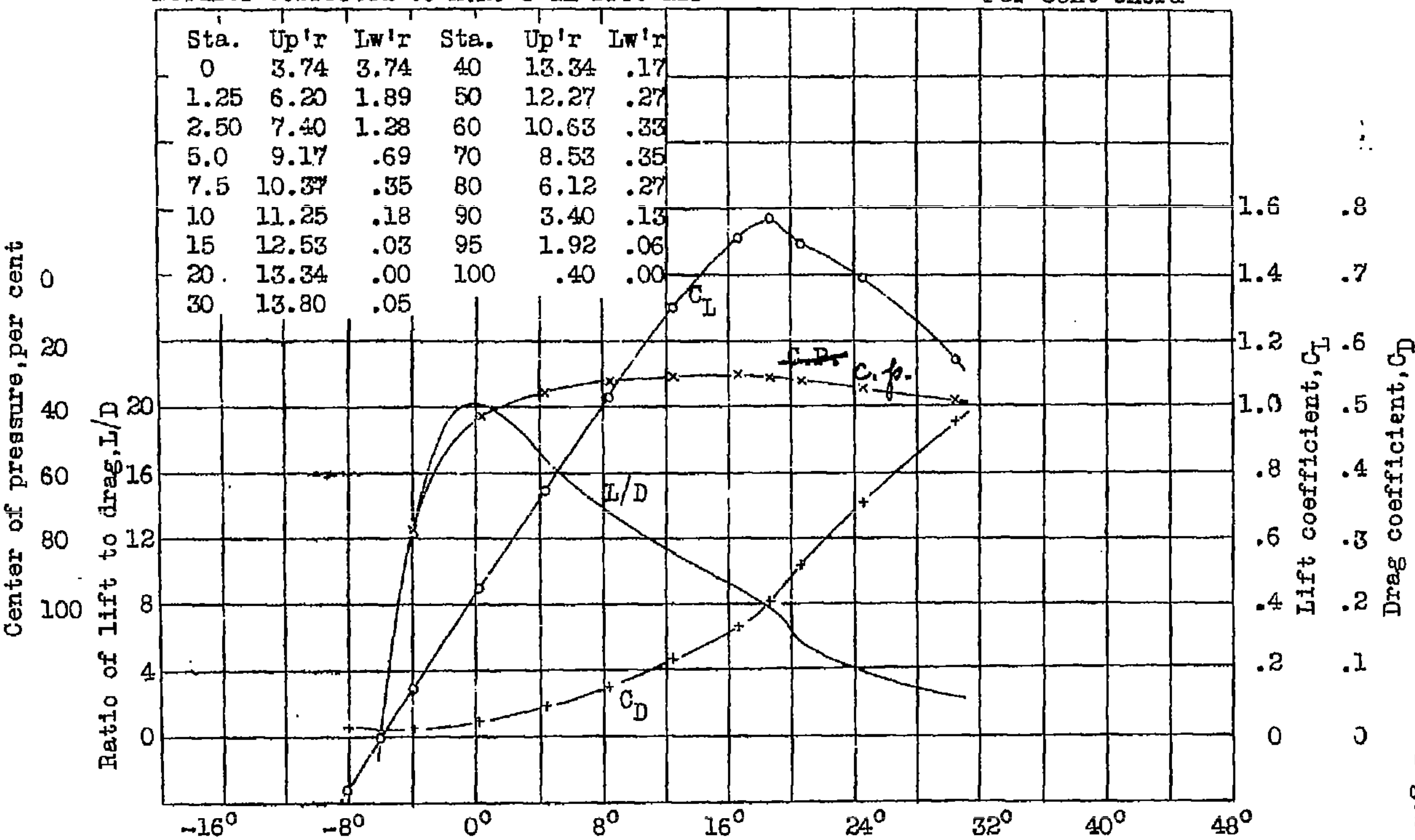
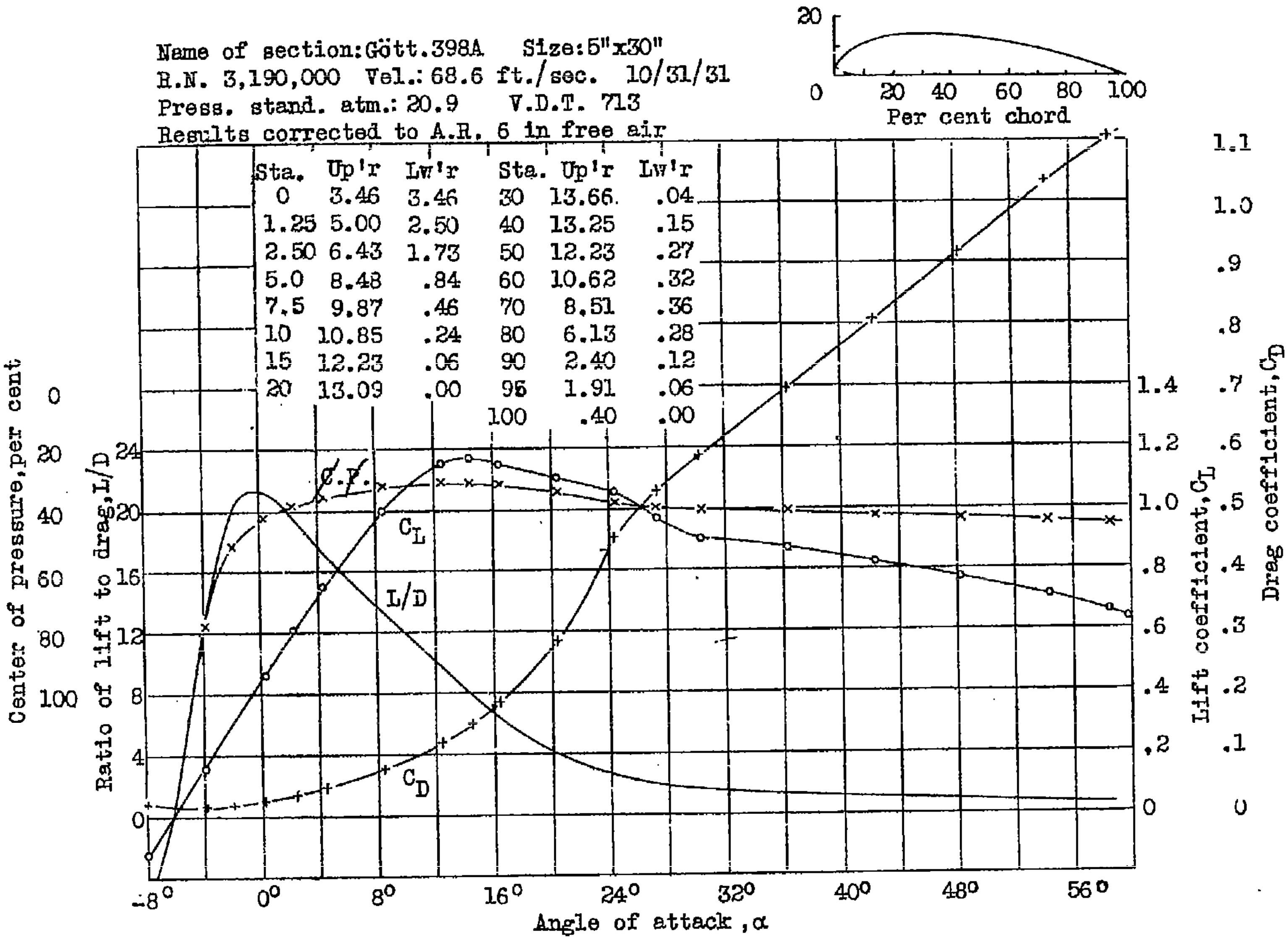


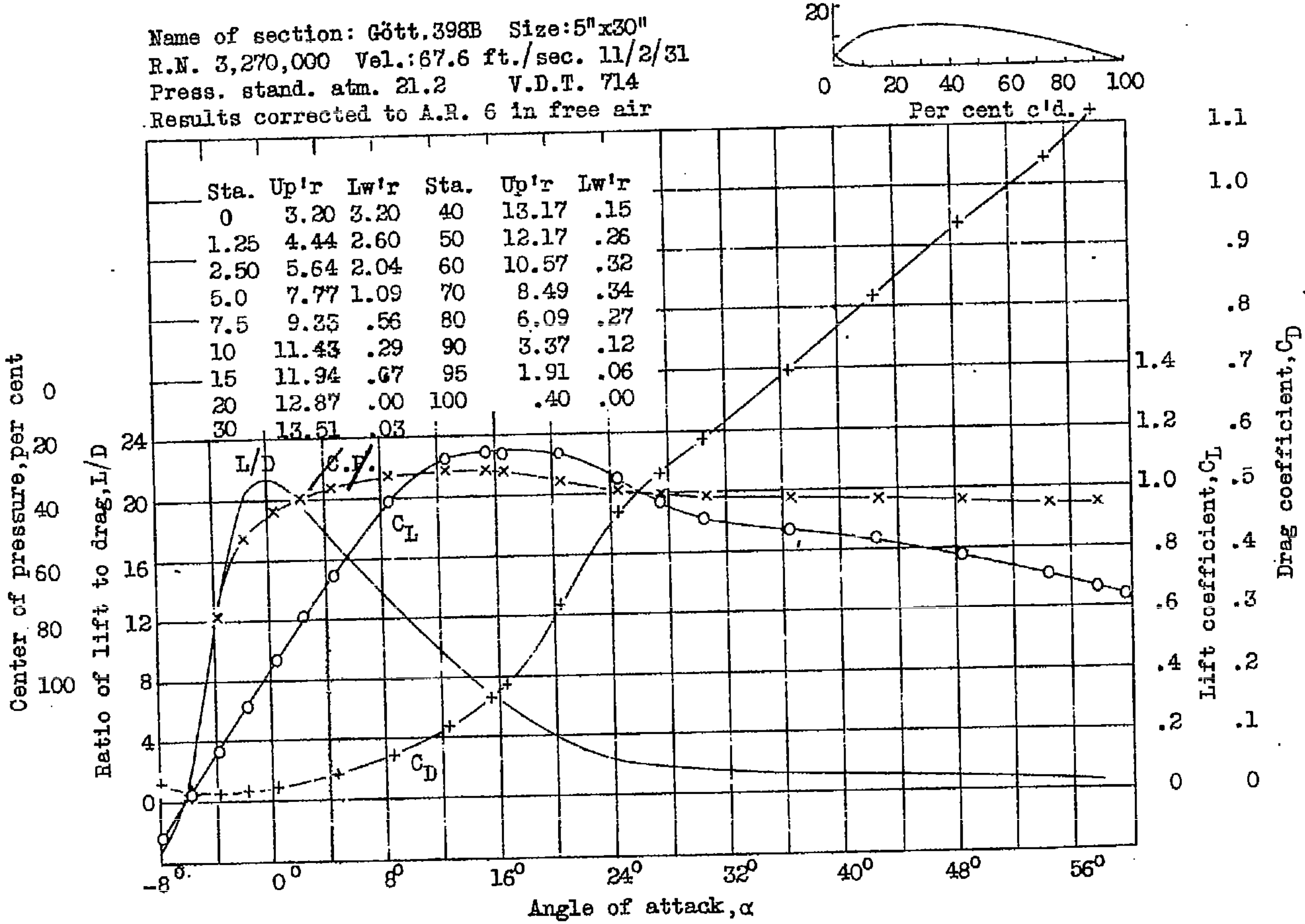
Fig.2 Göttingen 398

Fig. 2



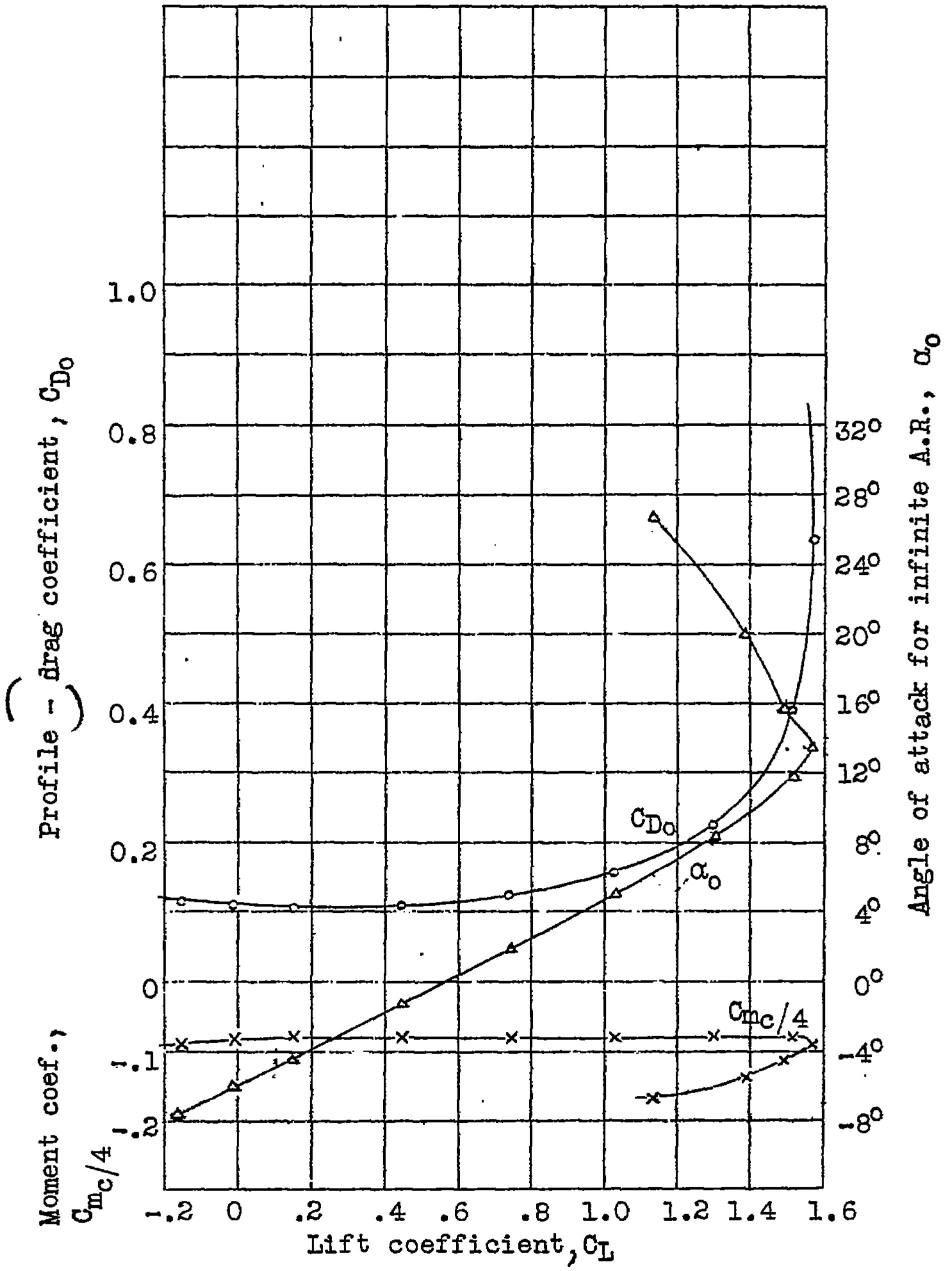
Sta.	Up'r	Lw'r	Sta.	Up'r	Lw'r
0	3.46	3.46	30	13.66	.04
1.25	5.00	2.50	40	13.25	.15
2.50	6.43	1.73	50	12.23	.27
5.0	8.48	.84	60	10.62	.32
7.5	9.87	.46	70	8.51	.36
10	10.85	.24	80	6.13	.28
15	12.23	.06	90	2.40	.12
20	13.09	.00	95	1.91	.06
			100	.40	.00

Fig.3 Göttingen 398 A



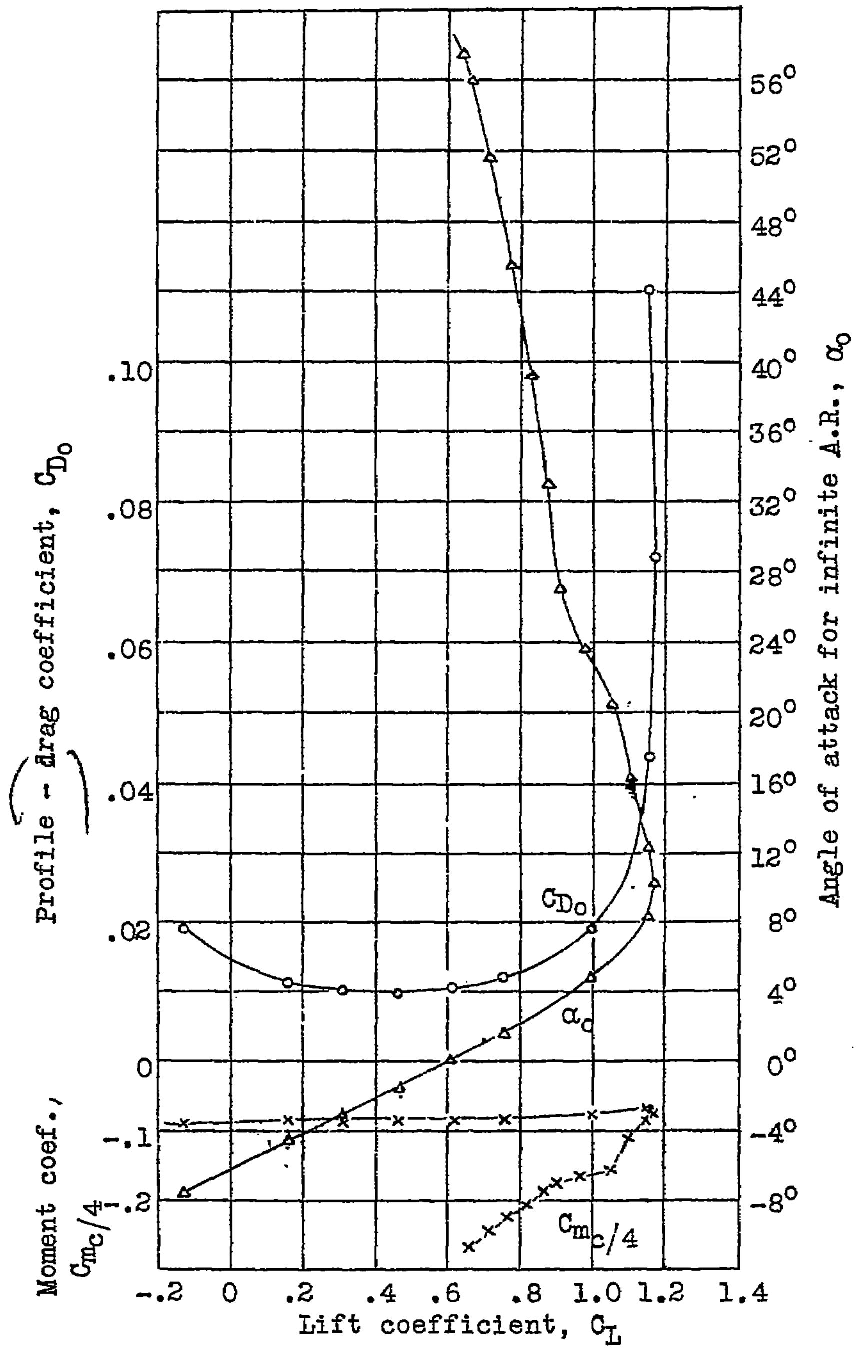
Sta.	Up'r	Lw'r	Sta.	Up'r	Lw'r
0	3.20	3.20	40	13.17	.15
1.25	4.44	2.60	50	12.17	.26
2.50	5.64	2.04	60	10.57	.32
5.0	7.77	1.09	70	8.49	.34
7.5	9.33	.56	80	6.09	.27
10	11.43	.29	90	3.37	.12
15	11.94	.07	95	1.91	.06
20	12.87	.00	100	.40	.00
30	13.51	.03			

Fig.4 Göttingen 398 B



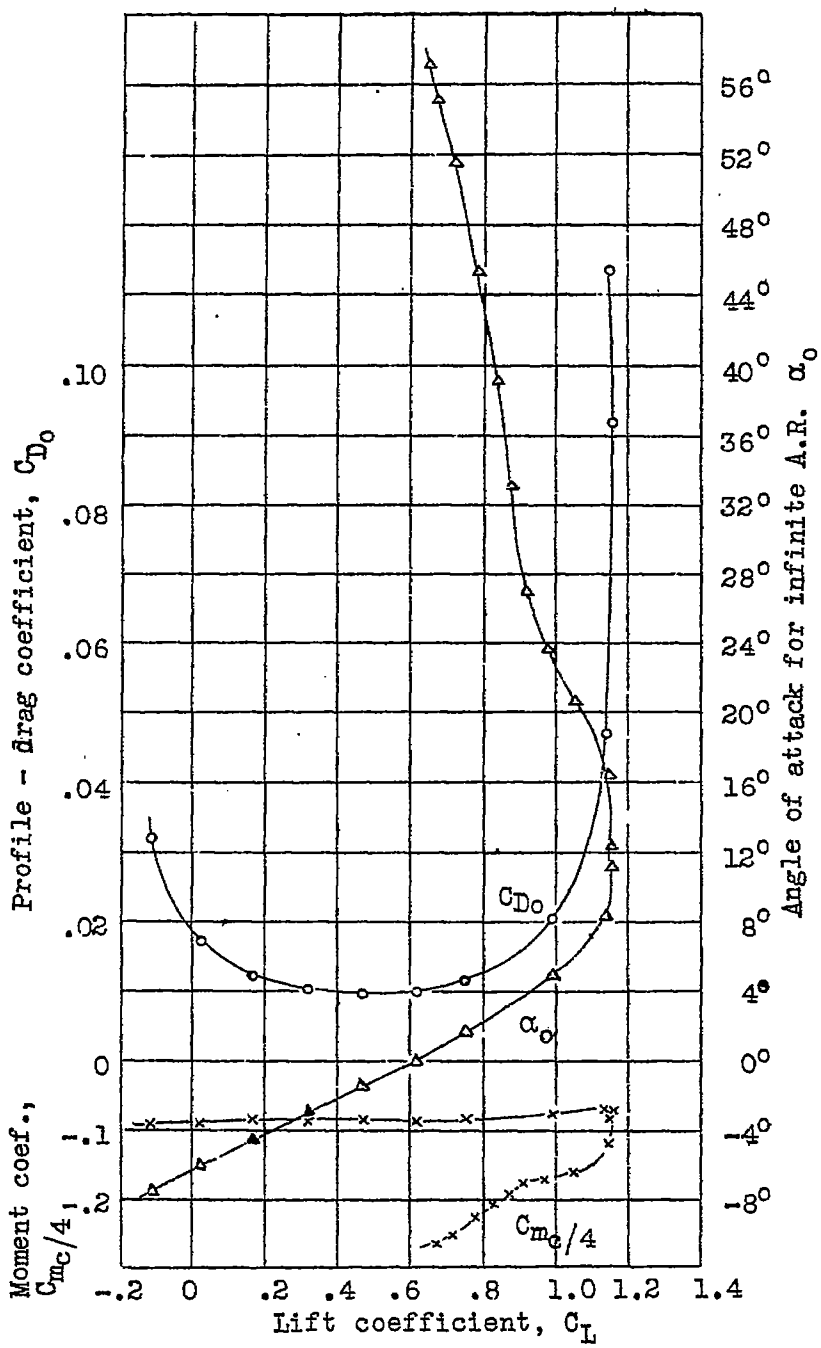
Name of section: Gött. 398 R.N.: 3,090,000
Date: 3/18/31, Where tested: L.M.A.L., V.D.T.:524

Fig. 5 Gött. 398 Infinite A.R. characteristics.



Name of section: Gött. 398 A R.N.: 3,190,000
Date: 10/31/31, Where tested: L.M.A.L., V.D.T.:713

Fig. 6 Gött. 398 A Infinite A.R. characteristics.



Name of section: Gött. 398B R.N.: 3,270,000
Date: 11/2/31, Where tested: L.M.A.L., V.D.T.: 714

Fig. 7 Gött. 398 B Infinite A.R. characteristics.

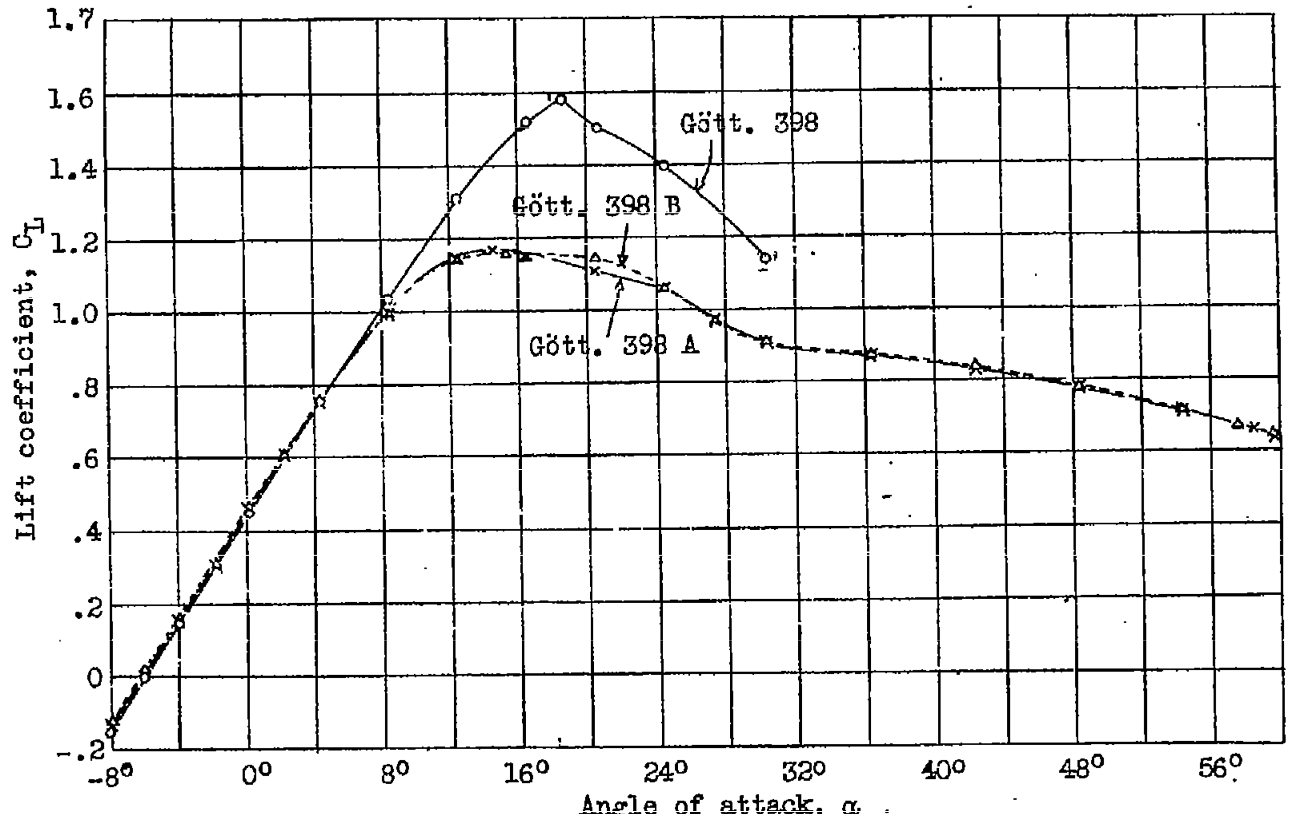


Fig. 8 Lift curves for normal and sharp-nosed airfoils.

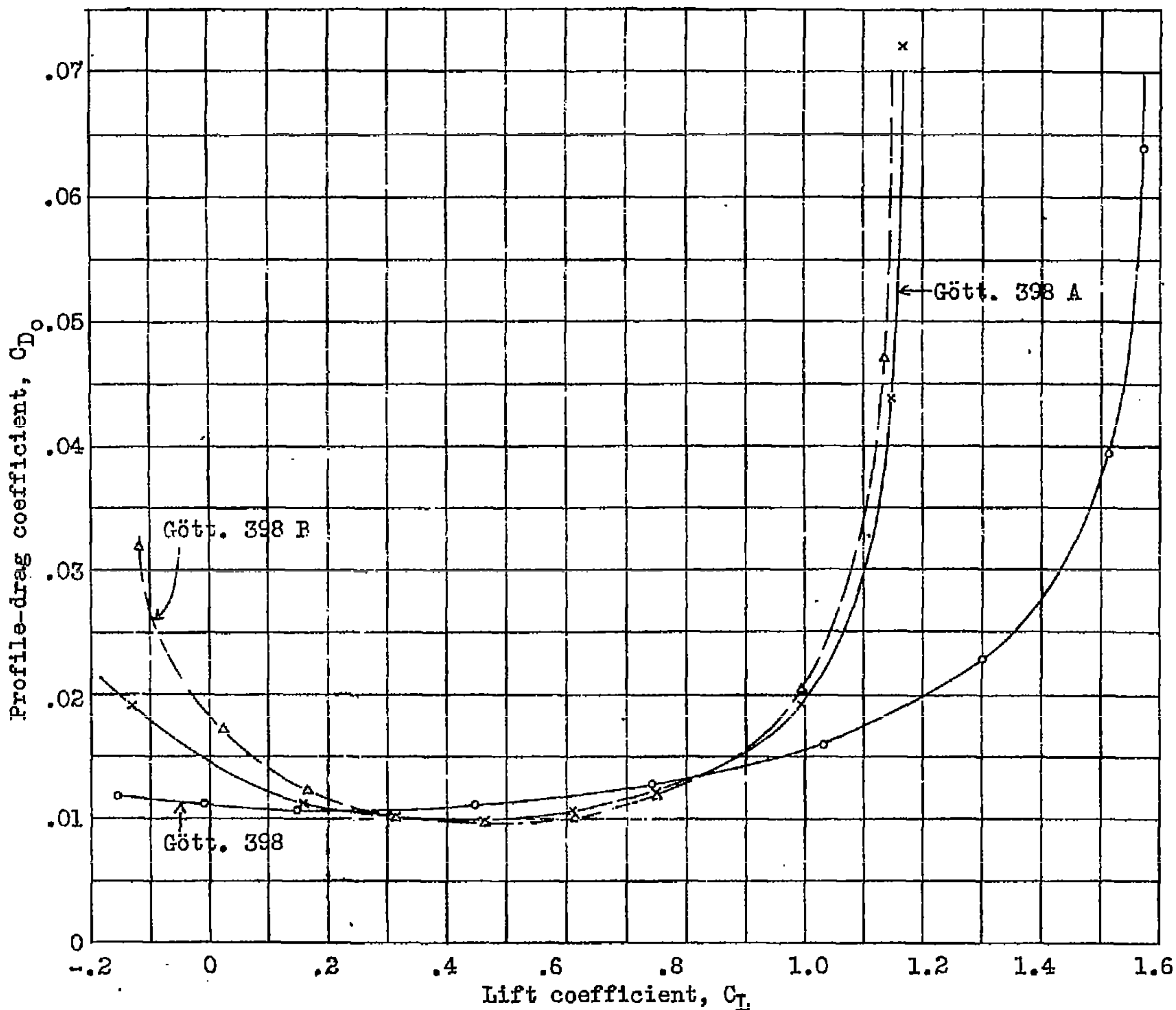


Fig.9 Profile-drag coefficients for normal and sharp-nosed airfoils.

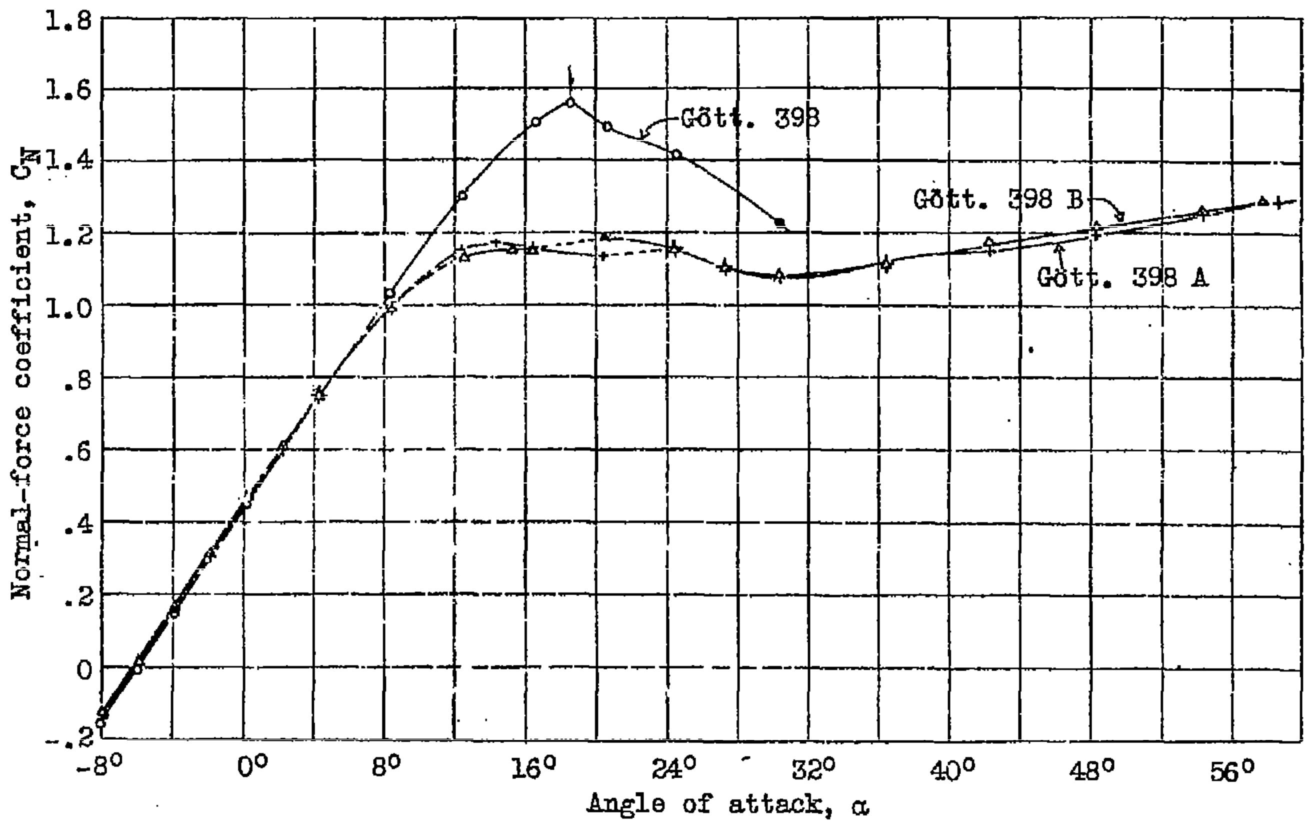


Fig.10 Variation of normal-force coefficient with angle of attack.