M. A. L. Library

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 397

THE AERODYNAMIC CHARACTERISTICS OF SIX COMMONLY USED AIRFOILS OVER A LARGE RANGE OF POSITIVE AND NEGATIVE ANGLES OF ATTACK

By Raymond F. Anderson

FILE COPY
To be returned to
the files of the Langley
Memorial Aeronautical
Laboratory

Washington
November, 1931

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 397

THE AERODYNAMIC CHARACTERISTICS OF SIX COMMONLY USED AIRFOILS OVER A LARGE RANGE OF POSITIVE AND NEGATIVE ANGLES OF ATTACK

By Raymond F. Anderson

Summary

This paper presents the results of tests of six commonly used airfoils: the M-6, the CYH, the N-22, the C-72, the Boeing 106, and the Göttingen 398. The lifts, drags, and pitching moments of the airfoils were measured through a large range of positive and negative angles of attack. The tests were made in the variable-density wind tunnel of the National Advisory Committee for Aeronautics at a large value of the Reynolds Number. For the N-22, the C-72, the Boeing 106, and the Göttingen 398 airfoils, the negative maximum lift coefficients were found to be approximately half the positive; but for the M-6 and the CYH, which have less effective camber, the negative values were, respectively, 0.8 and 0.6 of the positive values.

Introduction

A comparatively small amount of information is available on the aerodynamic characteristics of airfoils through the negative angle-of-attack range. The available data are from tests on only a few airfoils at low values of the Reynolds Number.

In order to obtain data on the strength of airplanes in the inverted flight condition, the Bureau of Aeronautics, Navy Department, requested that tests be made in the variable density wind tunnel of six commonly used airfoils (the M-6, the CYH, the N-22, the C-72, the Boeing 106, and the Göttingen 398) at negative angles of attack. In accordance with this request, routine measurements of lift, drag, and pitching moment were made on these airfoils through the

negative angle-of-attack range. The tests were made at a value of the Reynolds Number which corresponds to the flight condition of most airplanes near their landing speeds.

To make the data complete, the results of hitherto unpublished tests of the same airfoils at positive angles of attack are included in this paper. It presents the results of the first of two series of tests being made by the National Advisory Committee for Aeronautics to determine the aerodynamic characteristics of airfoils at negative angles of attack. A second paper will be published after tests on several other commonly used airfoils are completed.

Apparatus and Method

A brief description of the redesigned variable density wind tunnel and its method of operation will be found in reference 1. The customary 5 by 30 inch polished, rectangular, duralumin airfoils were used in the tests. The specified ordinates of the airfoils are given in Table I.

For tests at positive angles of attack airfoils are mounted on the supporting struts of the balance with the sting and struts attached on the flat side. For the tests at negative angles of attack, however, the airfoils were inverted and the sting was placed on the curved surface, so that the flat side, which was then the suction side, was free from obstructions which might have affected the value of the maximum lift coefficient.

The measurements of lift, drag, and pitching moment for both the positive and negative angle-of-attack ranges were made at a tank pressure of approximately 20 atmospheres and an air speed of approximately 70 feet per second, which correspond to a Reynolds Number of 3,100,000.

Results and Discussion

The method used in obtaining the final results, including the correction for the influence of the tunnel walls, is given in reference 2. The corrected data have been plotted against angle of attack in Figures 1 to 6.

Although results of tests at positive angles of attack and large values of the Reynolds Number were available in published form for the M-6 and the CYH airfoils (reference 2), these results are not included in this paper because they are from tests of unpolished models in the original tunnel. Instead, the results of later tests of polished models of these airfoils in the redesigned tunnel are given here. The positive angle-of-attack data for the other four airfoils were available from tests under similar conditions; consequently, the results of all the tests at positive and negative angles of attack are comparable.

For the purpose of this investigation, the most important characteristics are the maximum positive and negative values of C_L. Figures 3, 4, 5, and 6 indicate that for the N22, the C72, the Boeing 106, and the Göttingen 398 airfoils the negative values of maximum lift coefficient are nearly equal. The positive values for these four airfoils are also nearly the same. Such an agreement would be expected, as the profiles of the four airfoils do not differ greatly. The curves also indicate that for these airfoils the negative value of maximum lift coefficient is approximately half the positive value.

A smaller difference between the negative and positive values of maximum lift coefficient would be expected for airfoils having less effective camber, because for a symmetrical airfoil, the positive and negative values would be equal. The M-6 airfoil, which has the least effective camber of any in this group, has a negative value of maximum lift coefficient equal to 0.8 of the positive value. For the CYH, which has a moderate effective camber, the factor is 0.6. The variation of the maximum lift coefficients with the shape of an airfoil will be more thoroughly analyzed after the tests of additional commonly used airfoils are completed.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 21, 1931.

References

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.

TABLE I

Ordinates of the Airfoils in Per Cent of the Chord

Airfoil	NACA M6		NACA CYH		N 22		C 72		Boeing 106		Gött. 398	
Stations	Upr.	Lwr.	Upr.	Lwr.	Upr.	Lwr.	Upr.	Lwr.	Upr.	Lwr.	Upr.	Lwr.
L.E.Rad.			1.50						0.70			
0	0	0	3.50	3.50	3.37 84	3.37	3.49	3.49	2.98	2.98	3.74	3.74
1¼	1.97	-1.76	5.45	1.93	5.58 139.5	1.70 42.5	5.55	1.92	5.26	1.54	6.20	1.89
2½	2.81	-2.20	6.50	1.47	6.66 166.5	1.15 29	6.51	1.47	6.14	1.04	7.40	1.28
5	4.03	-2.73	7.90	.93	8.25 206	.62 15.5	7.89	.93	7.54	.42	9.17	.69
7½	4.94	-3.03	8.85	.63	9.33 233	.32 8	8.85	.64	8.56	.04	10.37	.35
10	5.71	-3.24	9.60	.42	10.13 253	.16 4	9.60	.43	9.44	- .28	11.25	.18
15	6.82	-3.47	10.68	.15	11.28 282	.03 1	10.69	.16	10.62	- .64	12.53	.03
20	7.55	-3.62	11.36	.03	12.01 300	0	11.36	.03	11.34	- .90	13.34	0
25	8.01	-3.71										
30	8.22	-3.79	11.70	0	12.42 310.5	.05 1	11.73	0	11.88	-1.18	13.80	.05
40	8.05	-3.90	11.40	0	12.01 300	.15 4	11.41	.21	11.54	-1.28	13.34	.17
50	7.26	-3.94	10.52	0	11.04 276	.24 6	10.53	.59	10.54	-1.30	12.27	.27
60	6.03	-3.82	9.15	0	9.57 239	.30 7.5	9.15	.85	9.08	-1.22	10.63	.33
65			8.30	0								
70	4.58	-3.48	7.41	.06	7.68 192	.32 8	7.36	.91	7.18	- .98	8.53	.35
80	3.06	-2.83	5.62	.38	5.51 138	.24 6	5.23	.72	4.96	- .72	6.12	.27
90	1.55	-1.77	3.84	1.02	3.06 76.5	.12 3	2.80	.40	2.54	- .42	3.40	.13
95	.88	-1.08	2.93	1.40	1.73 43.2	.05 1	1.52	.21	1.29	- .23	1.92	.06
100	.26	- .26	2.05	1.85	.40 10	0	.10	0	.04	- .04	.40	0

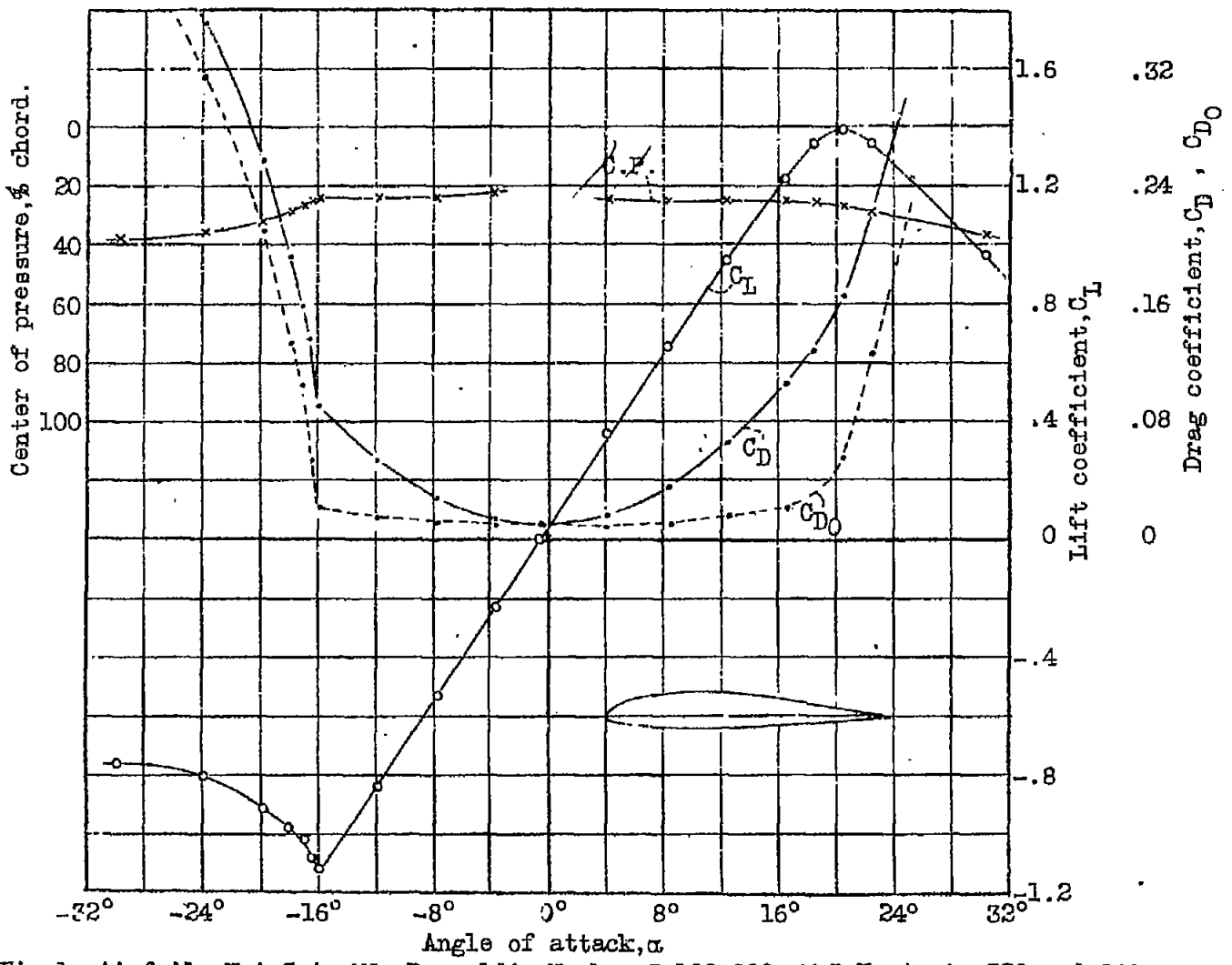

Fig.1 Airfoil, N.A.C.A. M6. Reynold's Number 3,100,000. V.D.T. tests, 526 and 640. Aspect ratio, 6. Tunnel wall correction applied. Dates, 3/31 and 7/31.

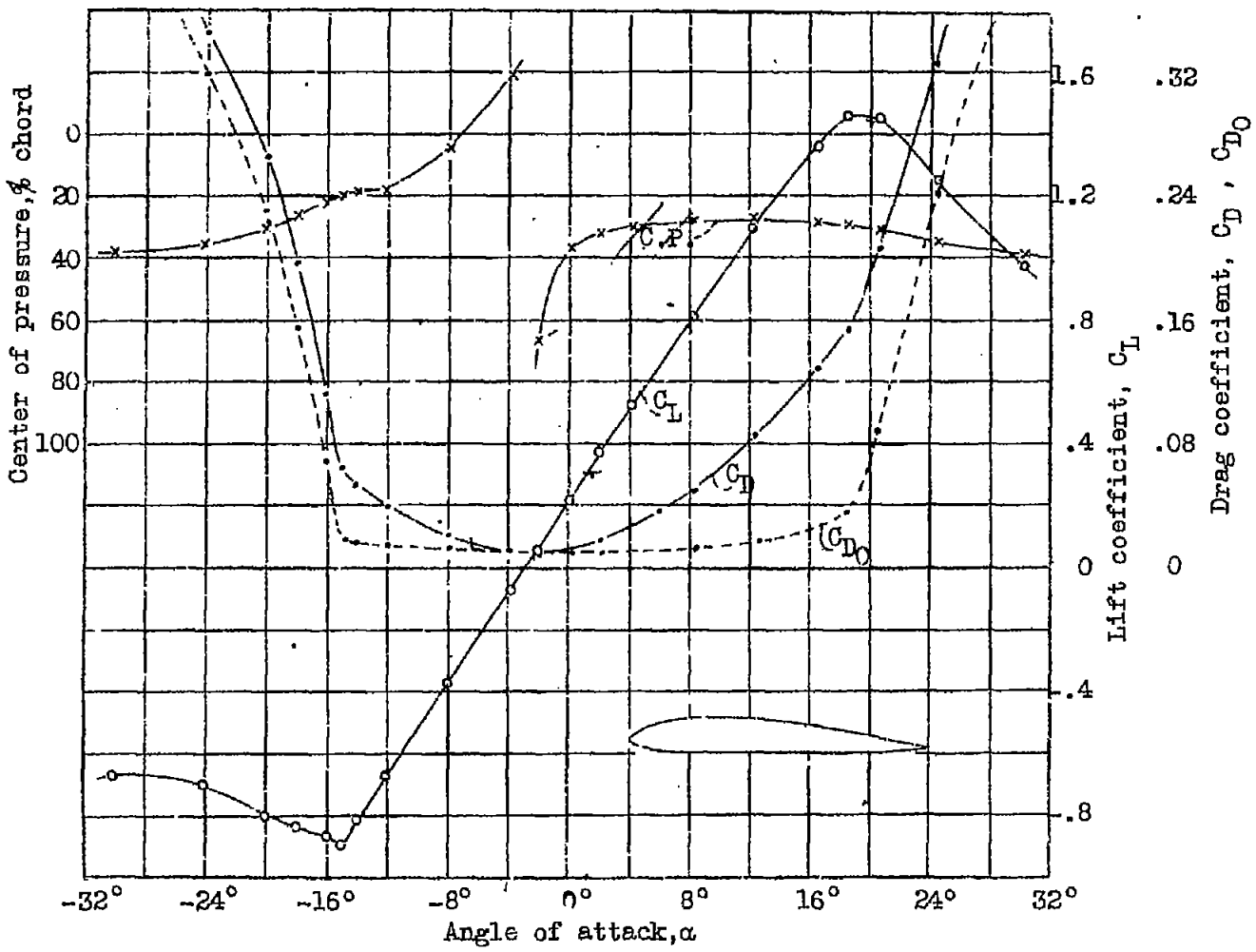

Fig.2 Airfoil,N.A.C.A. CYH. Reynold's Number 3,100,000. V.D.T. tests,536 and 641. Aspect ratio,6. Tunnel wall correction applied. Dates,3/31 and 7/31.

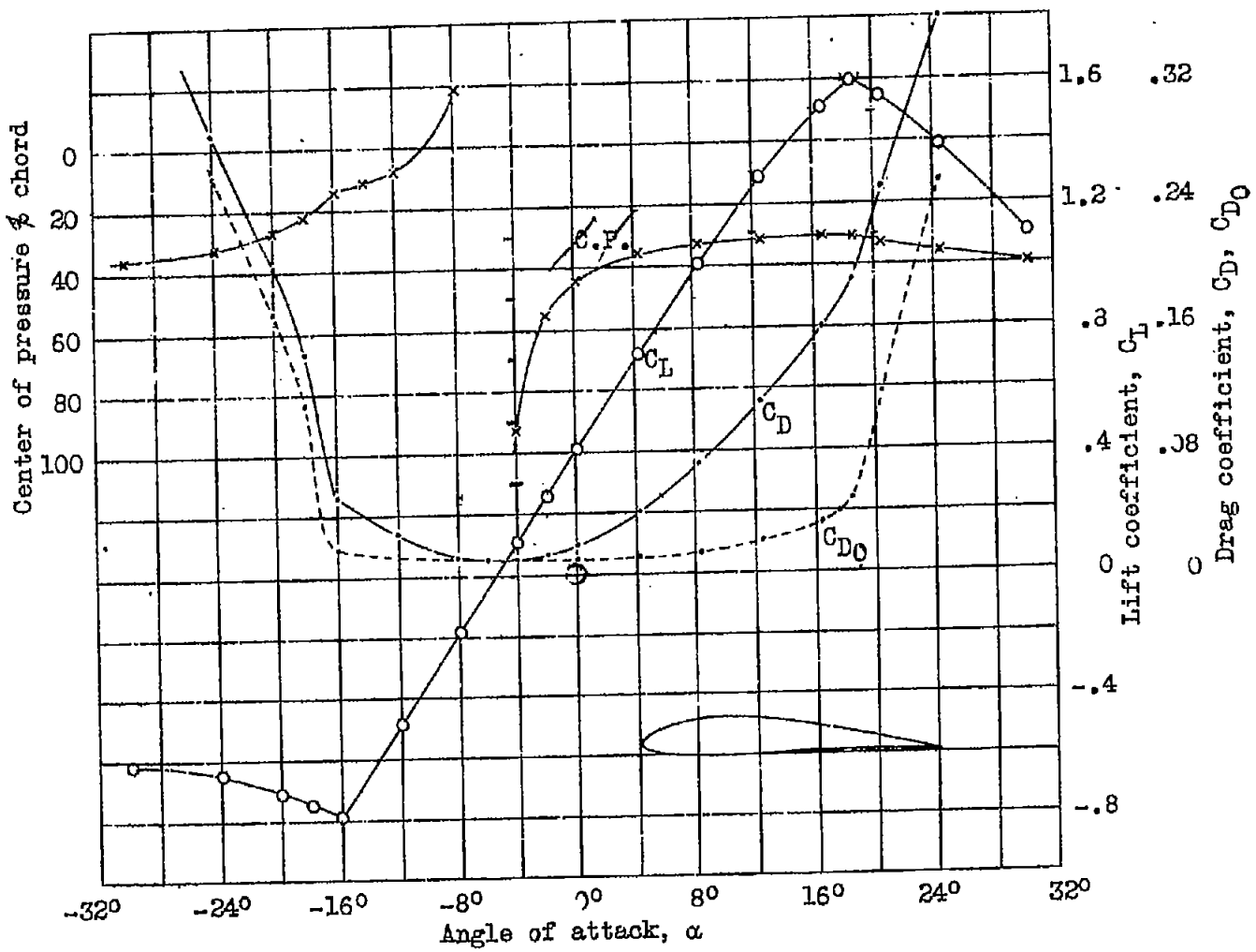

Fig.3 Airfoil, N 22. Reynold's Number, 3,100,000. V.D.T. tests, 542 and 638. Aspect ratio, 6. Dates 3/31 and 7/31. Tunnel wall correction applied.

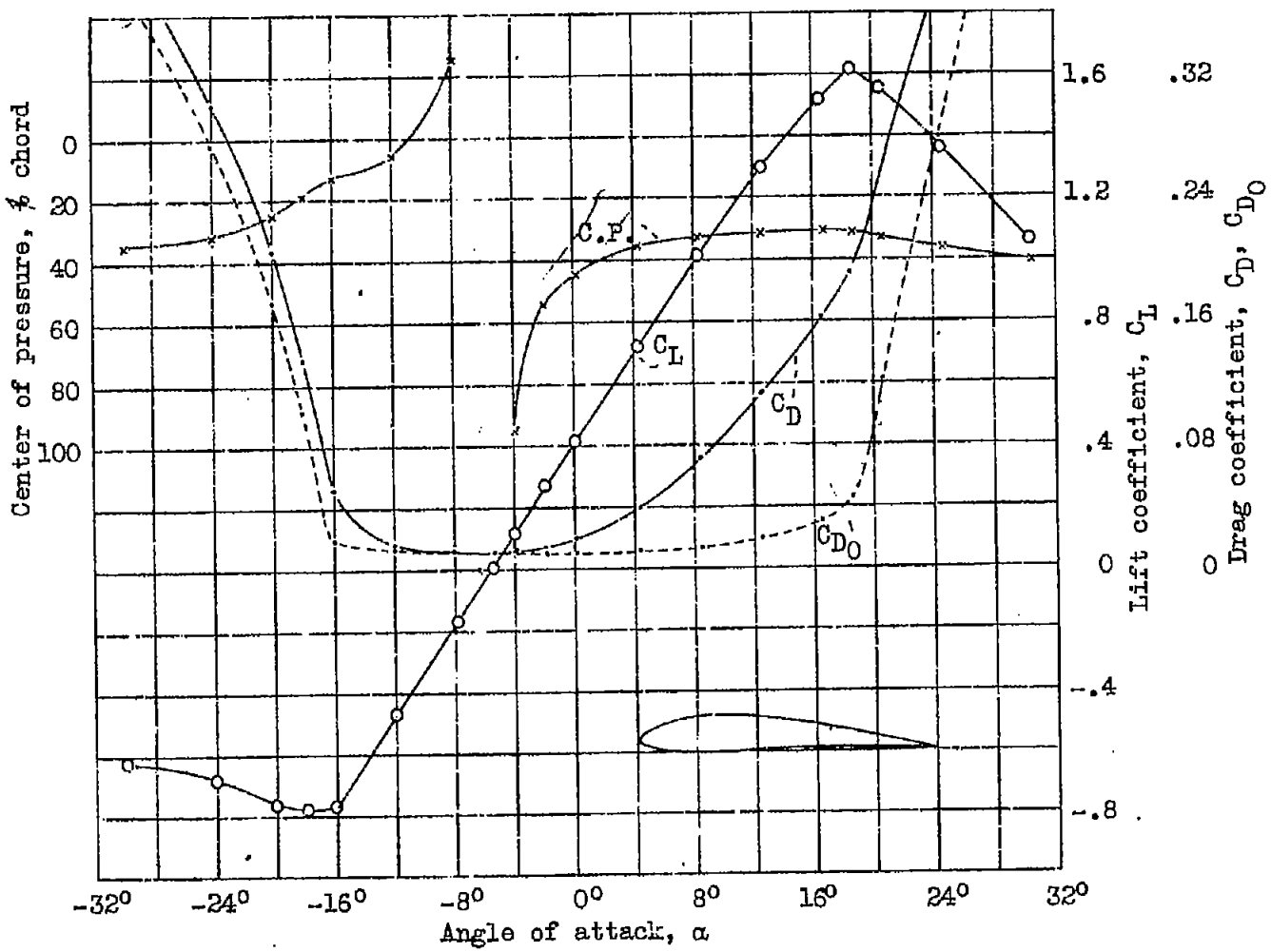

Fig.4 Airfoil, C 72. Reynold's Number, 3,100,000. V.D.T. tests, 529 and 637. Aspect ratio, 6. Dates 3/31 and 7/31. Tunnel wall correction applied.

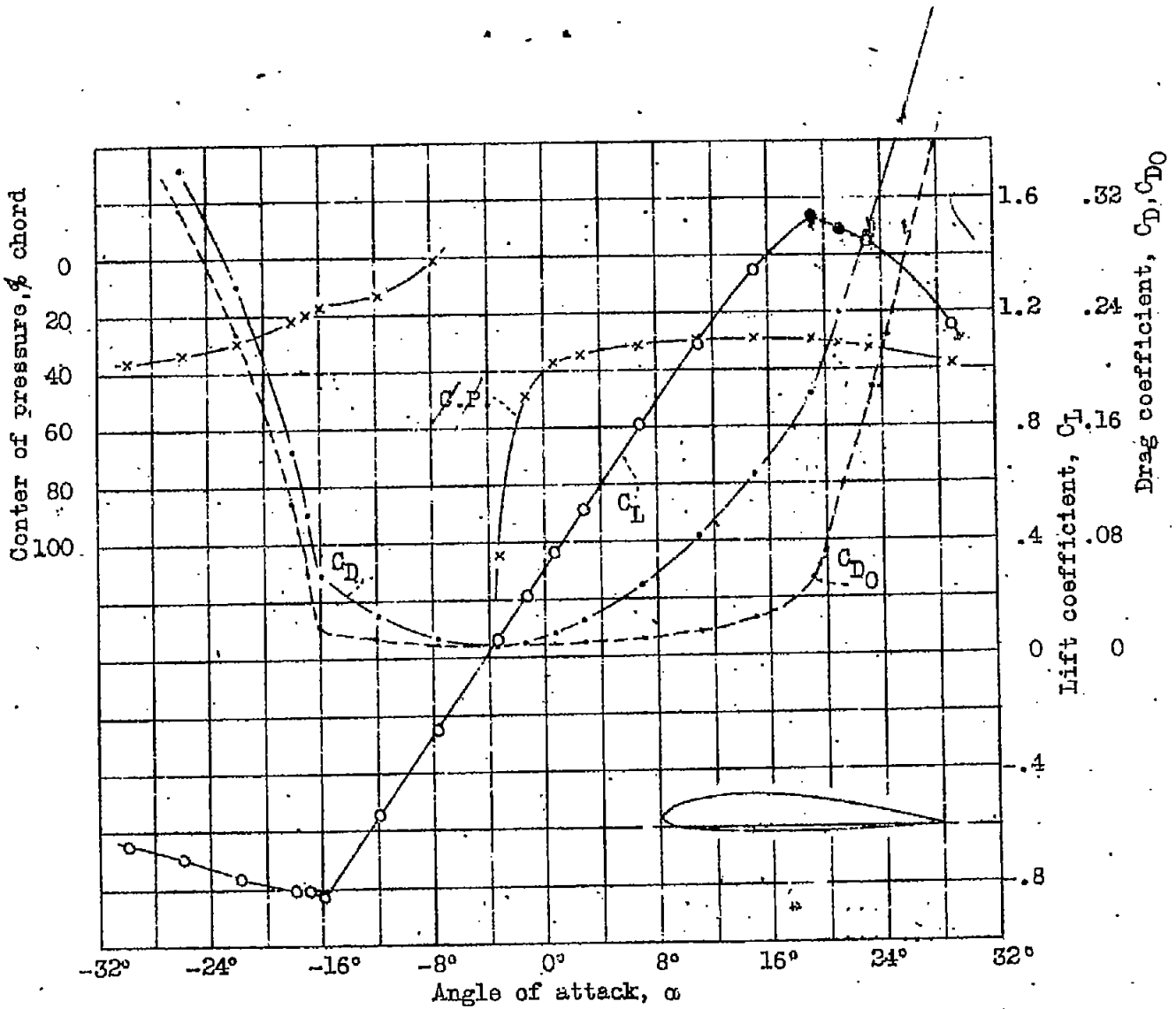

Fig. 5 Airfoil, Boeing 106. Reynold's Number, 3,100,000. V.D.T. tests, 531 and 635, Aspect ratio, 6. Dates 3/31 and 7/31. Tunnel wall correction applied.

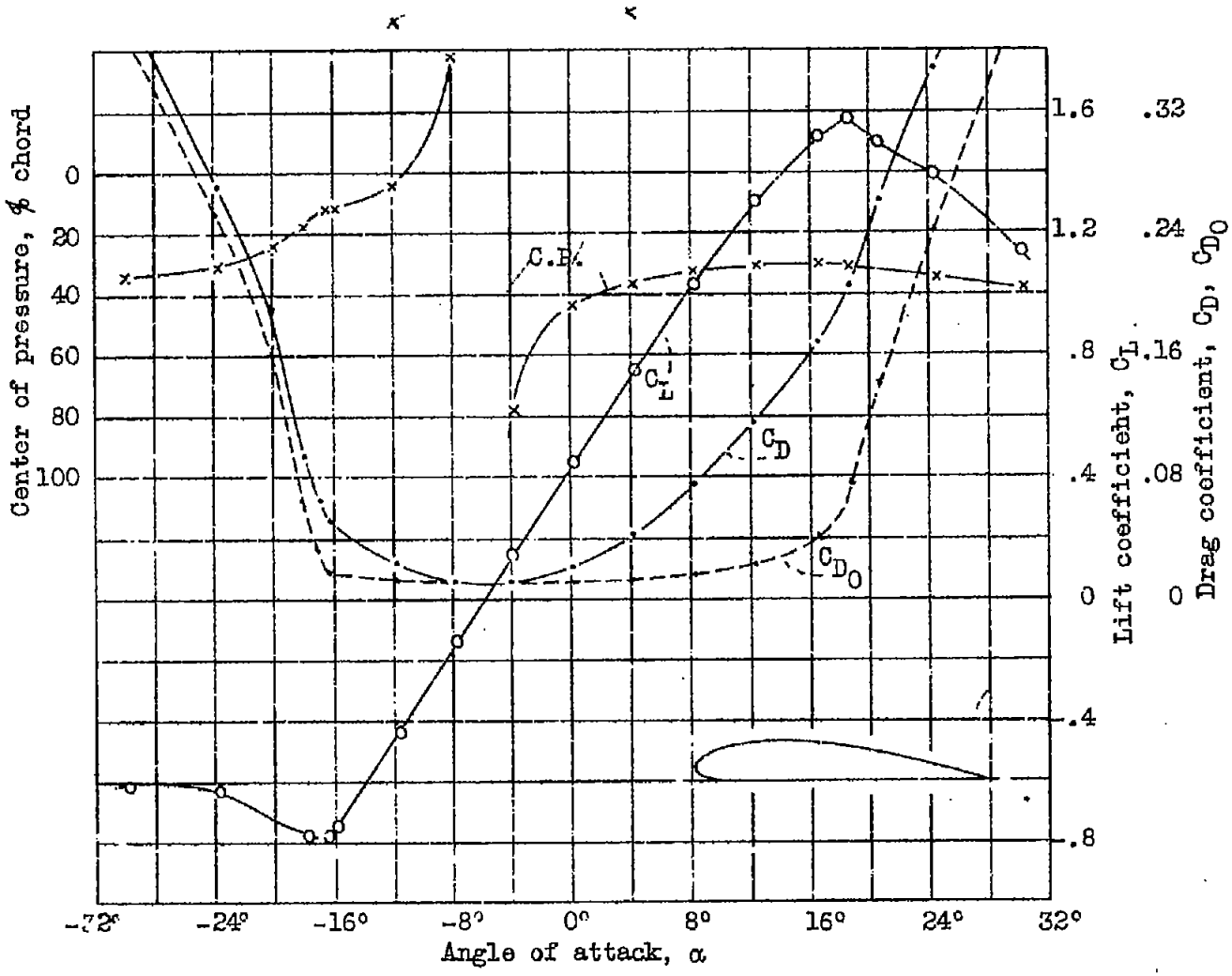

Fig. 6 Airfoil, Gött. 398. Reynold's Number, 3,100,000. V.D.T. tests, 624 and 639. Aspect ratio, 6. Dates 3/31 and 7/31. Tunnel wall correction applied.