TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 270

THE CHARACTERISTICS OF THE N.A.C.A. 97, CLARK Y, AND N.A.C.A.-M6 AIRFOILS WITH PARTICULAR REFERENCE TO THE ANGLE OF ATTACK

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Washington
December, 1927

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Summary

This note gives the aerodynamic characteristics of the N.A.C.A. 97, Clark Y, and N.A.C.A.-M6 airfoil sections as determined in the variable density wind tunnel at Langley Field, Virginia. Particular attention is called to the relation of the characteristics to the angle of attack in their use in airplane design.

In the adaptation of a certain airfoil section to an airplane design, it is necessary to make a careful study of the airfoil characteristics in order that the best performance may be attained on the completed airplane. Speed range and pay load are the important factors which are dependent directly on a careful selection and use of the wing section. The angle of wing setting or incidence on an airplane should be known in terms of the absolute angle of attack.

The angle between any reference line on an airfoil section at any time and that line when the direction of motion is such that the lift is zero, is called the absolute angle of attack (see Figure 1). It is this angle that is used in theoretical formulas for determining airfoil characteristics. One finds from experimental tests that the lift of an airfoil is directly proportional to the absolute angle of attack, being approximately the same for all sections. The minimum drag coefficient occurs at about zero lift or at about zero absolute angle of attack. The value of the minimum drag is, however, dependent on the choice of the section. Likewise, the maximum lift is determined by the burbling characteristics of the individual airfoil.

The ordinary or geometric angle of attack measured from the chord line is, with most airfoils, different from the absolute angle of attack. For checking rigging and angle of incidence it is most convenient to use the geometric angle as it can readily be measured. The designer, however, should be careful that he does not confuse the two, particularly if employing empirical formulas.

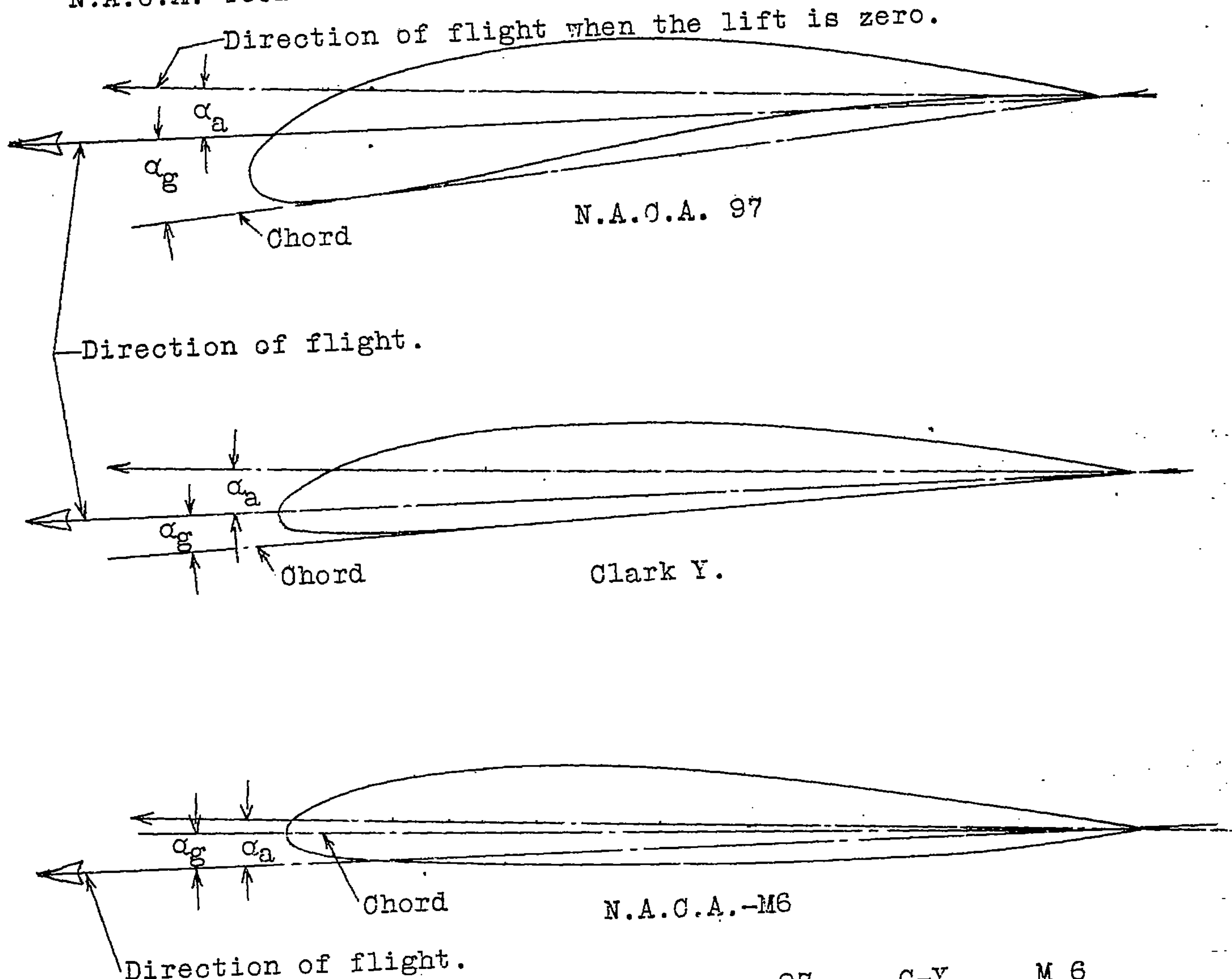
To illustrate the above points, suppose that the following three airfoil sections are chosen as suitable for use in design:

N.A.C.A. 97 - high camber,
Clark Y - medium camber,
N.A.C.A.-M6 - low camber.

These sections are all medium thick and the structural details of the wings would be very similar.

A medium sized airplane (say, a braced monoplane) carrying a gross load of about 5000 pounds with suitable wing area and powered with a 400 HP. engine will have, say, a landing speed of between 50 and 60 M.P.H. and a speed range of about 2.5. The high speed condition will make it necessary, therefore, that the airplane fly with the wings set to give a lift corresponding to a coefficient C_L of about 0.22. Should the Clark Y section be adopted, the geometric angle of attack for level flight at high speed would be -2.2° (see Figure 2). Had the M6 or 97 section been chosen, the respective angles would be $+2.3^{\circ}$ and -5.7°. However, on the basis of absolute angle of attack, the correct angle would be $+3.1^{\circ}$ for all three sections (Figure 3). The three airfoil sections are shown in Figures 2 and 3 in the above attitude for high-speed flight. The appearance of the sections is very misleading. It would scarcely be suspected that the 97 or Clark Y would give the same lift as the M6 in the attitude shown.

Referring to Figures 4 and 5, it may be seen that the drag coefficient curves as well as the lift curves based on absolute angle of attack are similar. Polar curves and curves of profile drag coefficient C_{D_P} plotted against C_L are given in Figures 6 and 7, respectively. The use of either of these latter curves for design eliminates possible errors due to the wrong use of the angle of attack. Figure 7 includes curves of induced drag coefficient C_{D_i}, for convenience in obtaining the correct C_D for a wing of any aspect ratio. C_P curves are given (Figure 8) for the Clark Y and M6 to complete the data. Similar information for the 97 is not available; however, for a section with a high camber like the 97, the C_P travel is more than for a section like the Clark Y.



		97	C-Y	M 6
Geometrical Angle of Attack	α_g	-5.7°	-2.2°	$+2.3^\circ$
Absolute Angle of Attack	α_a	$+3.1^\circ$	$+3.1^\circ$	$+3.1^\circ$

Figure 1.
Airfoil Attitude At High Speed
same lift on each Airfoil, $C_L=0.22$

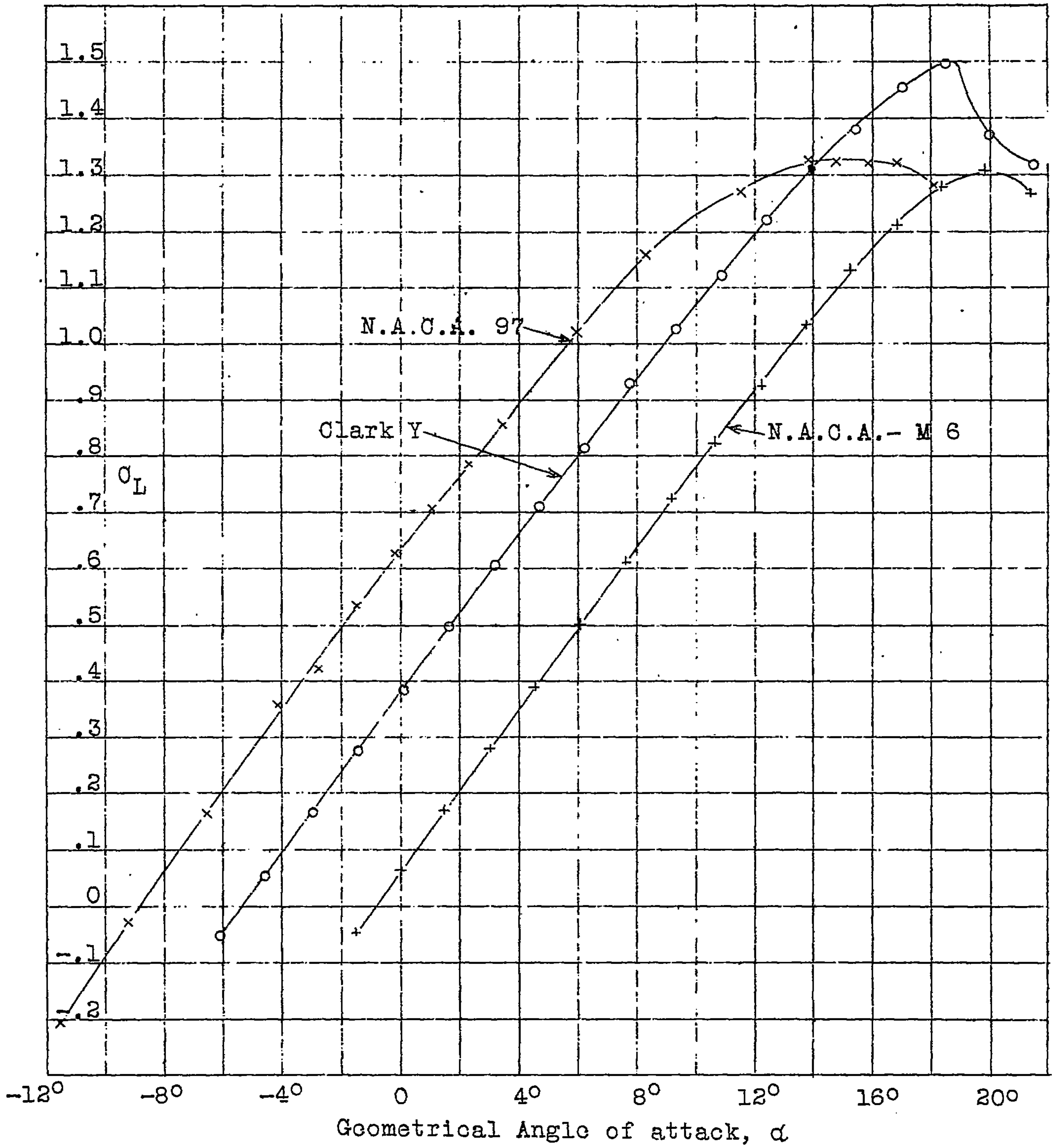


Fig.2

naca 97 58-5

(172-2 A) m6
186-1 Clark Y

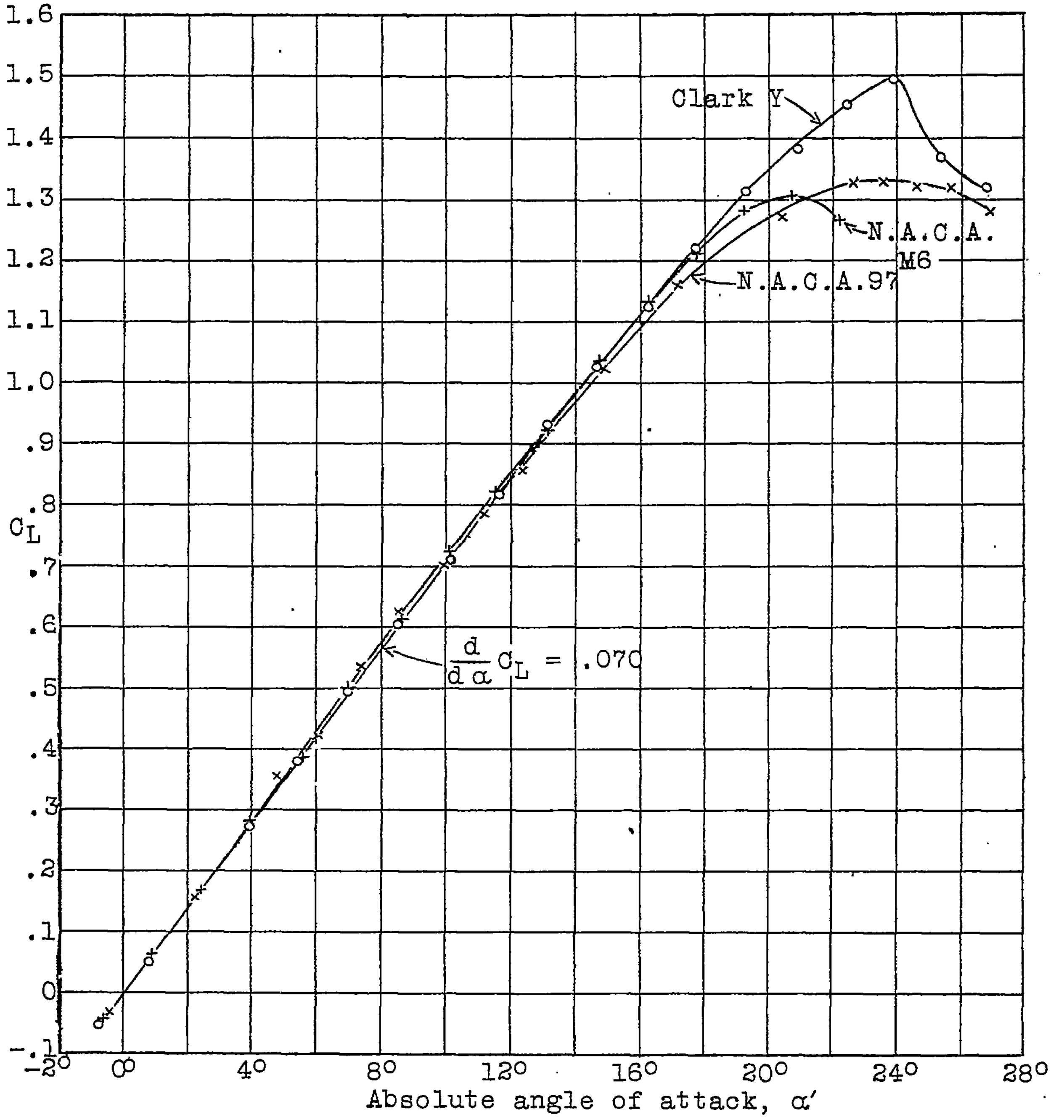

1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
C_L
.7
.6
.5
.4
.3
.2
.1
0
-.1
-2°
0°
4°
8°
12°
16°
20°
24°
28°
Absolute angle of attack, α′
Clark Y
N.A.C.A. M6
N.A.C.A. 97
$\frac{d}{d\alpha} C_L$ = .070

Fig.3.

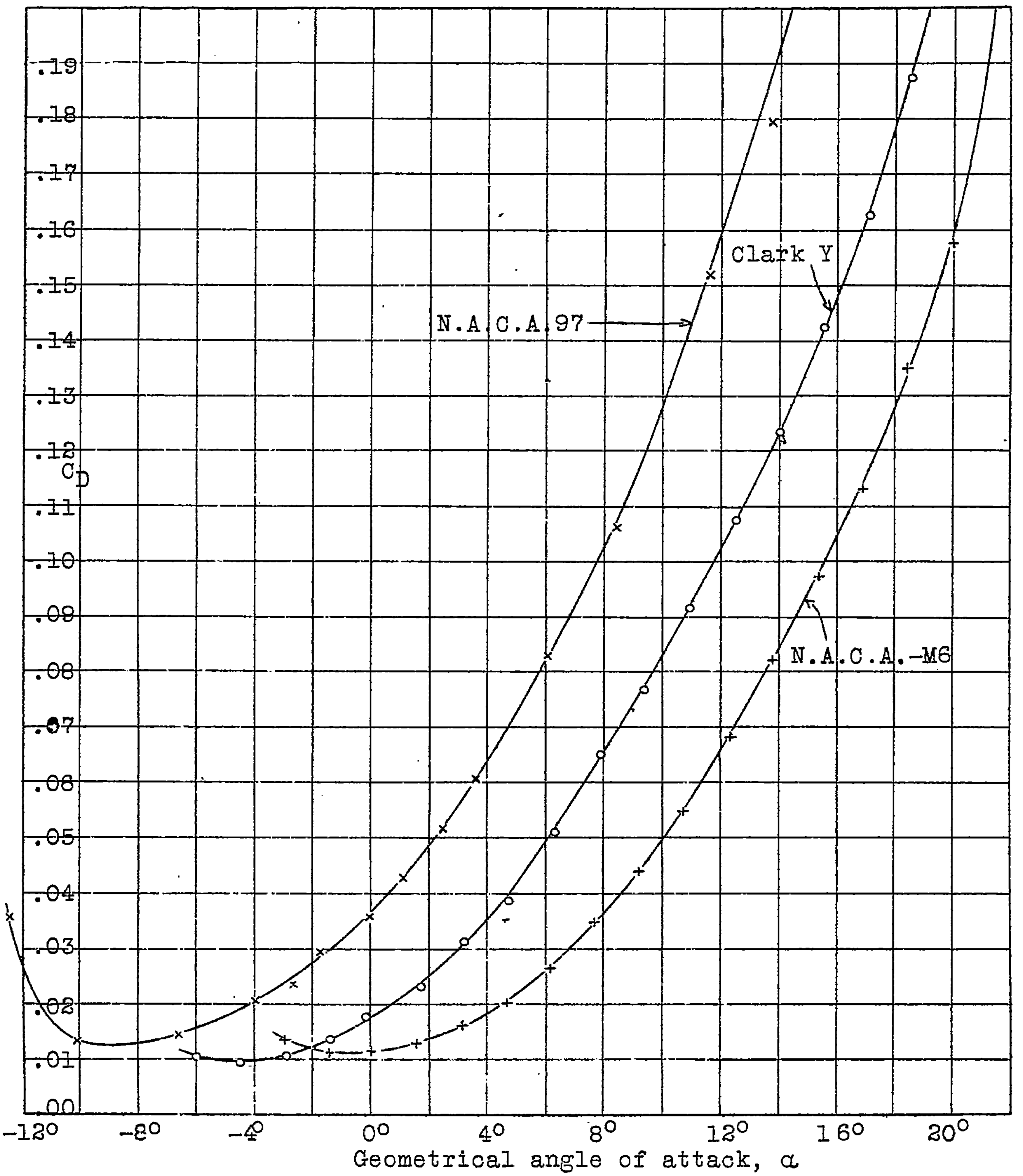


Fig.4.

Corrected for effect of tunnel walls.

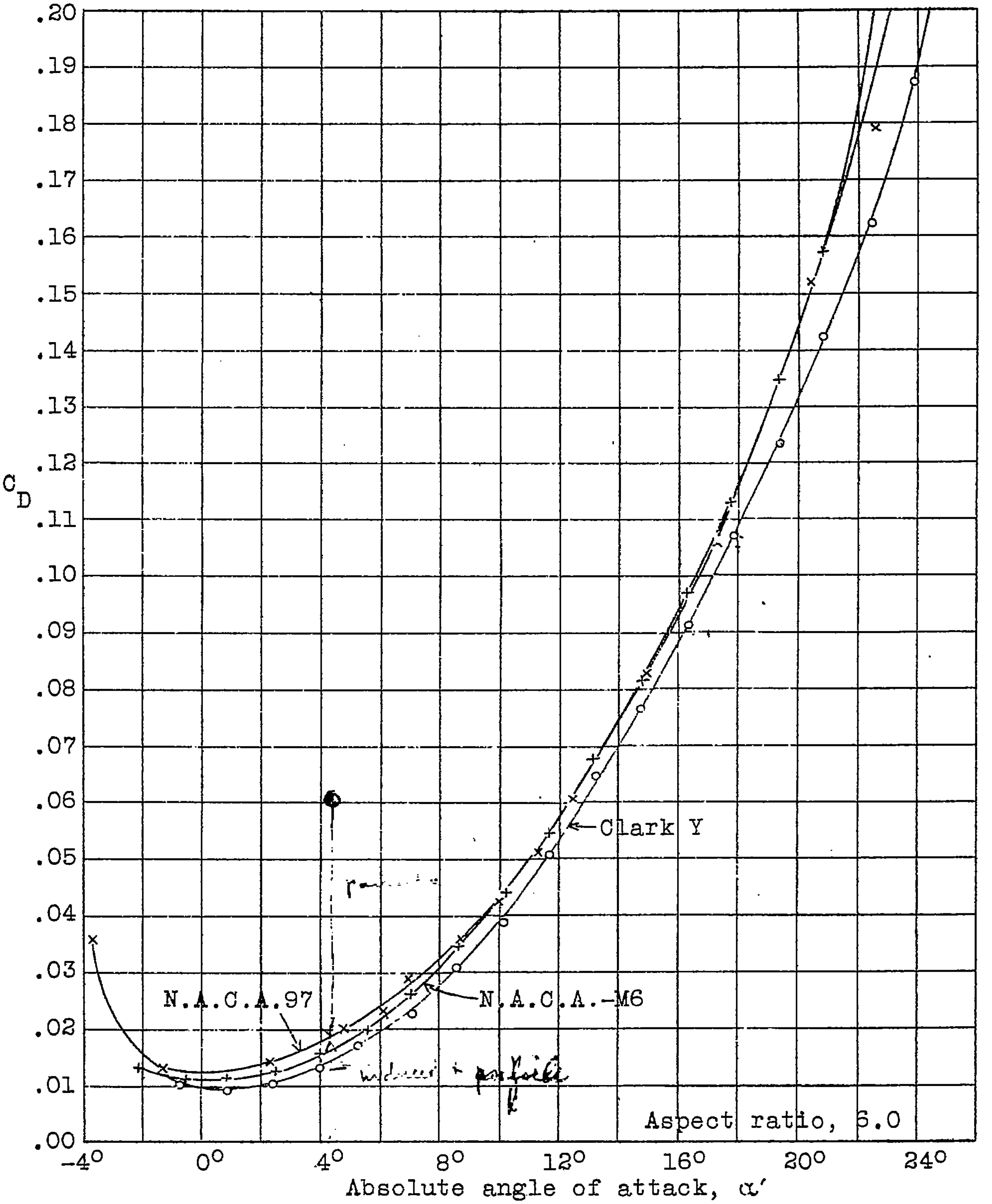

.20
.19
.18
.17
.16
.15
.14
.13
.12
C_D
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
Clark Y
N.A.C.A.97
N.A.C.A.-M6
Aspect ratio, 6.0
-4°
0°
4°
8°
12°
16°
20°
24°
Absolute angle of attack, α′

Fig.5.

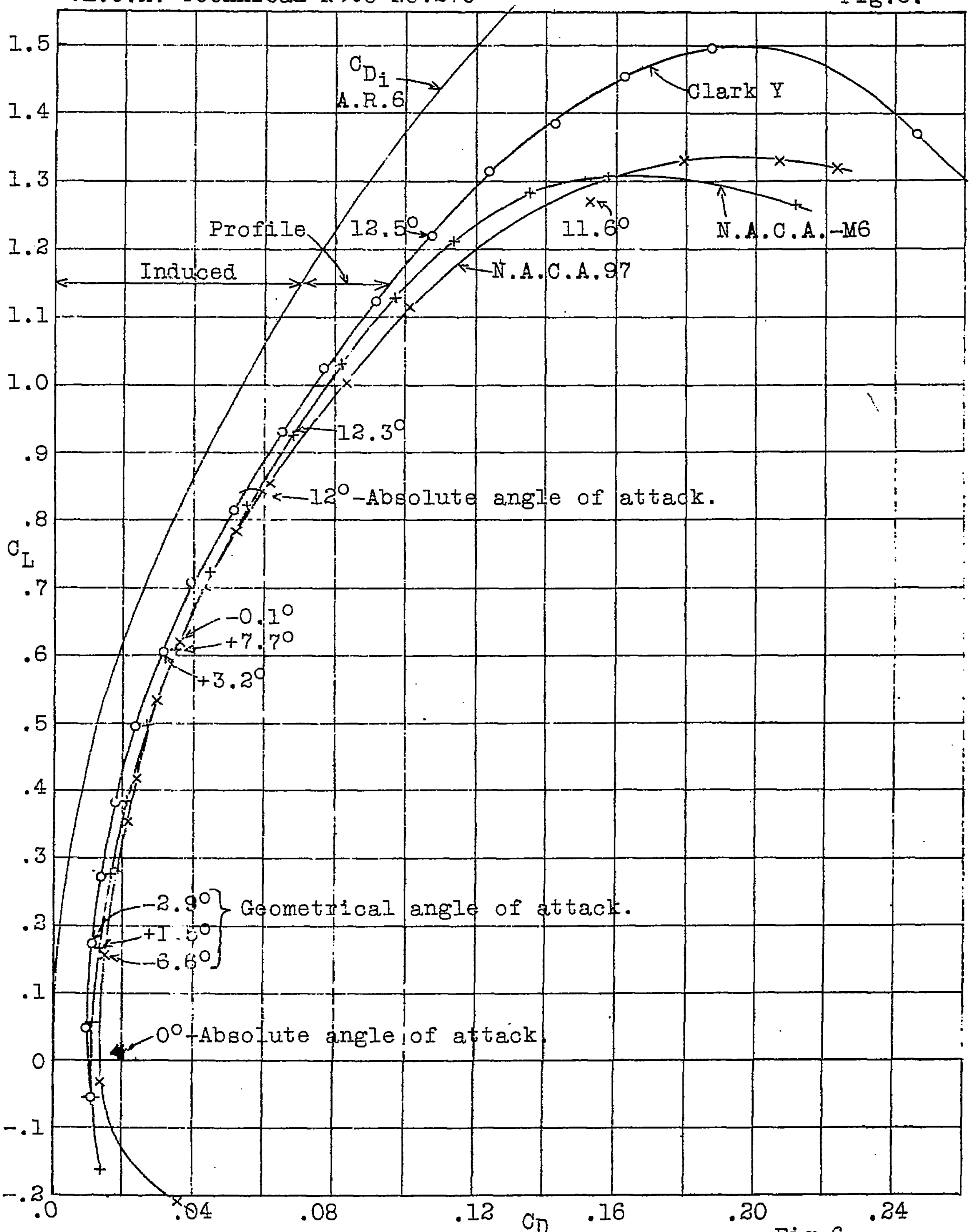

1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
C_L
.0
.04
.08
.12
.16
.20
.24
C_D
C_{D_i}
A.R.6
Clark Y
Profile
12.5°
11.6°
N.A.C.A.-M6
Induced
N.A.C.A.97
12.3°
12°-Absolute angle of attack.
-0.1°
+7.7°
+3.2°
-2.9°
+1.5°
-6.6°
Geometrical angle of attack.
0°-Absolute angle of attack.

Fig.6.

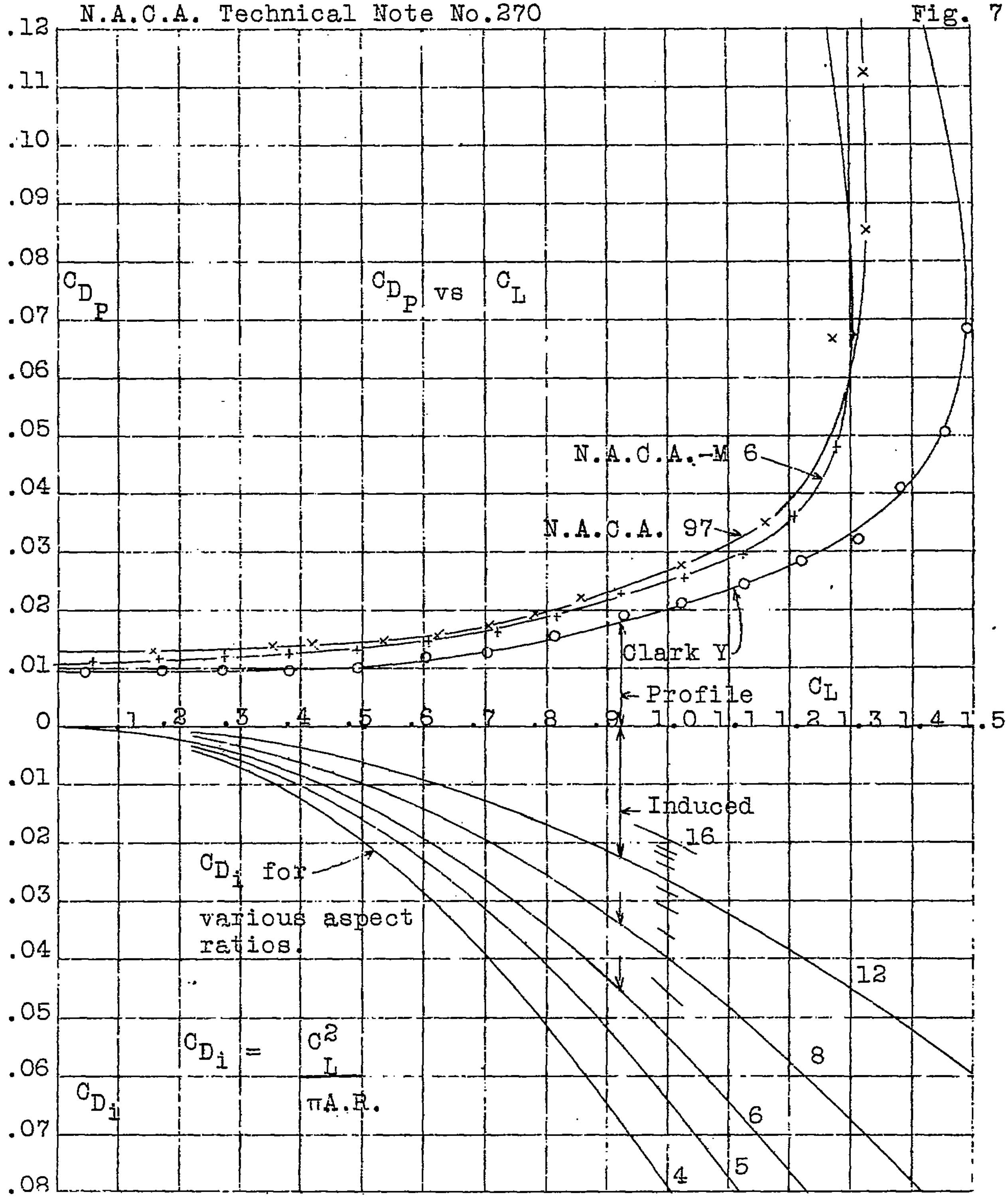

C_{D_P} vs C_L
C_{D_P}
N.A.C.A.-M 6
N.A.C.A. 97
Clark Y
Profile
C_L
Induced
16
C_{D_i} for various aspect ratios.
12
8
6
5
4
$C_{D_i} = \frac{C_L^2}{\pi A.R.}$
C_{D_i}
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5

Fig.7

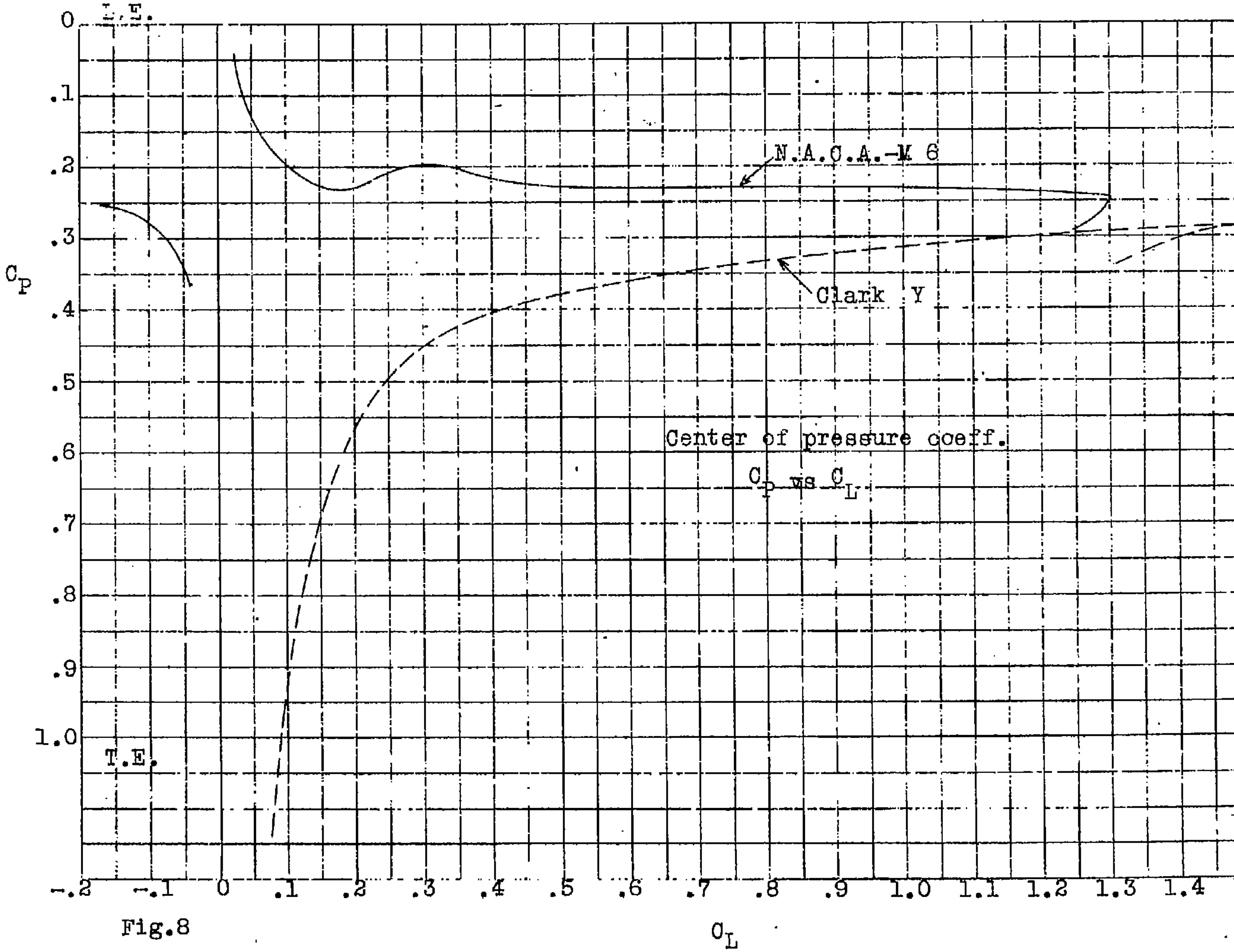

L.E.
T.E.
C_P
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
N.A.C.A.-M 6
Clark Y
Center of pressure coeff.
C_P vs C_L
-.2
-.1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
C_L

Fig.8