TO: Library L.M.A.L.

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 294

WIND TUNNEL FORCE TESTS IN WING SYSTEMS THROUGH LARGE ANGLES OF ATTACK

By Carl J. Wenzinger and Thomas A. Harris
Langley Memorial Aeronautical Laboratory

Washington
August, 1928

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 294.

WIND TUNNEL FORCE TESTS IN WING SYSTEMS THROUGH LARGE ANGLES OF ATTACK.

By Carl J. Wenzinger and Thomas A. Harris.

Summary

Force tests on a systematic series of wing systems over a range of angle of attack from minus forty-five degrees to plus ninety degrees are covered in this report. The investigation, conducted in the atmospheric wind tunnel of the Langley Memorial Aeronautical Laboratory, was made on monoplane and biplane wing models to determine the effects of variations of tip shape, aspect ratio, flap setting, stagger, gap, decalage, sweep back, and airfoil profile. Effects produced by the variables are given in a preliminary form by a series of comparative curves, to be followed at a later date by a complete report on the tests.

Introduction

Incidental to securing data on the autorotational characteristics of a series of wing systems, force tests were conducted over a large range of angle of attack. Since little information has been made available with respect to the behavior of wing systems at large angles of attack, the results of these force tests are presented herewith in preliminary form, in order that the data may become immediately available.

The results provide valuable data because the large range of angle of attack covers practically all attitudes attainable by an airplane in flight, and the models tested are representative of several types of wing systems in common use to-day.

Models and Tests

The wing models were of five-inch chord and aspect ratio six, except as noted below. They had the Clark Y profile in all but a few tests in which the N.A.C.A. M1 profile was used. Except to show tip effects, circular tipped models were used throughout the tests. All tests were conducted at the Langley Memorial Aeronautical Laboratory in the five-foot atmospheric wind tunnel which has a circular closed throat test section. The models were mounted in the wind tunnel on the usual wire balance as shown in Figure 1.

The tests were arranged to enable determination of the effects produced by the following variations in the geometry of the wing systems:

Monoplane Wings

A. Tip. (Figures 2, 3)

(1) Rectangular

(2) Negative rake

(3) Circular

Monoplane Wings (Cont.)

B. Aspect Ratio. (Figures 4, 5)

(1) Four

(2) Six

(3) Eight

C. Flap Setting. (Figures 6, 7. Trailing edge flap 20 per cent of chord.)

(1) 15 degrees up

(2) 0 degrees

(3) 15 degrees down

(4) 25 degrees down

(5) 30 degrees down

D. Profile. (Figures 8, 9. Monoplane wing comparison.)

(1) Clark Y

(2) N.A.C.A.-M1

Biplane Wing Systems

E. Stagger. (Figures 10, 11)

(1) -25 per cent

(2) 0

(3) +25 per cent

(4) +50 per cent

F. Gap. (Figures 12, 13)

(1) Gap/chord = 1.5

(2) Gap/chord = 1.0

(3) Gap/chord = 0.5

Biplane Wing Systems (Cont.)

G. Decalage. (Figures 14, 15)

(1) +3 degrees

(2) 0 degrees

(3) -3 degrees

H. Sweep back. (Figures 16, 17. 10 degrees swept-back wing used with straight wing.)

(1) Upper wing swept back, midspan stagger 0 per cent

(2) Lower wing swept back, midspan stagger 0 per cent

(3) Upper wing swept back, midspan stagger +50 per cent

(4) Lower wing swept back, midspan stagger -50 per cent

I. Profile. (Figures 18, 19. Biplane wing comparison.)

(1) Upper wing - Clark Y

Lower wing - Clark Y

(2) Upper wing - Clark Y

Lower wing - N.A.C.A.-M1

(3) Upper wing - N.A.C.A.-M1

Lower wing - Clark Y

Lift and drag forces were measured for angles of attack ranging from -45 degrees to +90 degrees. Tests were conducted at a dynamic pressure of 20.05 kg per m², corresponding to an average air speed of 17.9 meters per second (40.0 M.P.H.), and an average Reynolds Number of 153,000.

All readings were corrected for the drag of the supporting system. The biplane strut drag was found to be negligible, and was therefore disregarded. Data were not corrected for tunnel wall and blocking effects, as the determination of these corrections for large angles of attack is a problem which requires extensive research.

Lift and drag forces were measured to within an accuracy of ±1.5 per cent. Airfoil ordinates of the wooden wing models were finished to the limits of ±.003 in.

Results

For purposes of direct comparison, the test results are presented in groups of curves, each group showing the effects of one of the variables previously listed. The curve groups, given in Figures 2 to 19, are arranged for each variable in two sections, the group of absolute lift and drag coefficients (C_L and C_D) versus angle of attack, and the polar curve group (C_L versus C_D).

The absolute coefficients C_L and C_D, were computed from

$$C_L = \frac{L}{q\ S}$$

$$C_D = \frac{D}{q\ S}$$

where L = lift

D = drag

q = dynamic pressure = $\frac{1}{2} \rho V^2$

ρ = mass density of air = 0.12497 ($kg - m^{-4}\ sec^2$) at 15°C and 760 mm = 0.002378 ($lb.-ft.^{-4}\ sec^2$).

V = velocity of air

S = total area of wing system,

all in consistent units.

Discussion

A general survey of the curves illustrates the considerable effects which changes in the arrangement of the wing systems have on the lift and drag characteristics, particularly at large angles of attack.

For the monoplanes, the most striking differences are due to changes in profile and in trailing edge flap angle, which produce large differences in maximum lift.

For the biplanes, large differences in drag for changes in stagger are notable. These drag variations are due to the shielding of the upper wing by the lower at large angles of attack.

More detailed discussion and conclusions will be included in a complete report to be presented at a later date.

C o n c l u s i o n s

The major changes in monoplane characteristics are produced by variations in profile and in trailing edge flap angle, and for the biplanes the effects of changes in stagger are noteworthy.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, June 25, 1928.

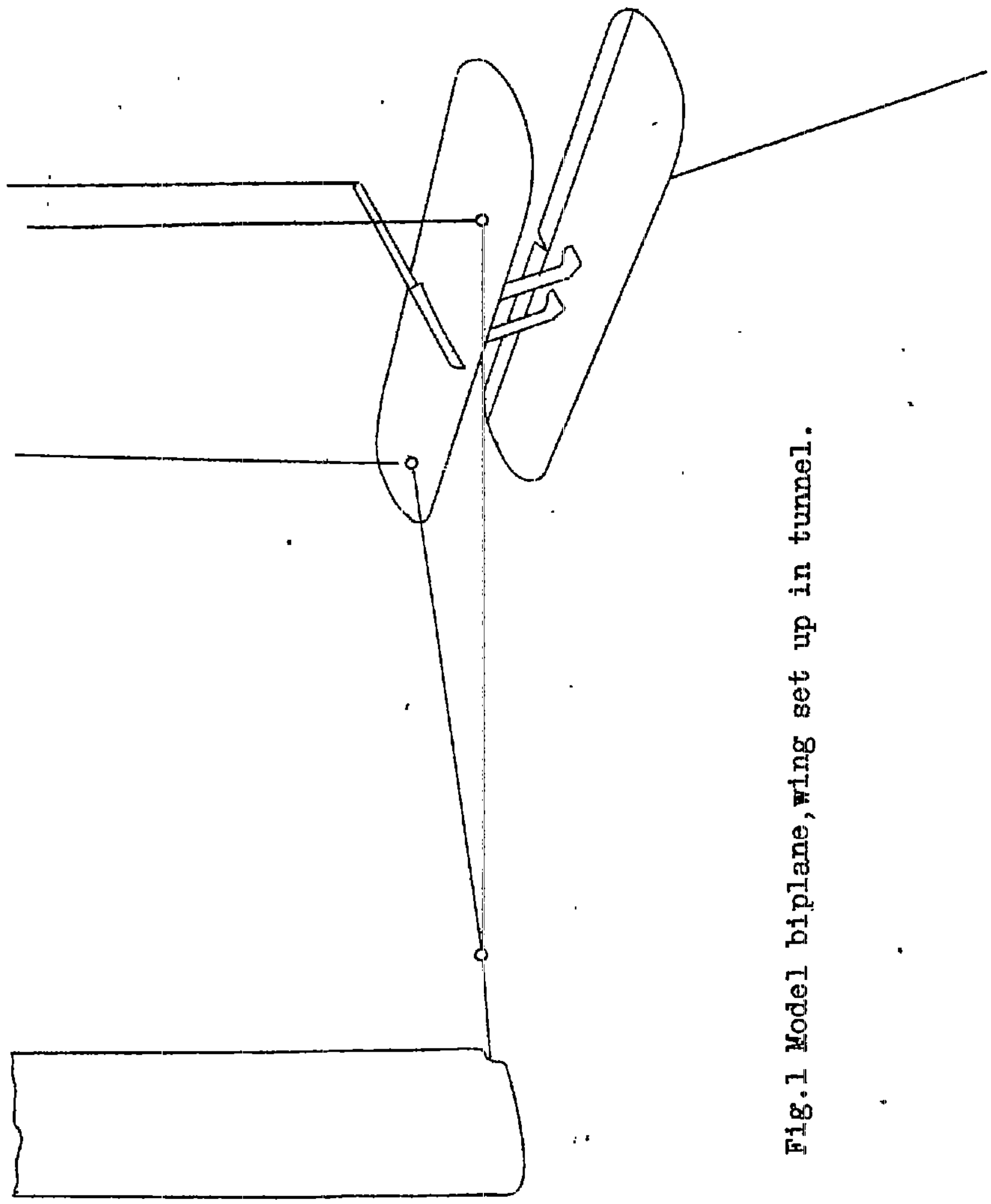


Fig.1 Model biplane, wing set up in tunnel.

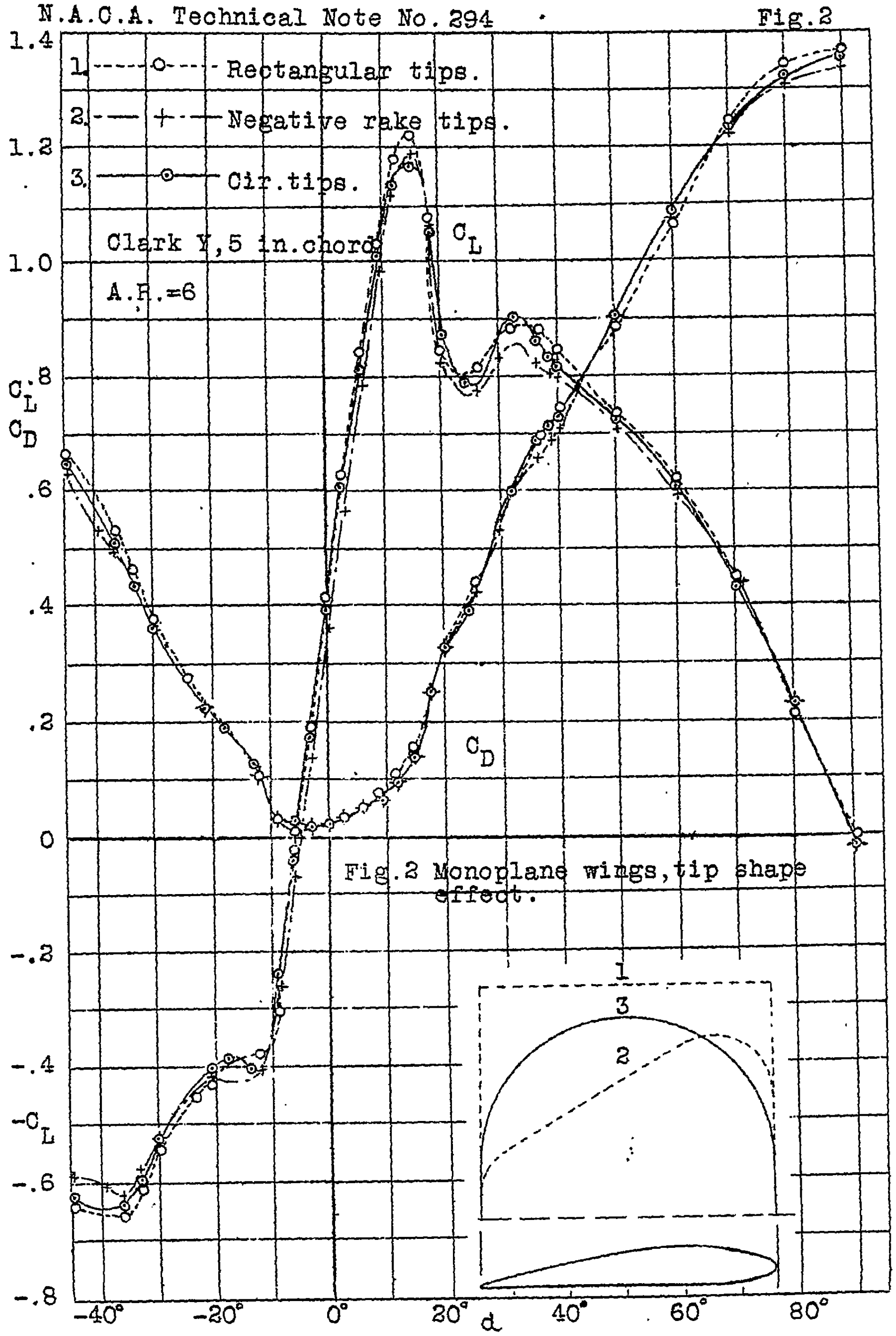


Fig.2 Monoplane wings,tip shape effect.

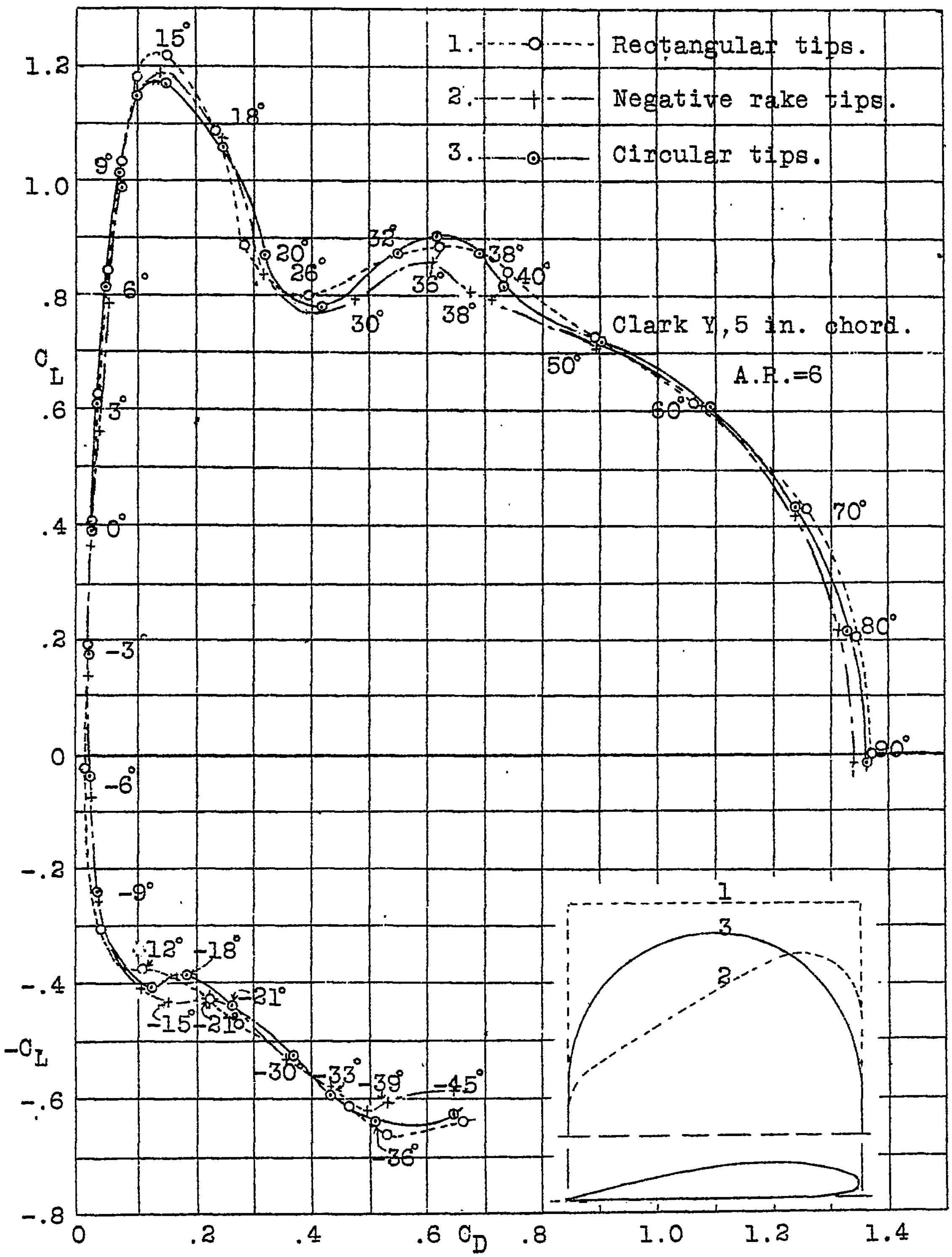


Fig.3 Monoplane wings,tip shape effect.

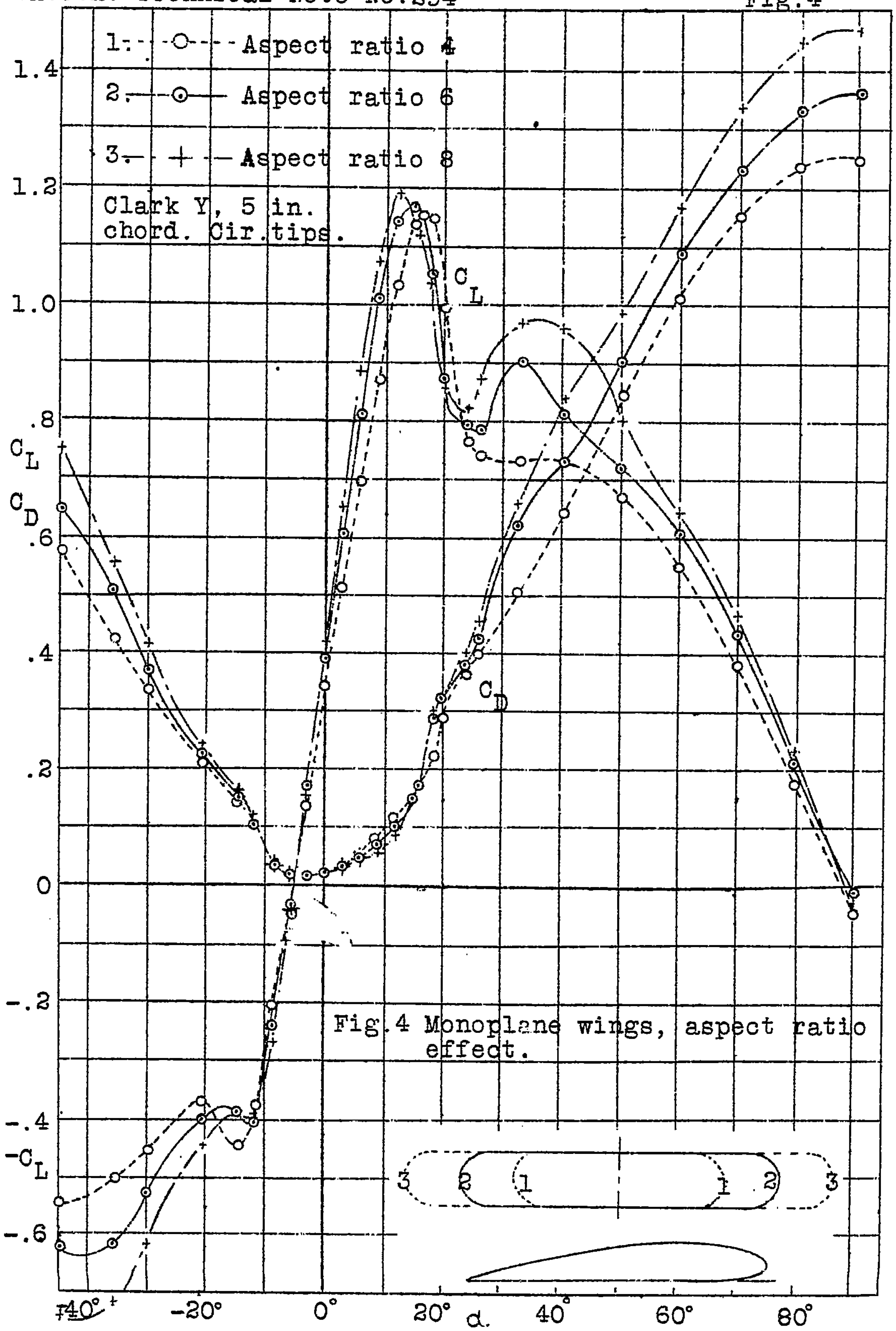


Fig.4 Monoplane wings, aspect ratio effect.

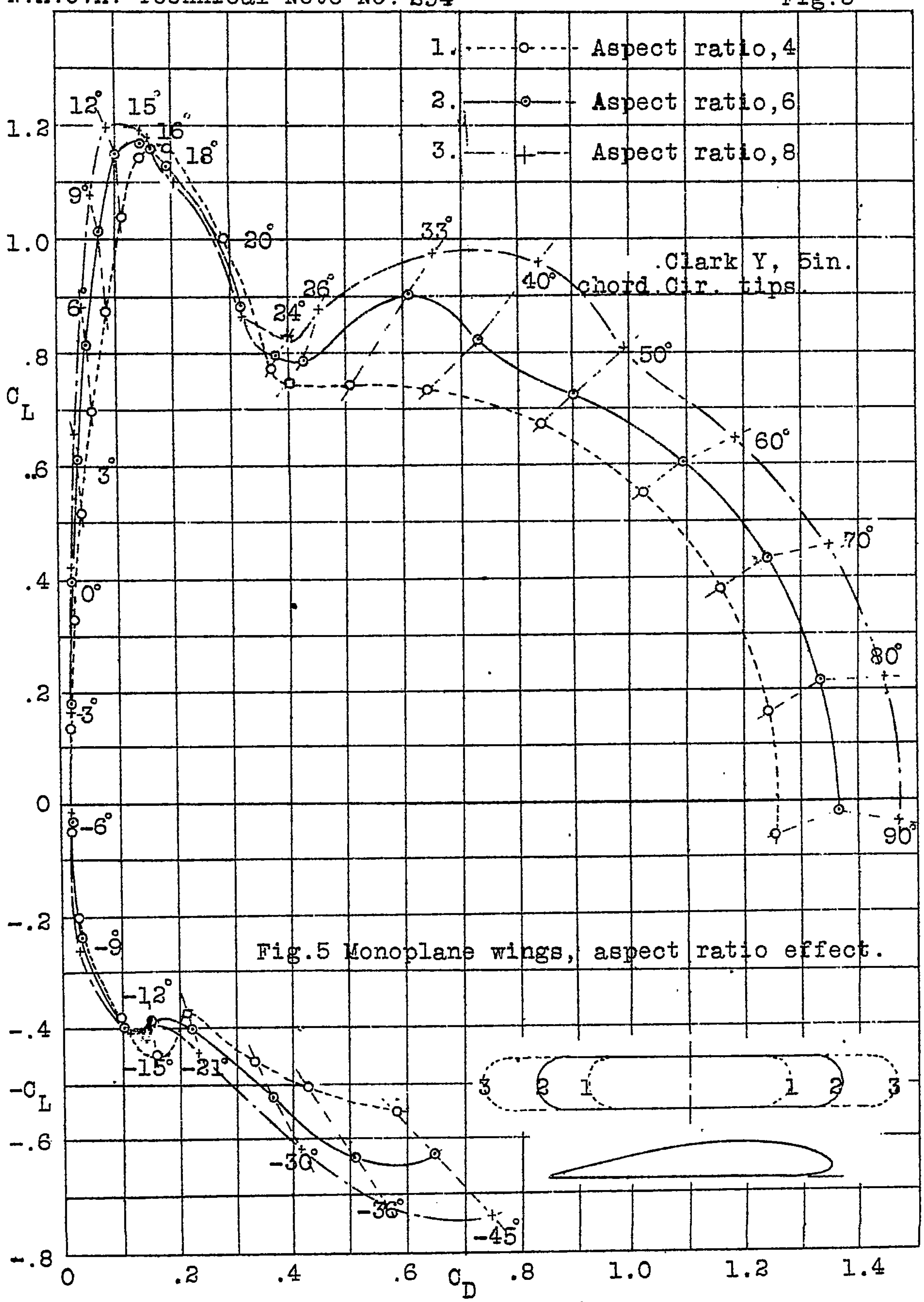


Fig.5 Monoplane wings, aspect ratio effect.

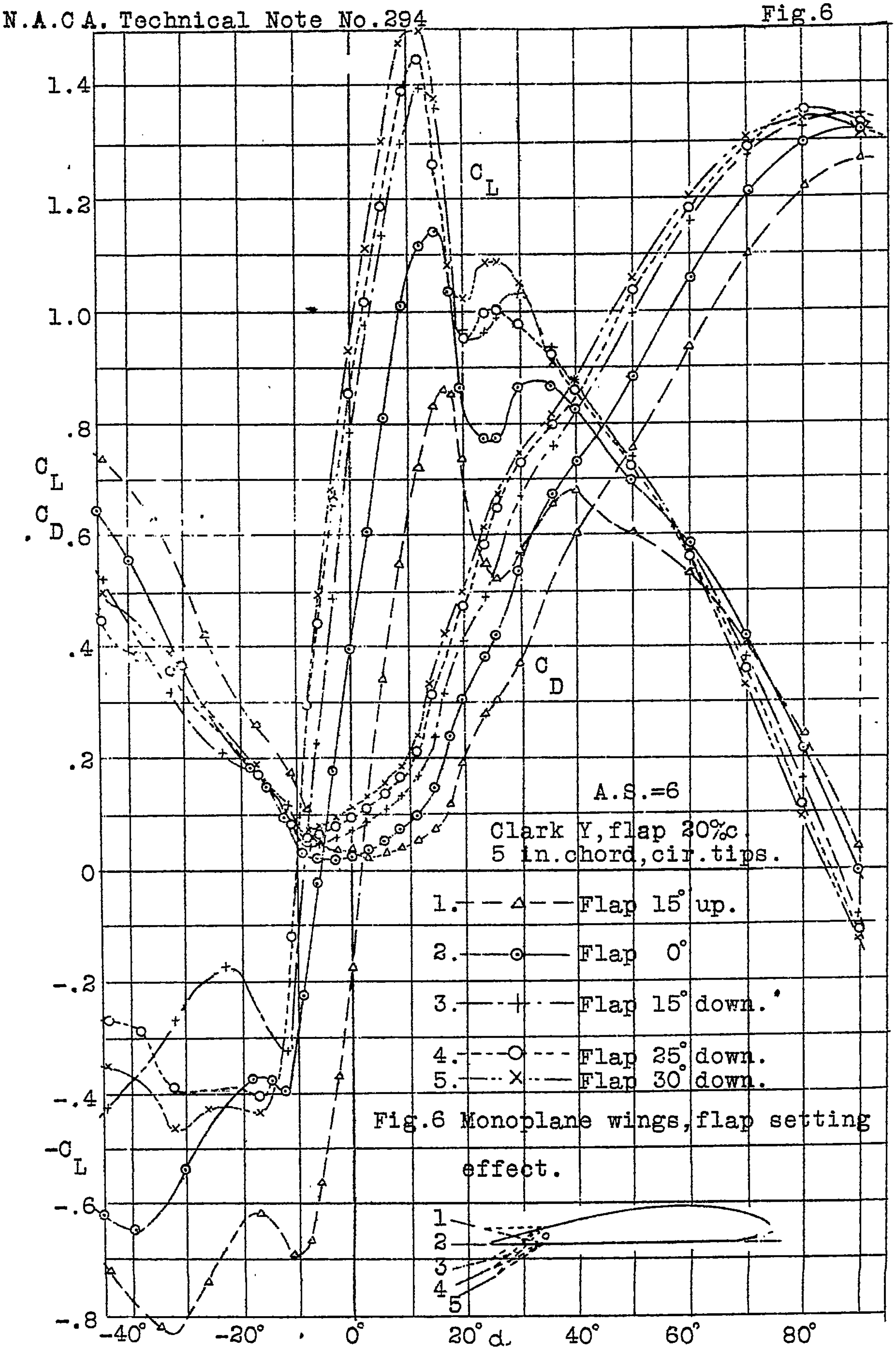
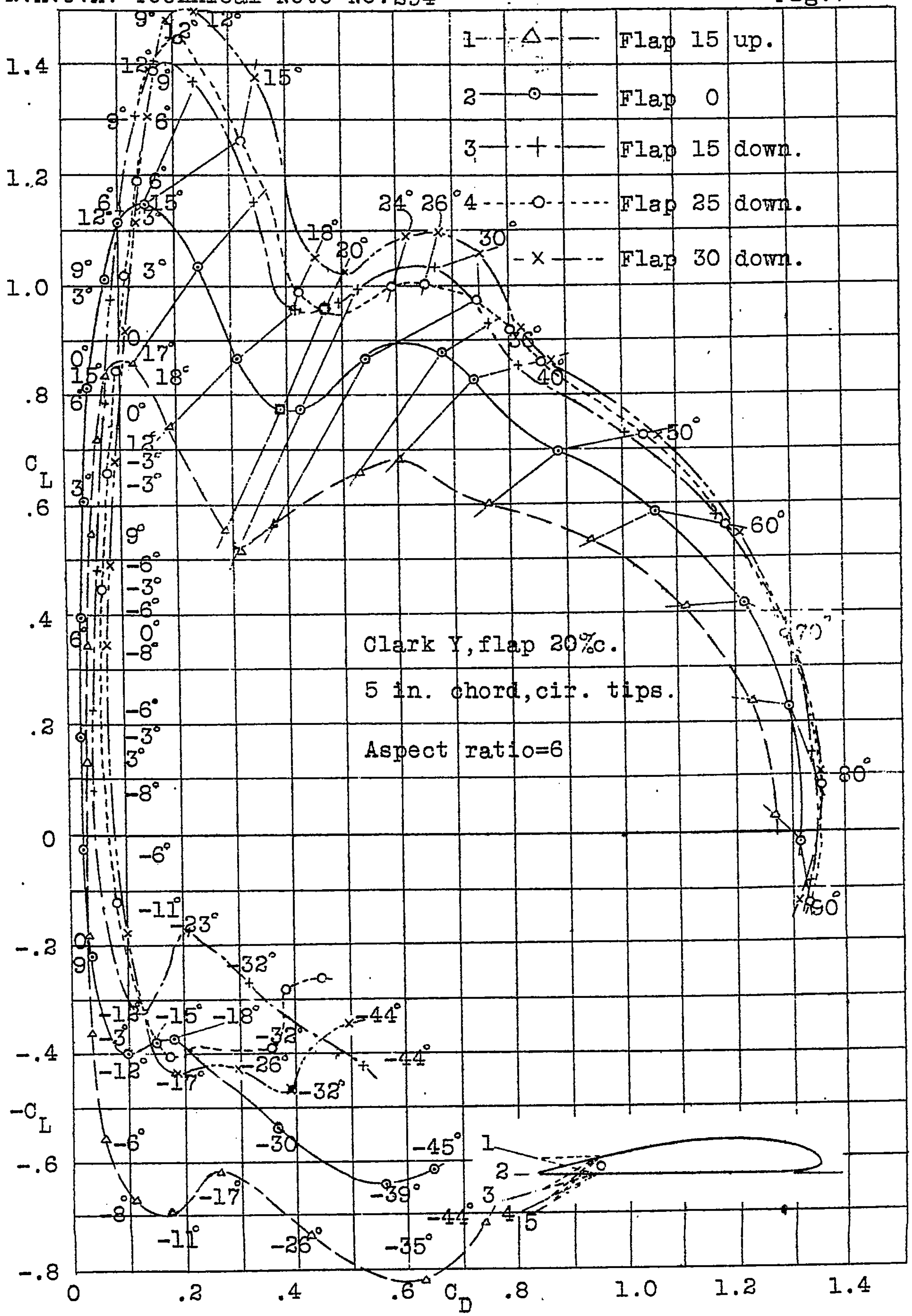


Fig.6 Monoplane wings, flap setting effect.


1 Flap 15 up.
2 Flap 0
3 Flap 15 down.
4 Flap 25 down.
Flap 30 down.
Clark Y, flap 20%c.
5 in. chord, cir. tips.
Aspect ratio=6
C_L
$-C_L$
C_D

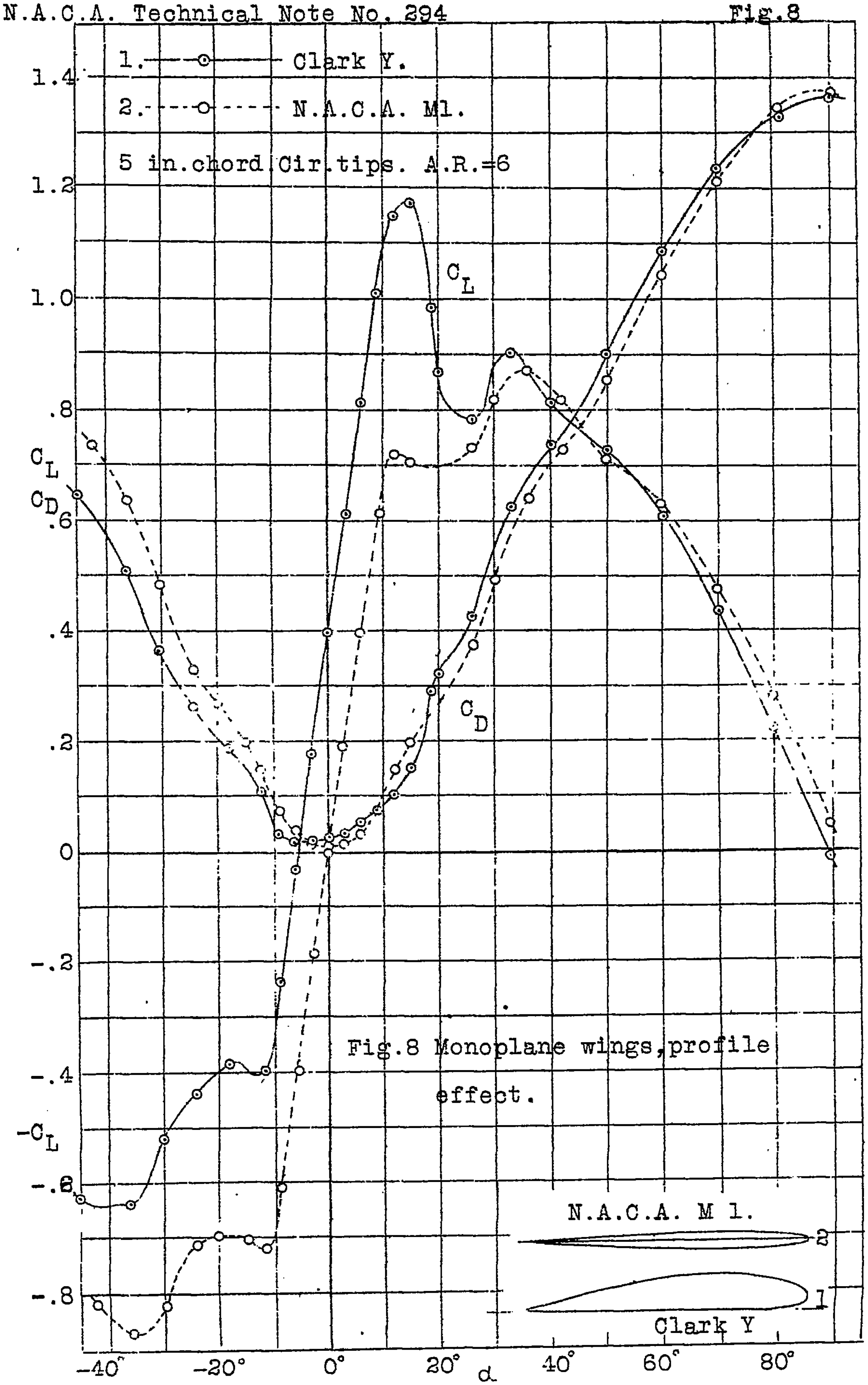


Fig.8 Monoplane wings, profile effect.

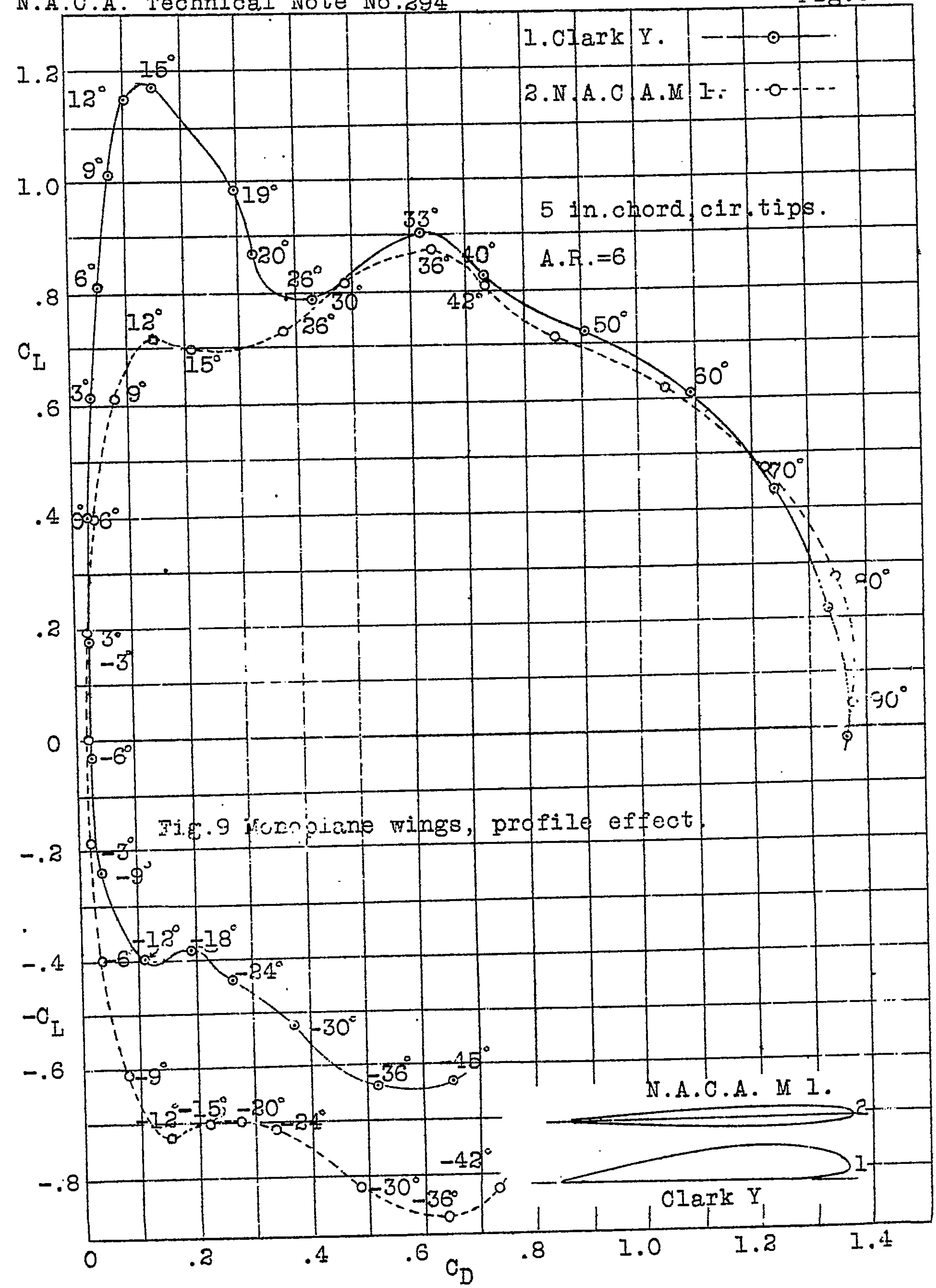


Fig.9 Monoplane wings, profile effect.

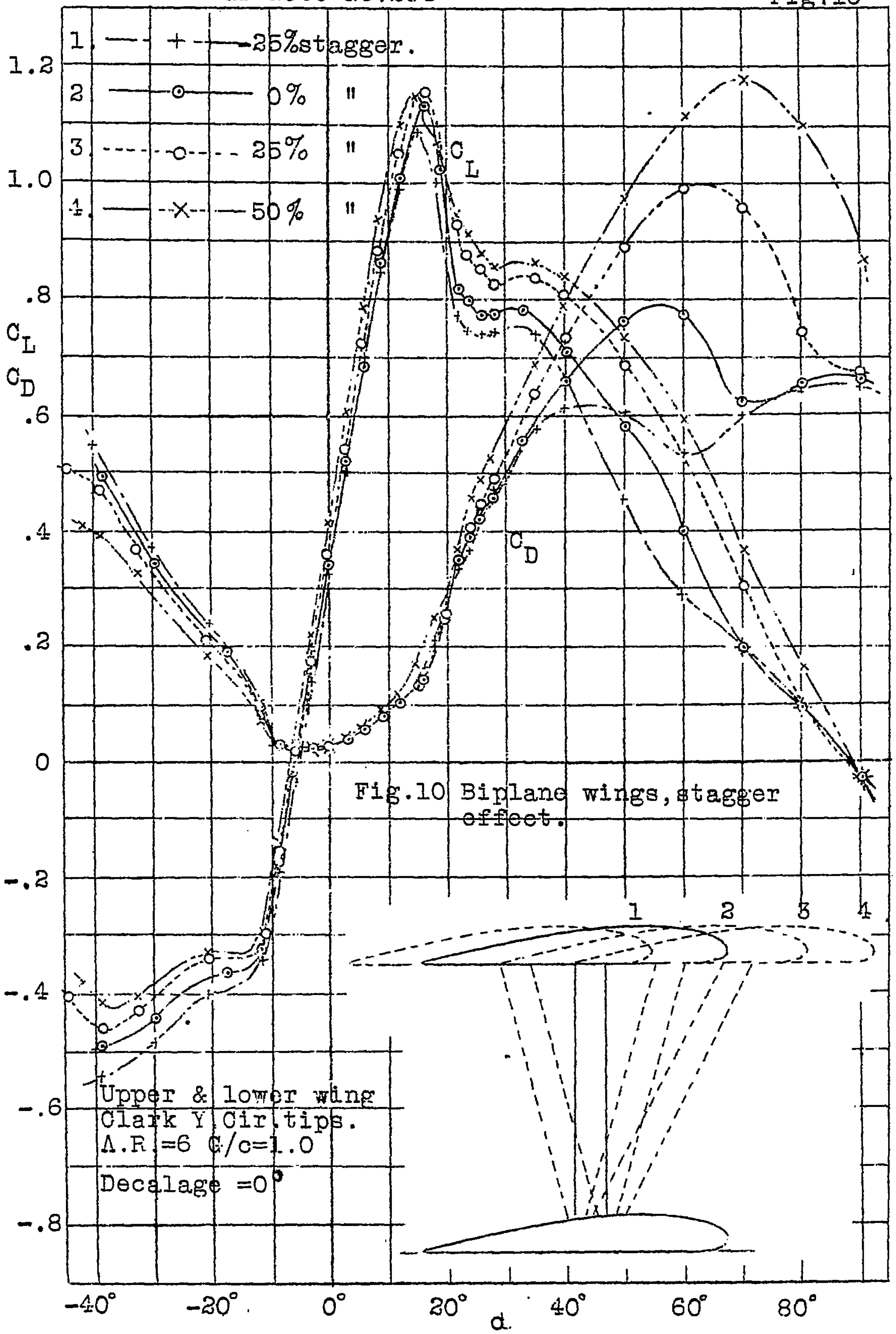


Fig.10 Biplane wings, stagger effect.

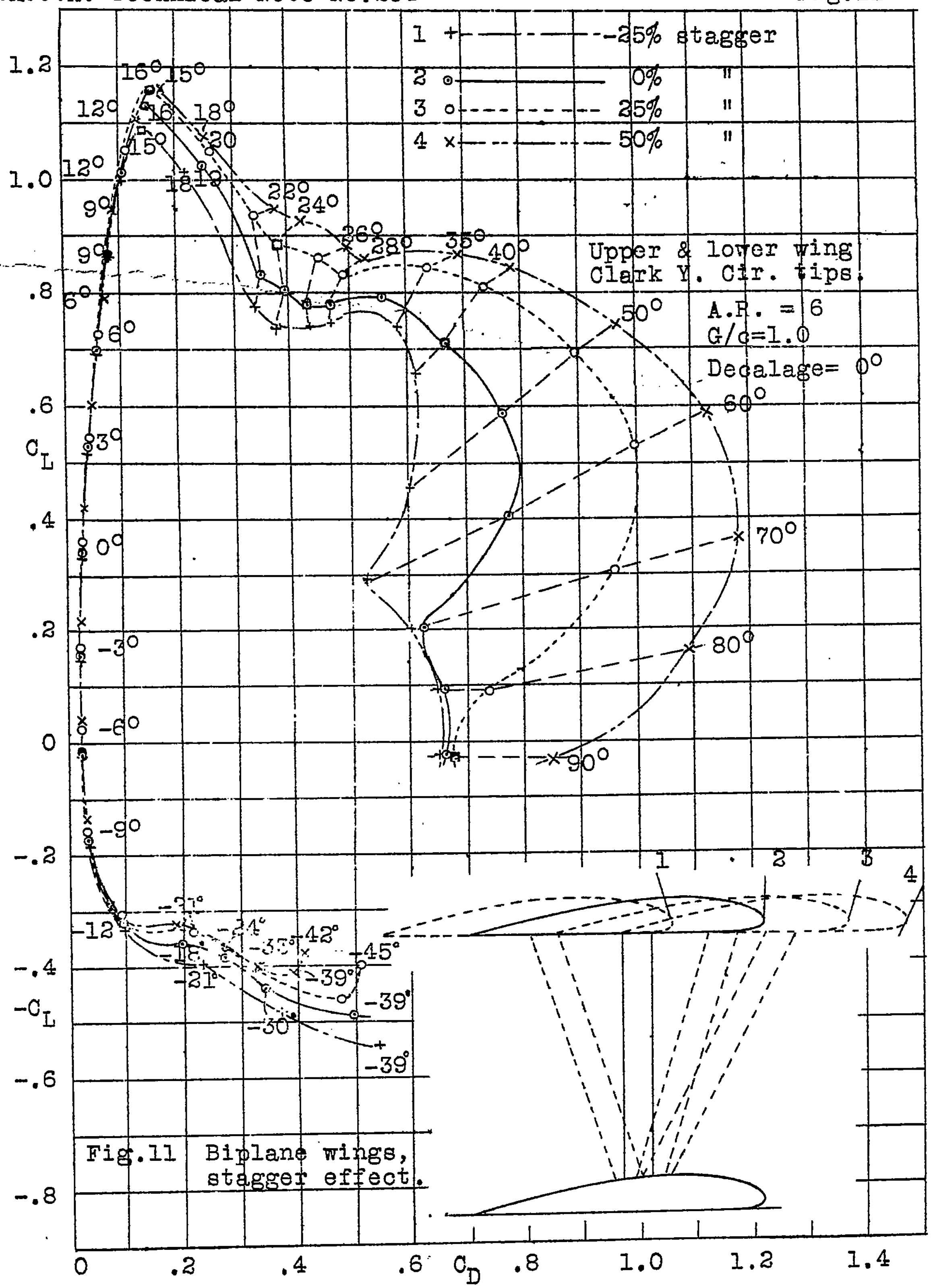


Fig.11 Biplane wings, stagger effect.

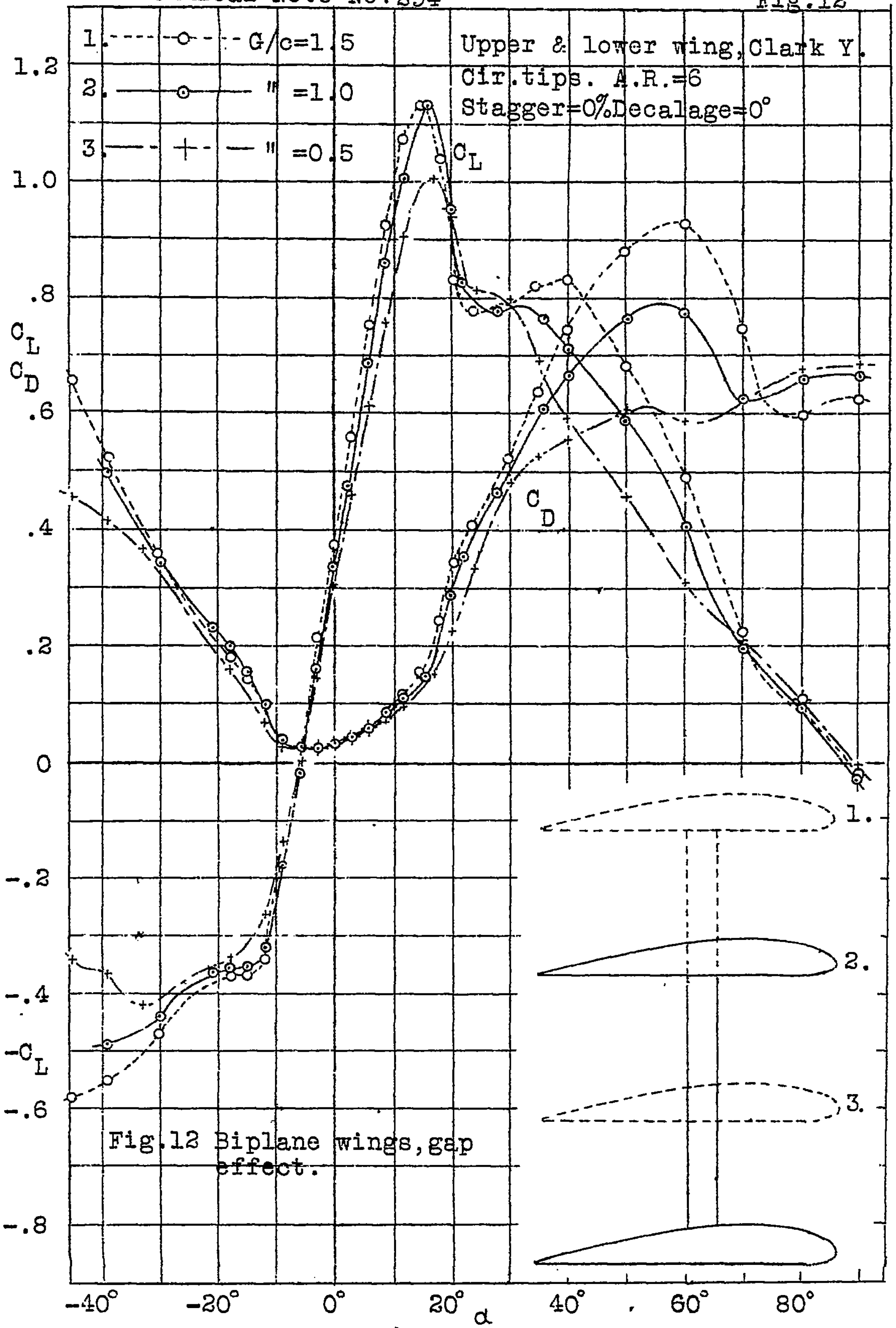


Fig.12 Biplane wings, gap effect.

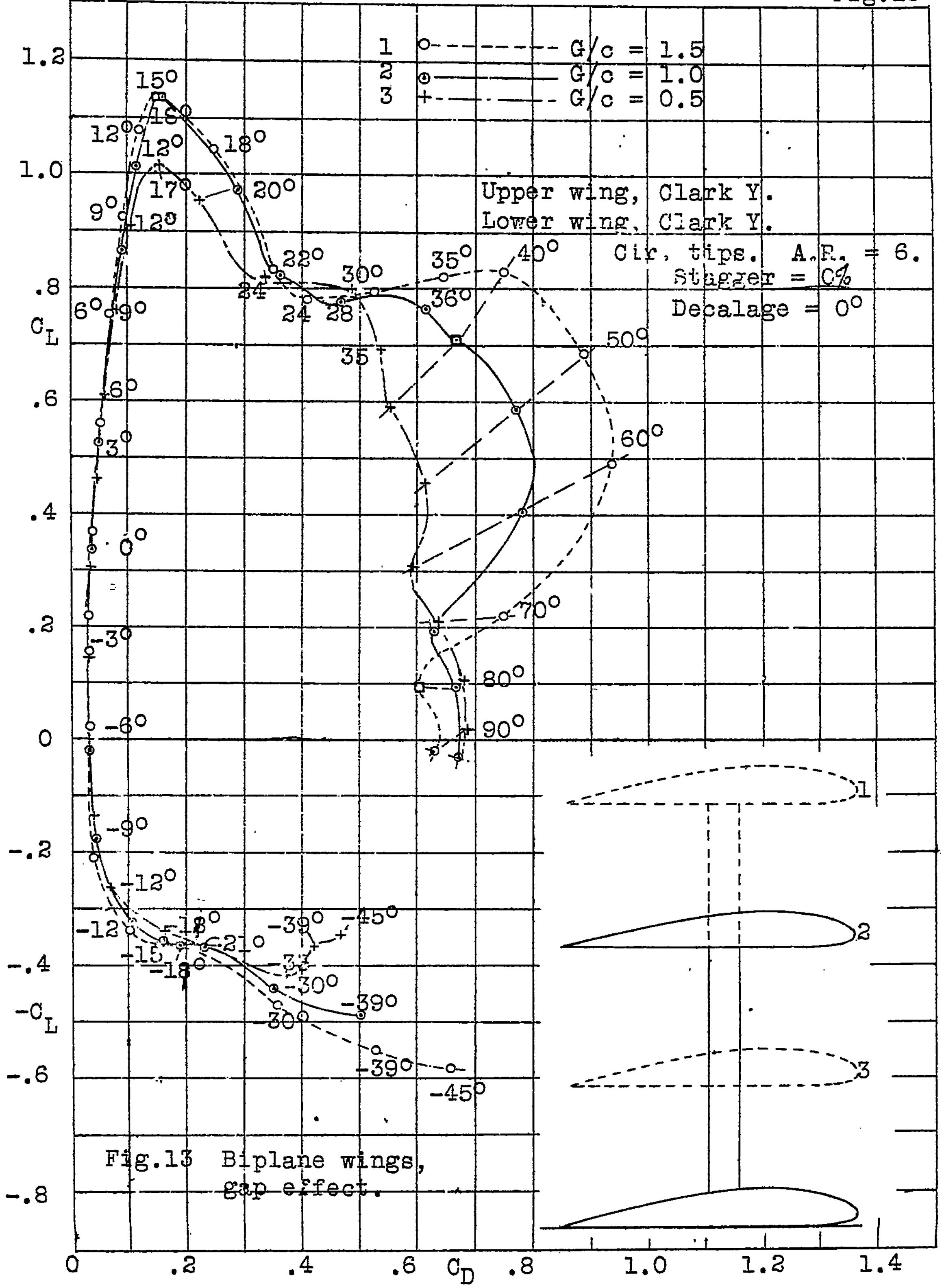


Fig.13 Biplane wings, gap effect.

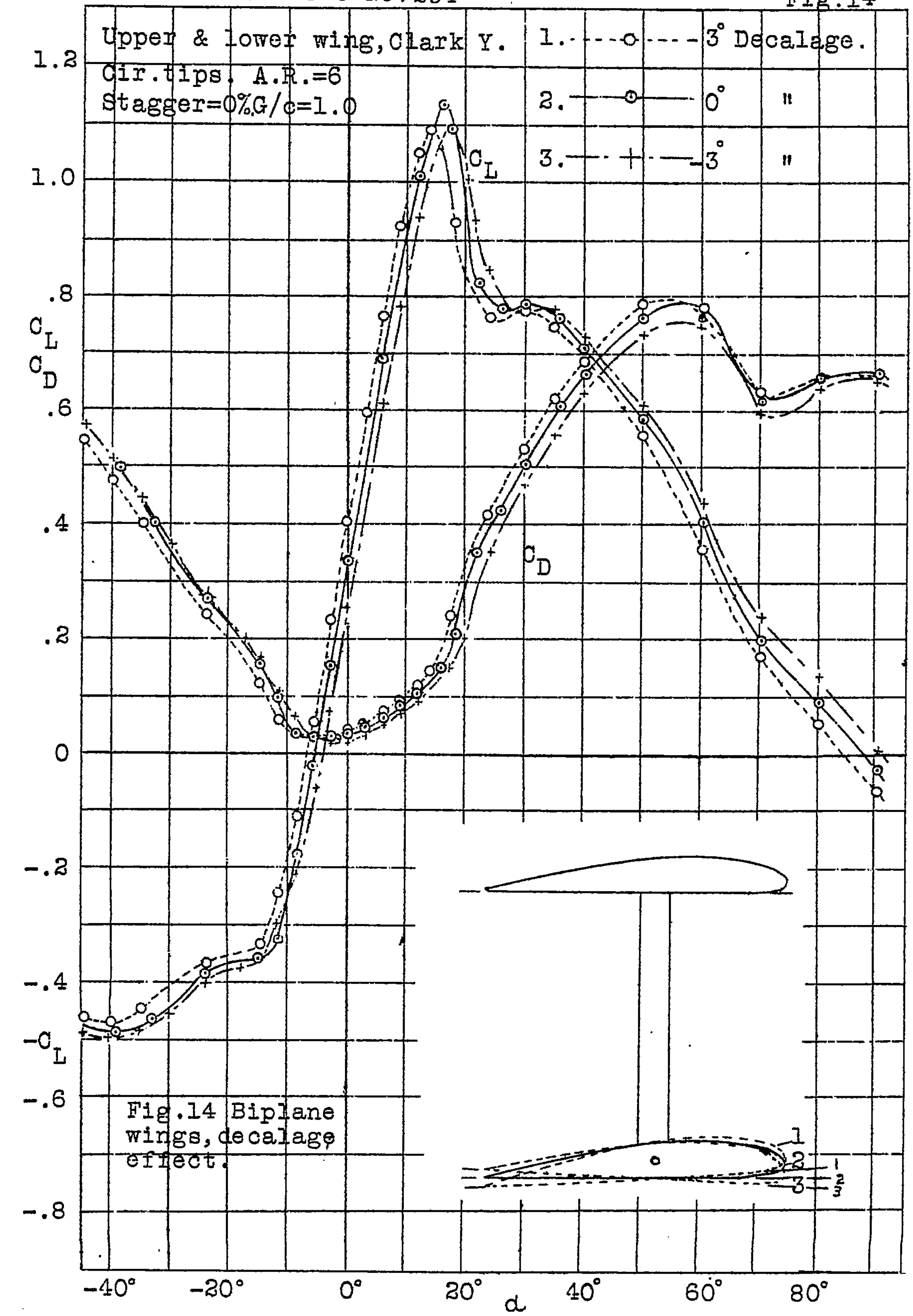


Fig.14 Biplane wings, decalage effect.

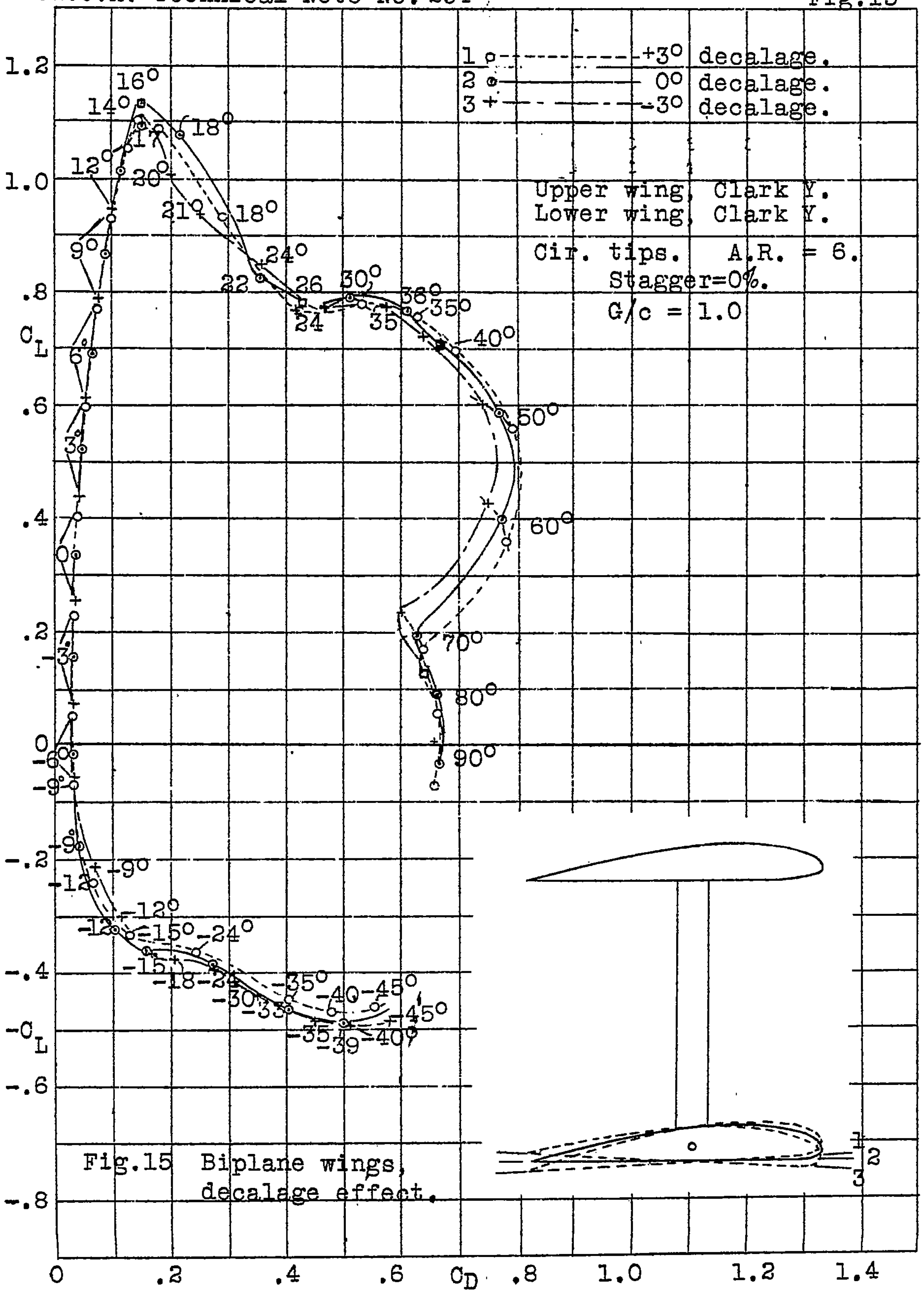


Fig.15 Biplane wings, decalage effect.

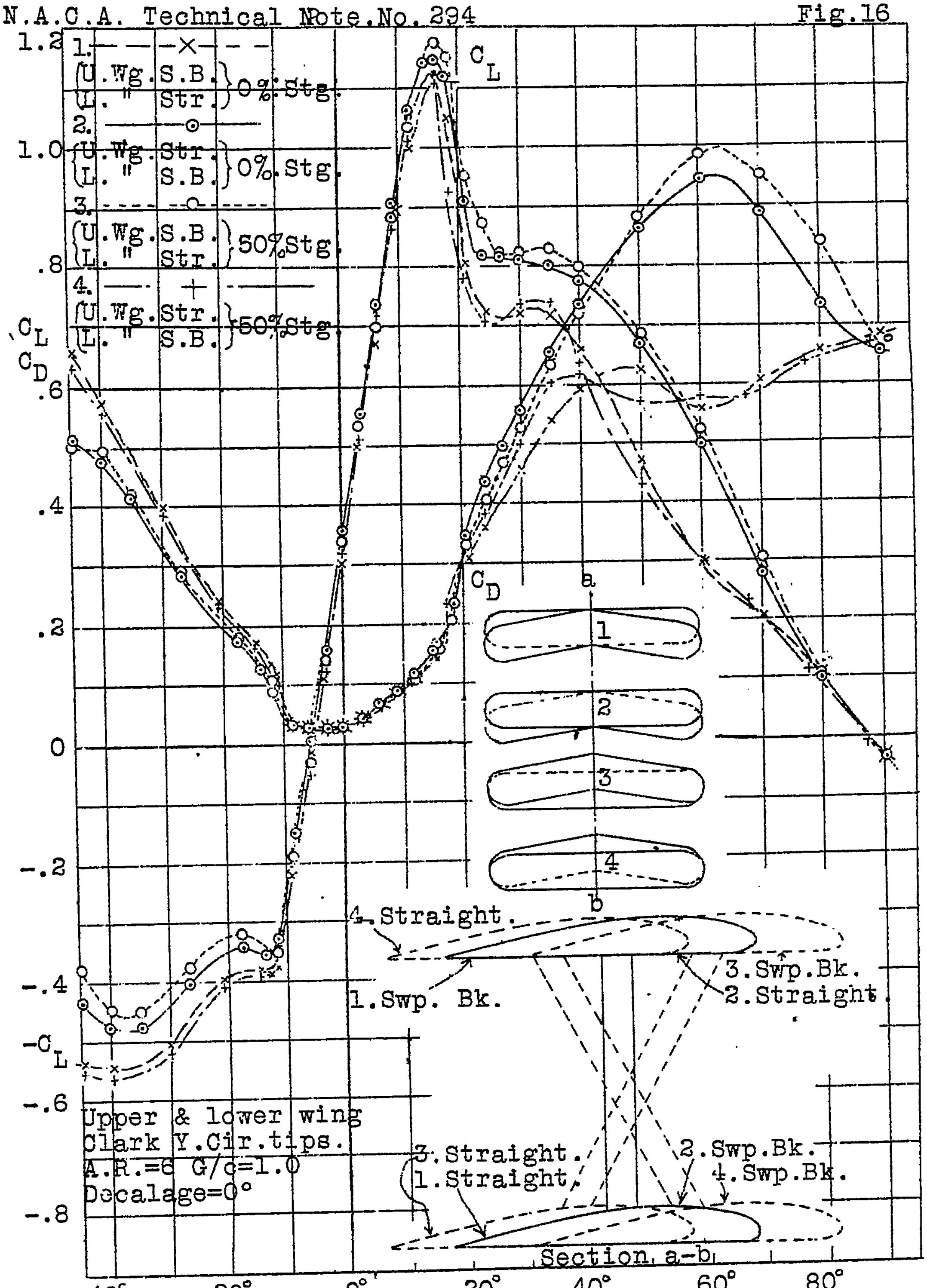


Fig.16 Biplane wings, sweepback wing effect.

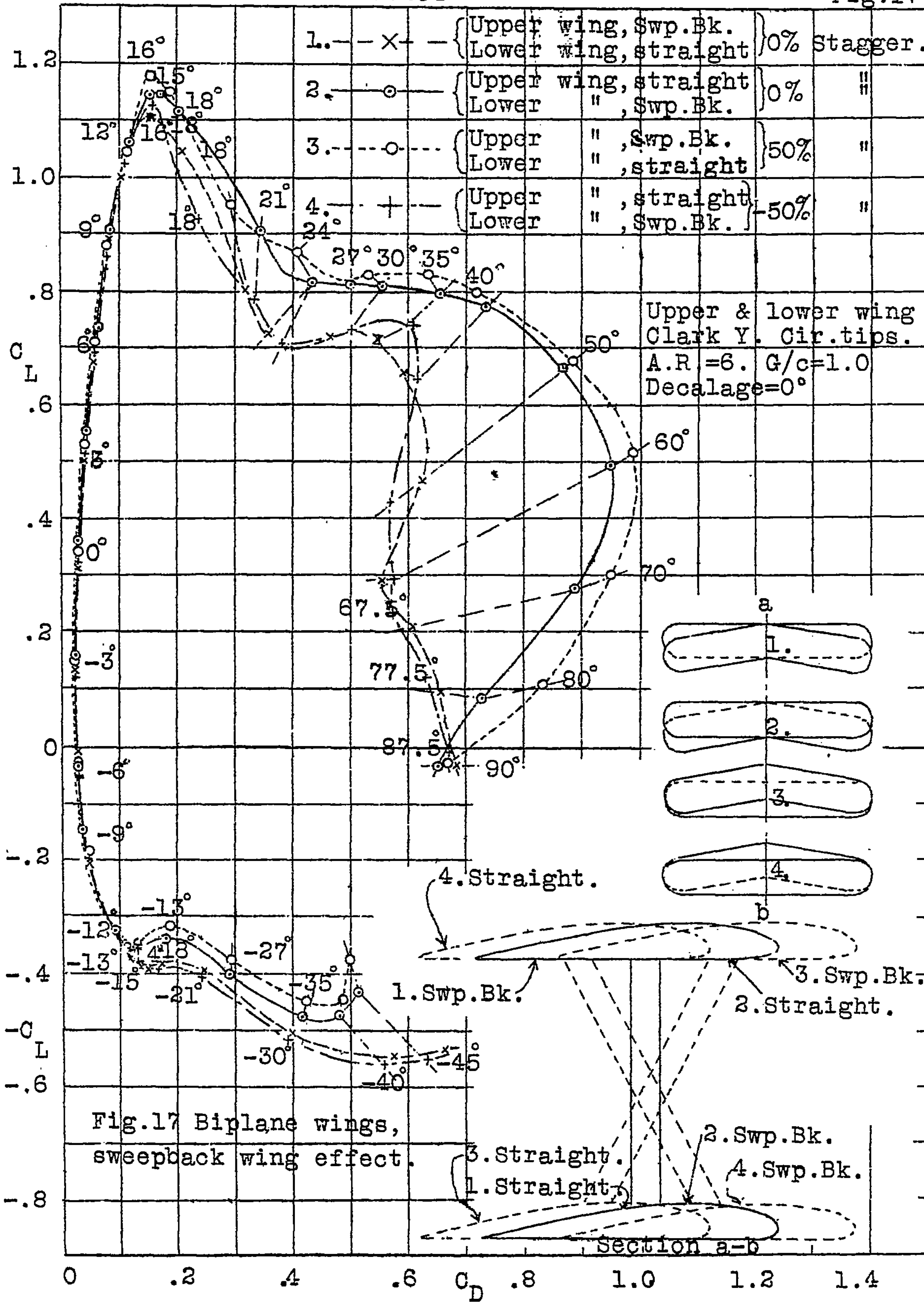


Fig.17 Biplane wings, sweepback wing effect.

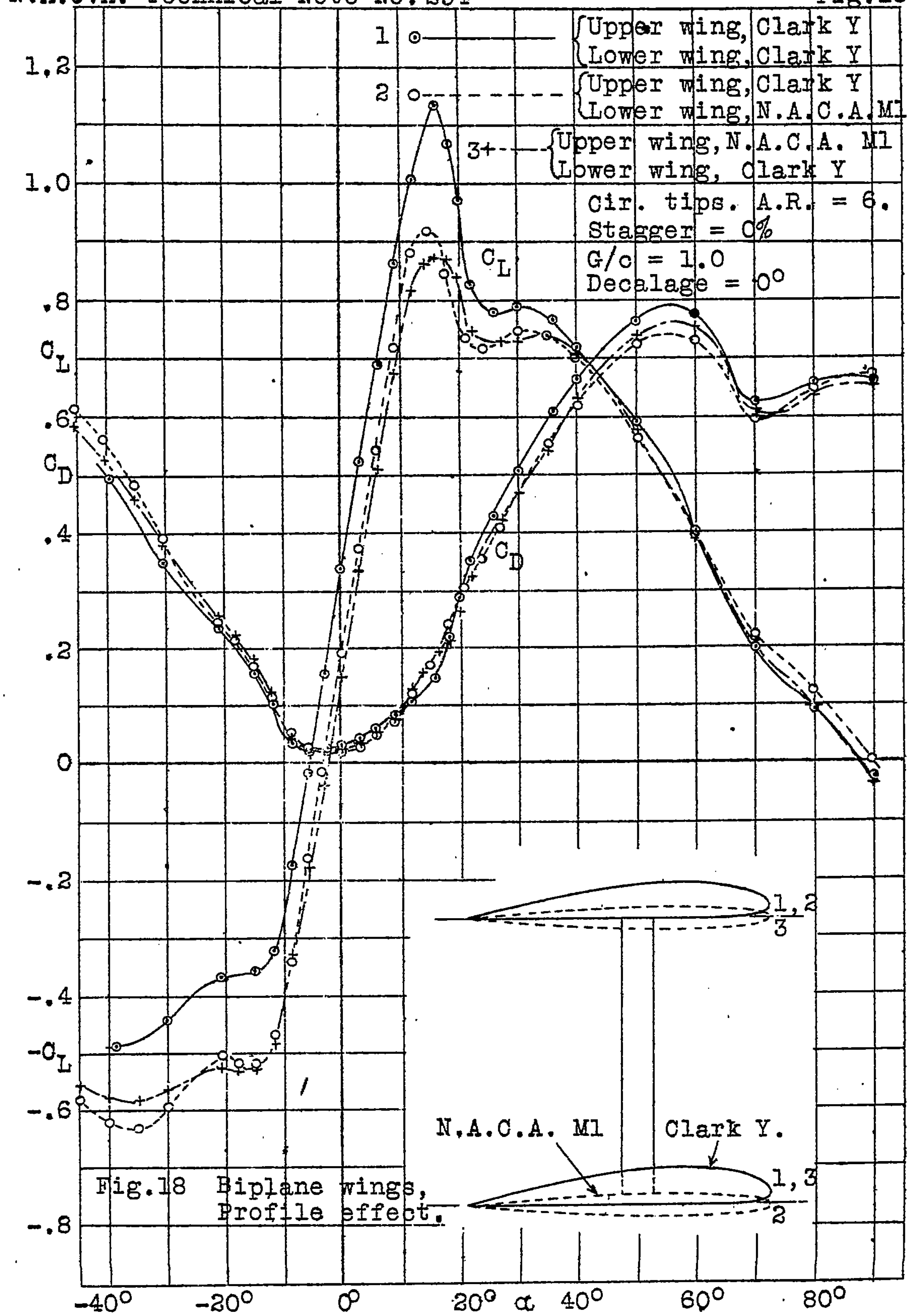


Fig. 18 Biplane wings, Profile effect.

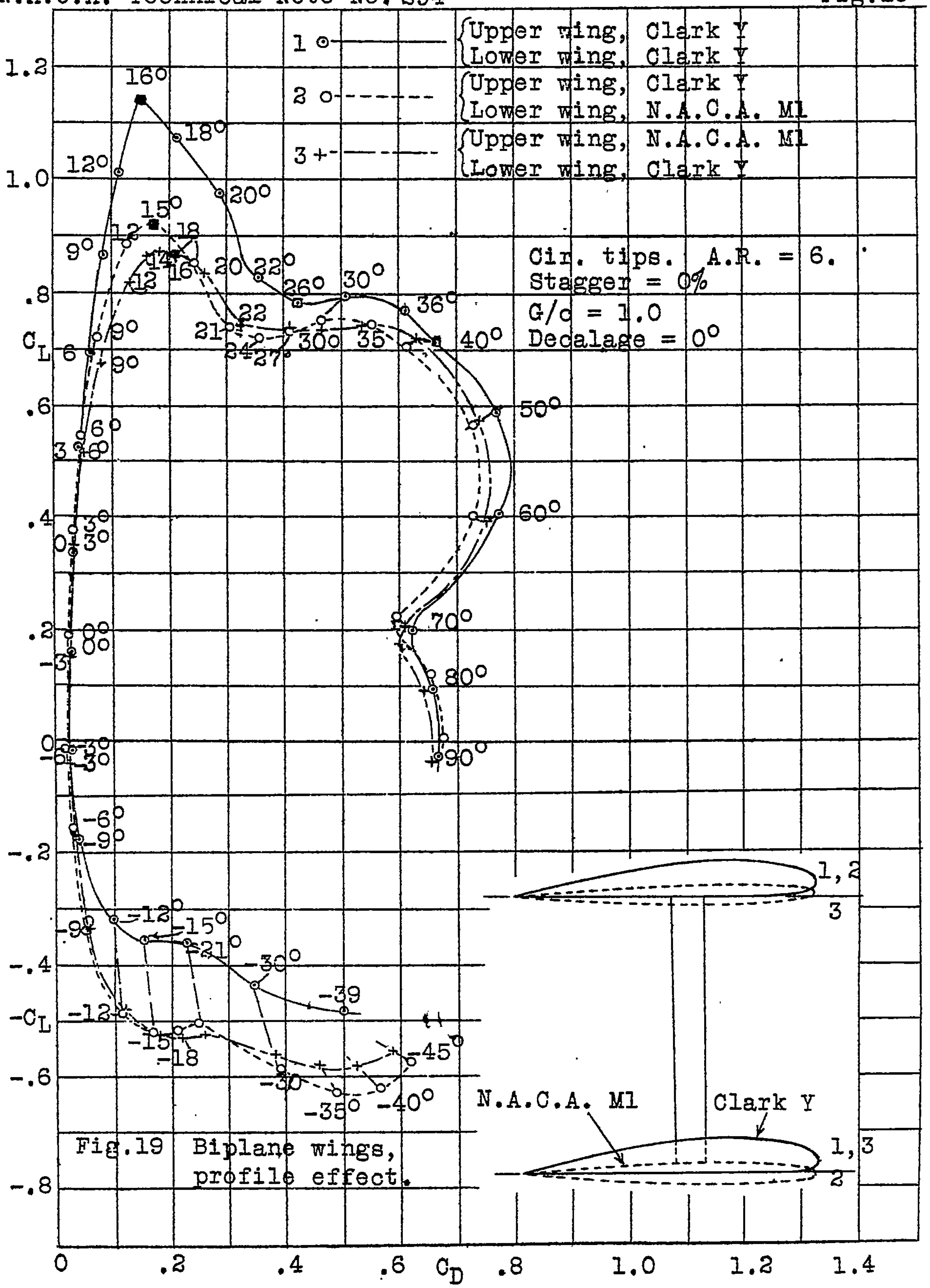


Fig.19 Biplane wings, profile effect.