TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 326

WIND TUNNEL PRESSURE DISTRIBUTION TESTS ON AN AIRFOIL WITH TRAILING EDGE FLAP

By Carl J. Wenzinger and Oscar Loeser, Jr.
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Summary

This report deals with pressure distribution tests on an airfoil with a conventional trailing edge flap. These tests were conducted in the Atmospheric Wind Tunnel of the National Advisory Committee for Aeronautics.

Maximum chord loadings were obtained with the flap displaced downward and with the airfoil at large angles of attack. Greater changes were produced in the normal force and in the center of pressure travel by up-flap than by an equal down-flap displacement.

Introduction

This investigation was conducted for the purpose of obtaining information on the distribution of pressure for two-dimensional flow over an airfoil equipped with a plain trailing edge flap. The tests were made in the Five-Foot Atmospheric Wind Tunnel (Reference 1) of the Langley Memorial Aeronautical Laboratory.

When a trailing edge flap is displaced from its neutral position, the magnitude and distribution of pressure over both airfoil and flap are changed. The property of increasing or decreasing lift has resulted in the common use of flaps as ailerons for controlling the attitude, and hence the motion of an airplane in flight. Flaps are also used to a limited extent to obtain lower landing speeds by increasing the maximum lift coefficient of the wing.

To use flaps as control surfaces, it is desirable to know how much control can be obtained by displacing them and also the force required to operate them. For a flap used on a wing to decrease landing speed, in addition to the above information, it is necessary to know how flap displacement affects the balance or "trim" of the airplane.

The foregoing factors can be determined by a study of the normal force characteristics, center of pressure movement, and the moments of the air loads on the flap about the hinge. The results of numerous force tests have already been published, but relatively little information is available from pressure distribution tests. The pressure distribution tests described in this report are a part of a preliminary test program which has been carried out at this laboratory on several different types of flaps.

Method of Test and Apparatus

The tests described in this report were made by the so-called "plane flow" method. The test airfoil was mounted between end planes which extended across the tunnel and several chord lengths fore and aft of the model. Pressures along a section of the airfoil midway between the planes were measured by means of a single row of orifices which were connected to a liquid multiple manometer.

In Figure 1 the airfoil is shown mounted in the wind tunnel. It was arranged so that the angle of attack could be varied from the outside. The airfoil used was the N.A.C.A. 84-M with a 15-inch chord and a length of 25½ inches. A trailing edge flap, 20 per cent of the chord in width, was hinged as shown in Figure 2. In the construction of the wooden model, the ordinates were kept accurate to within ±0.020 inch of those specified in Table I. The pressure orifice positions along the chord are given in Table II and Figure 2.

Tubes from the orifices were brought out through the lower end of the airfoil and connected to the liquid multiple manometer. This manometer, shown in Figure 3, has the tubes spaced proportionately to the orifice positions on the airfoil. Using this arrangement, photostat records were taken of the liquid heights for each angle of attack and flap setting. On the photostats, curves were faired through the meniscuses of the indicating liquid, producing the type of diagram shown in Figure 4. Here the horizontal line indicates the value of the static pressure in the wind tunnel test section.

The tests were made at a dynamic pressure of 4.09 lb. per sq.ft., corresponding to a velocity of about 40 m.p.h., and a

Reynolds Number of 455,000.

Results

The data obtained from the tests are presented in graphical form as follows:

Figure 5-A. Isometric chord load diagram versus angle of attack (flap 30° up).

5-B. (Flap 15° up)

5-C. (Flap 0°)

5-D. (Flap 15° down)

5-E. (Flap 30° down)

Figure 6. Normal force coefficient versus angle of attack (flap angles constant).

Figure 7. Normal force coefficient versus flap angle (angles of attack constant).

Figure 8. Center of pressure coefficient versus angle of attack (flap angles constant).

Figure 9. Center of pressure coefficient versus flap angle (angles of attack constant).

Figure 10. Hinge moment coefficient versus flap angle (angles of attack constant).

The normal force and center of pressure data were obtained by integration of the photostat pressure diagrams for area and for moment about the leading edge. The hinge moment data were obtained by integration of the flap portion of the diagrams for moment about the hinge line.

The various coefficients were computed as follows, all factors being in consistent units:

(1) Normal force coefficient (C_{NF}):

$$C_{NF} = \frac{A}{q\ c}$$

where

A = area of the pressure diagram,

c = chord,

q = dynamic pressure, expressed as a head of the manometer liquid.

(2) Center of pressure coefficient (C_P):

$$C_P = \frac{M}{A\ c}$$

where

M = moment about the leading edge.

(3) Hinge moment coefficient (C_h):

$$C_h = \frac{M_H}{q\ c^2}$$

where

M_H = moment about the flap hinge.

The coefficients of normal force and center of pressure may be relied upon to an accuracy of about ±3 per cent. However, due to the small number of pressure orifices in the flap which made fairing of the pressure diagrams somewhat uncertain, the hinge moment coefficients can only be depended upon for an accuracy of about ±15 per cent.

Discussion

Since the tests were made using a two-dimensional air flow, the results should be considered on the basis of an airfoil of practically infinite aspect ratio. Application of the results to airfoils of finite aspect ratio with either ailerons or flaps would require the use of correction factors such as those given in References 2, 3, and 4. Scale effect should also be considered, due to the tests having been made at the relatively low Reynolds Number of 455,000.

However, the general effects of the results of the tests on an airfoil with 20 per cent flap are indicated by the diagrams and curves. The isometric pressure diagrams are of particular interest because they show the manner in which the air loads along the chord of the airfoil change with flap displacement and with angle of attack. The peaks of the loads occur at the leading edge as in the case of a plain airfoil but, in general, greater loads act near the trailing edge as a result of the flap displacement. These latter loads also reverse their direction of application, depending upon whether the flap is displaced upwards or downwards from the neutral position.

The curves of normal force, center of pressure, and hinge moment coefficients, were included as characteristics of the particular airfoil and flap combination.

Conclusions

1. Maximum chord loadings are obtained at large angles of attack and with the flap displaced in the downward direction.

2. In general, upward movement of the flap produces greater changes in the C_{NF} and in the C.P. travel than downward movement of the same magnitude. Greater hinge moments, however, are obtained with the flap displaced downward.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 8, 1929.

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TABLE I.

N.A.C.A. 84-M Airfoil Ordinates

15-inch chord model

Station in per cent of chord	Ordinate upper surface per cent of chord	Ordinate lower surface per cent of chord
0.000	2.920	2.920
1.000	4.947	1.366
2.000	5.920	0.858
4.000	7.390	0.333
6.000	8.450	0.087
8.000	9.320	0.000
10.000	10.090	0.000
12.000	10.750	0.000
16.000	11.930	0.000
20.000	12.855	0.000
25.000	13.675	0.000
30.000	14.160	0.000
40.000	14.475	0.000
50.000	13.920	0.000
60.000	12.425	0.000
70.000	10.250	0.000
80.000	7.580	0.000
90.000	4.285	0.000
95.000	2.606	0.000
99.000	0.993	0.000
100.00	0.253	0.253

TABLE II.

Orifice Locations

N.A.C.A. 84-M Airfoil with Flap

15-inch chord model

Upper		Lower	
No.	Per cent chord from L.E.	No.	Per cent chord from L.E.
--	0.00	1	0.00
2	3.75	3	5.60
4	8.59	5	10.60
6	15.89	7	18.06
8	29.02	9	31.30
10	46.46	11	48.85
12	66.75	13	68.60
14	77.75	15	75.90
16	86.45	17	84.60
18	100.00	—	100.00

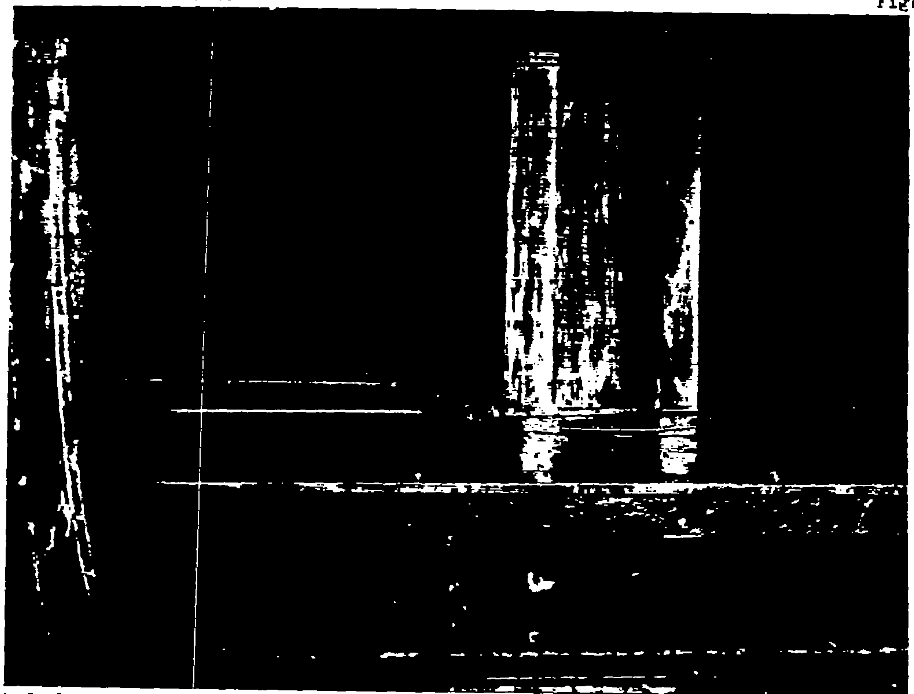

Fig.1 Airfoil mounted on plane flow apparatus.

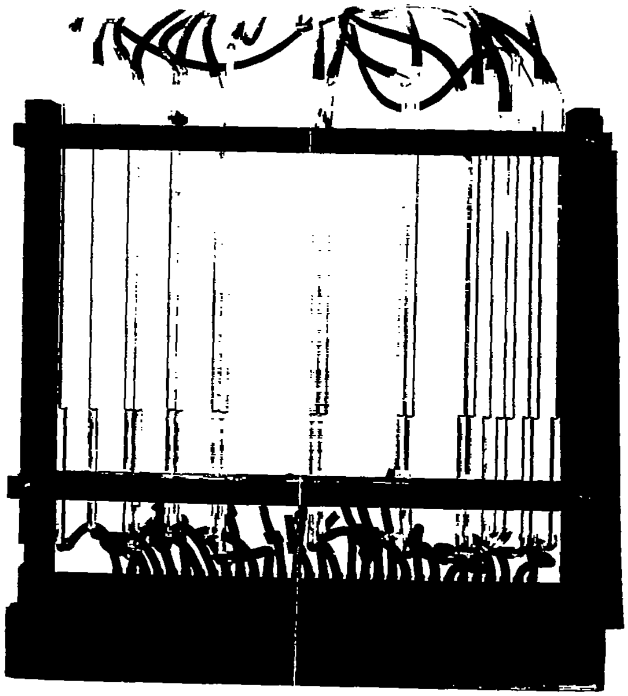

Fig.3 Liquid multiple manometer.

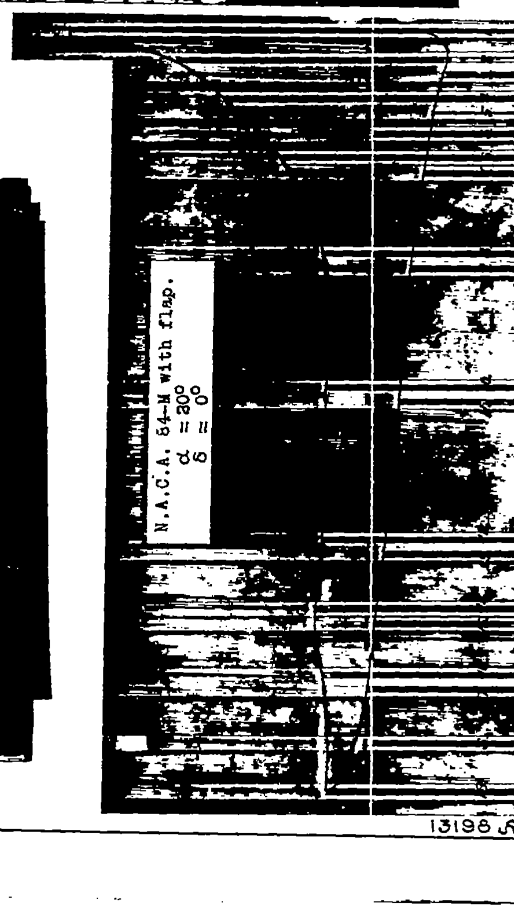

Fig.4 Specimen photostat pressure record.

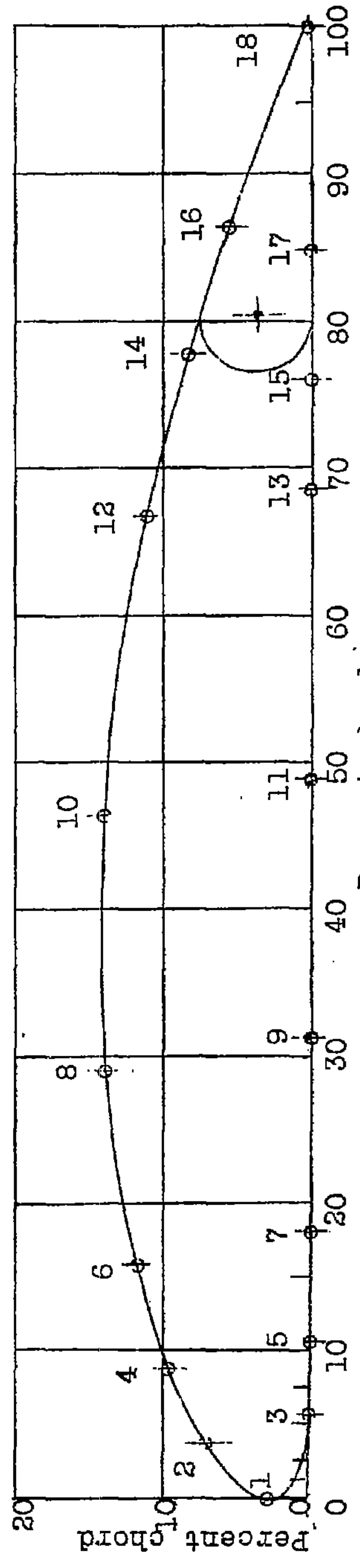

Fig.2 N.A.C.A. 84M profile showing flap and orifices. 15 in. chord model.

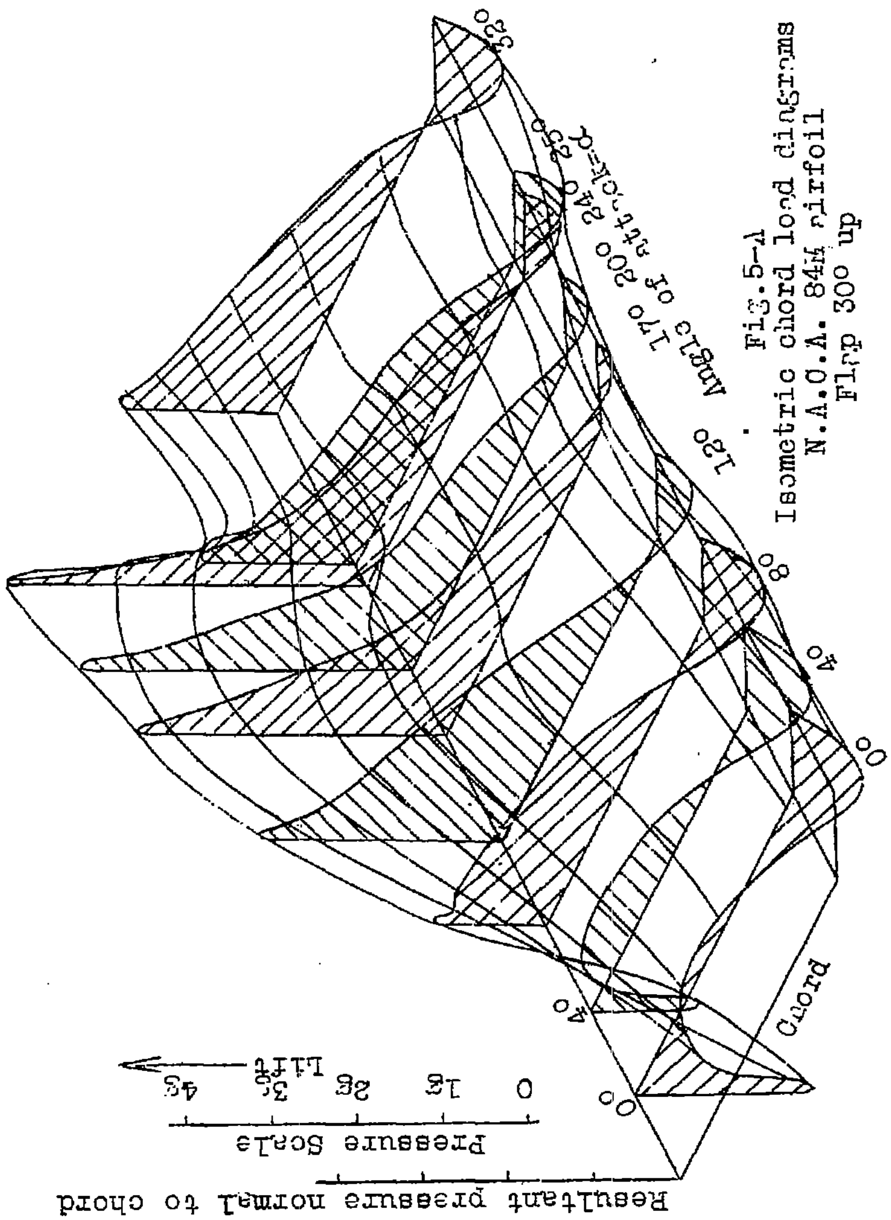

Fig.5-A
Isometric chord load diagrams
N.A.C.A. 84M airfoil
Flap 30° up

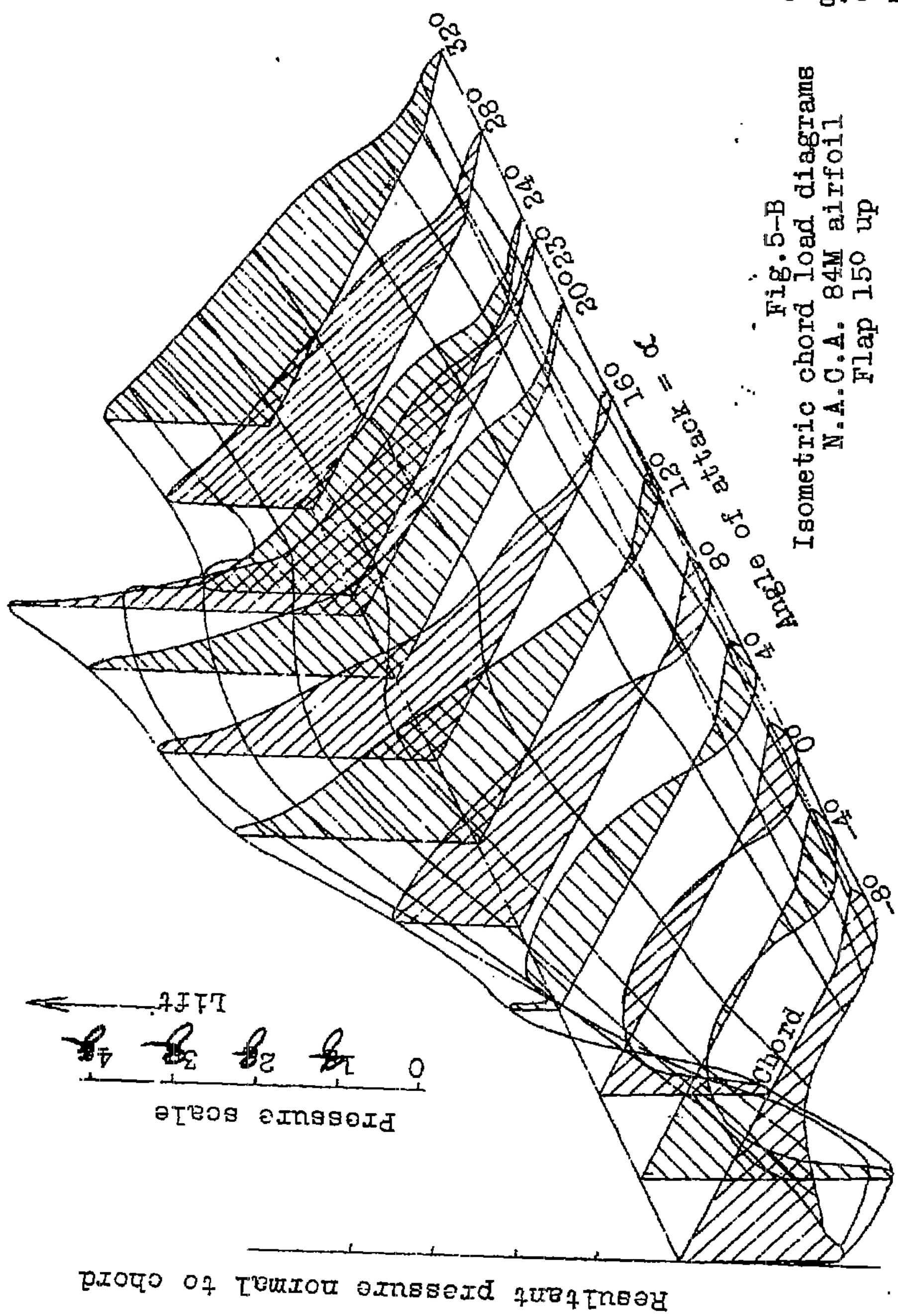

Fig.5-B
Isometric chord load diagrams
N.A.C.A. 84M airfoil
Flap 15° up

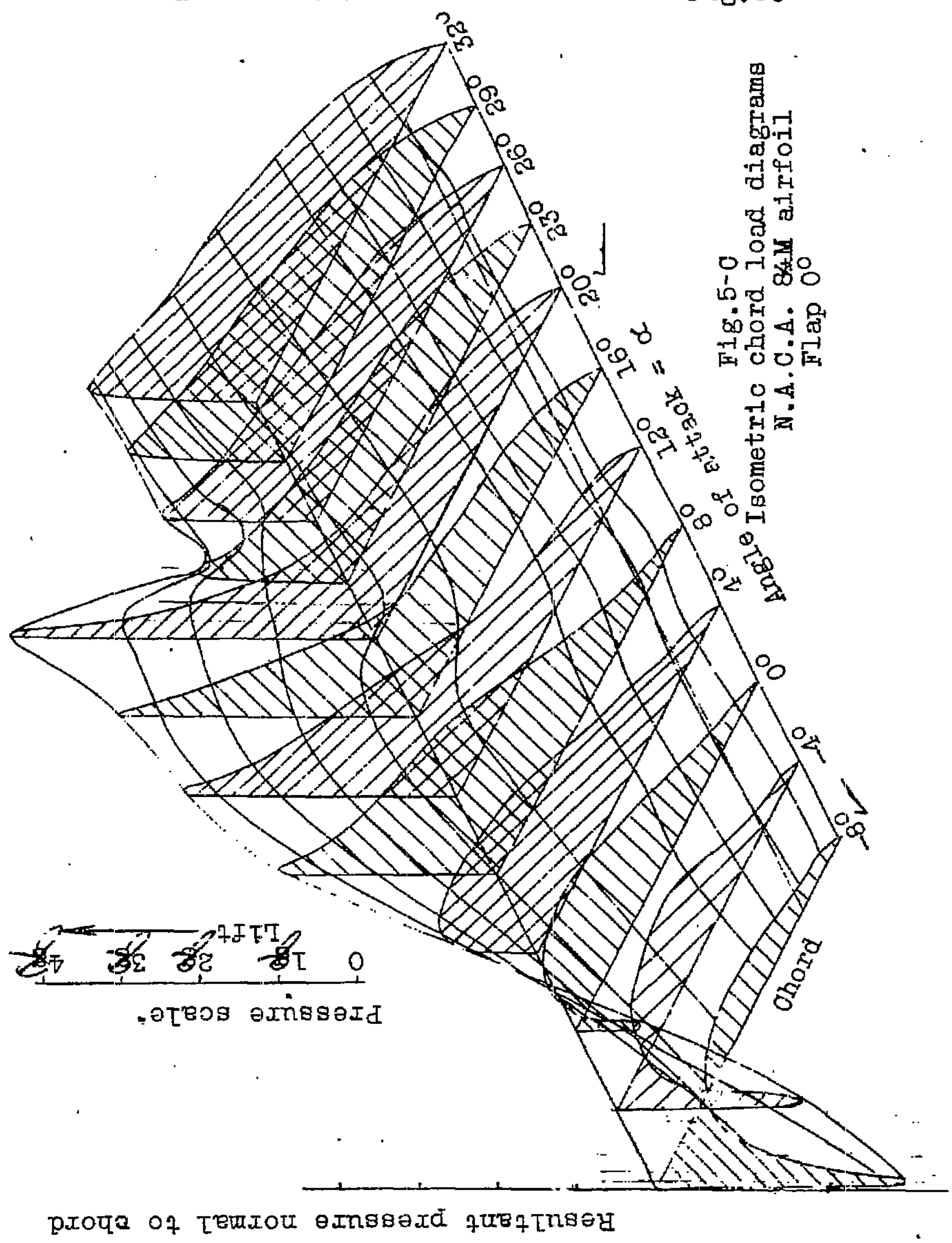

Fig.5-C
Isometric chord load diagrams
N.A.C.A. 84M airfoil
Flap 0°

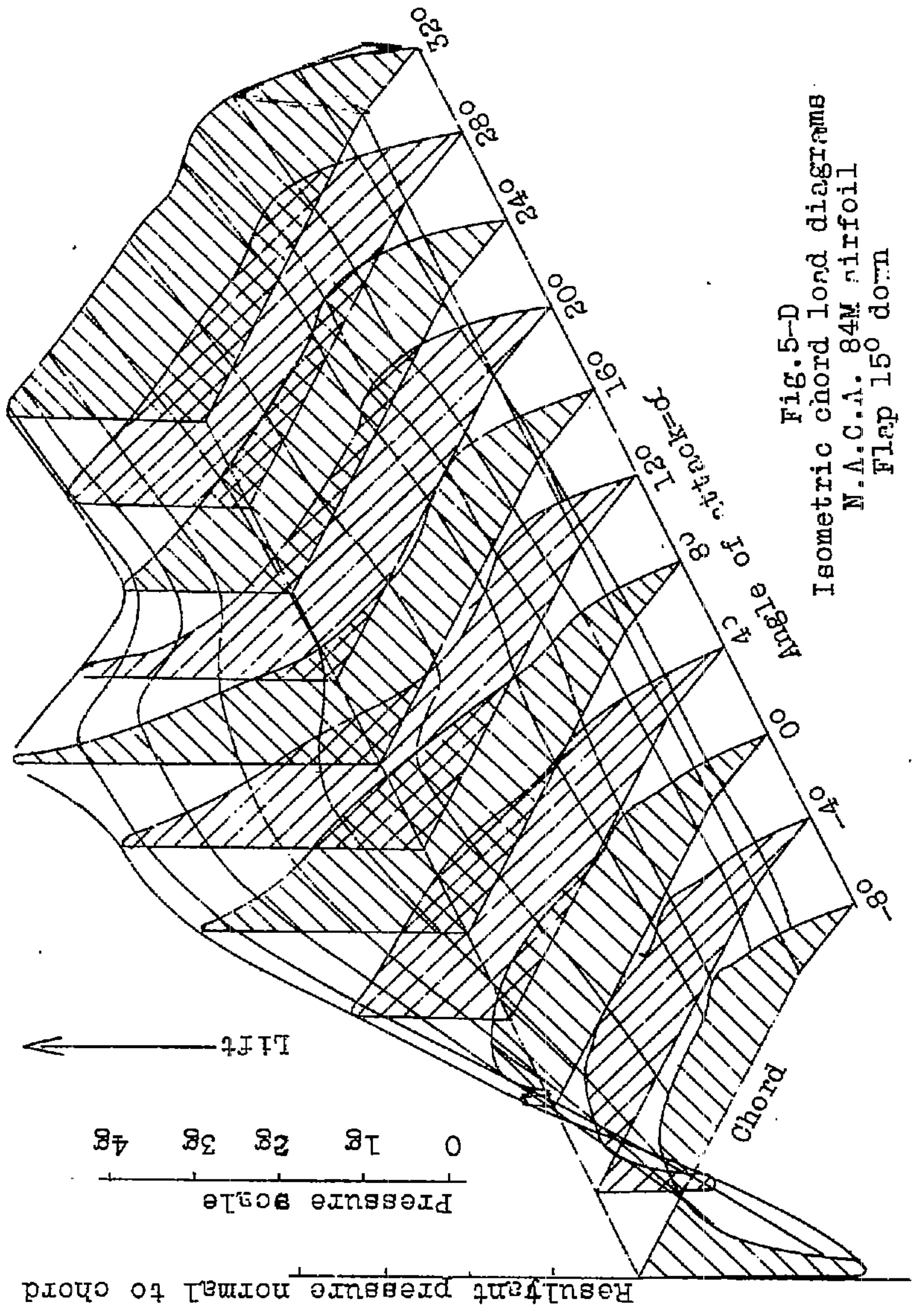

Fig.5-D
Isometric chord load diagrams
N.A.C.A. 84M airfoil
Flap 15° down

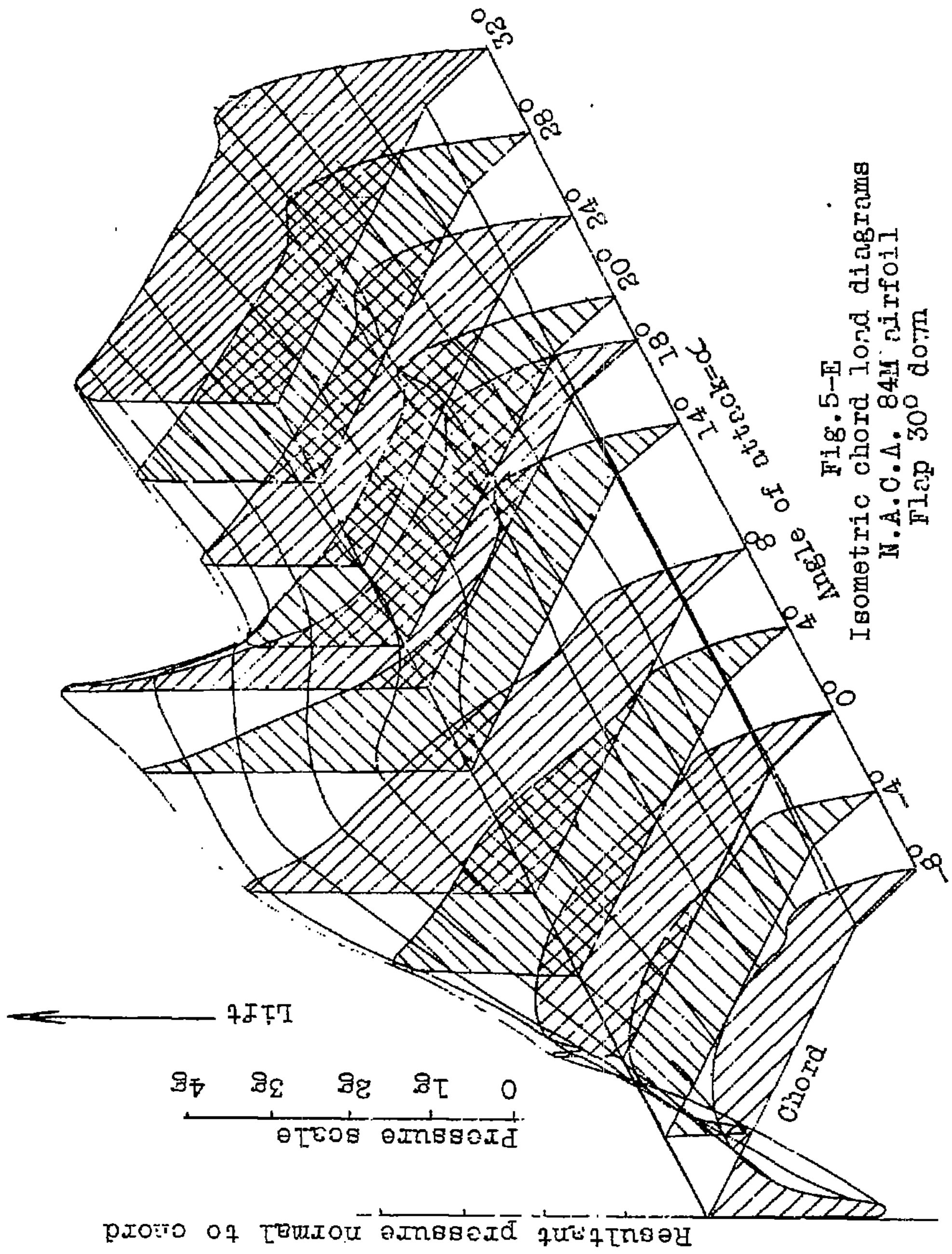

Fig.5-E
Isometric chord load diagrams
N.A.C.A. 84M airfoil
Flap 30° down

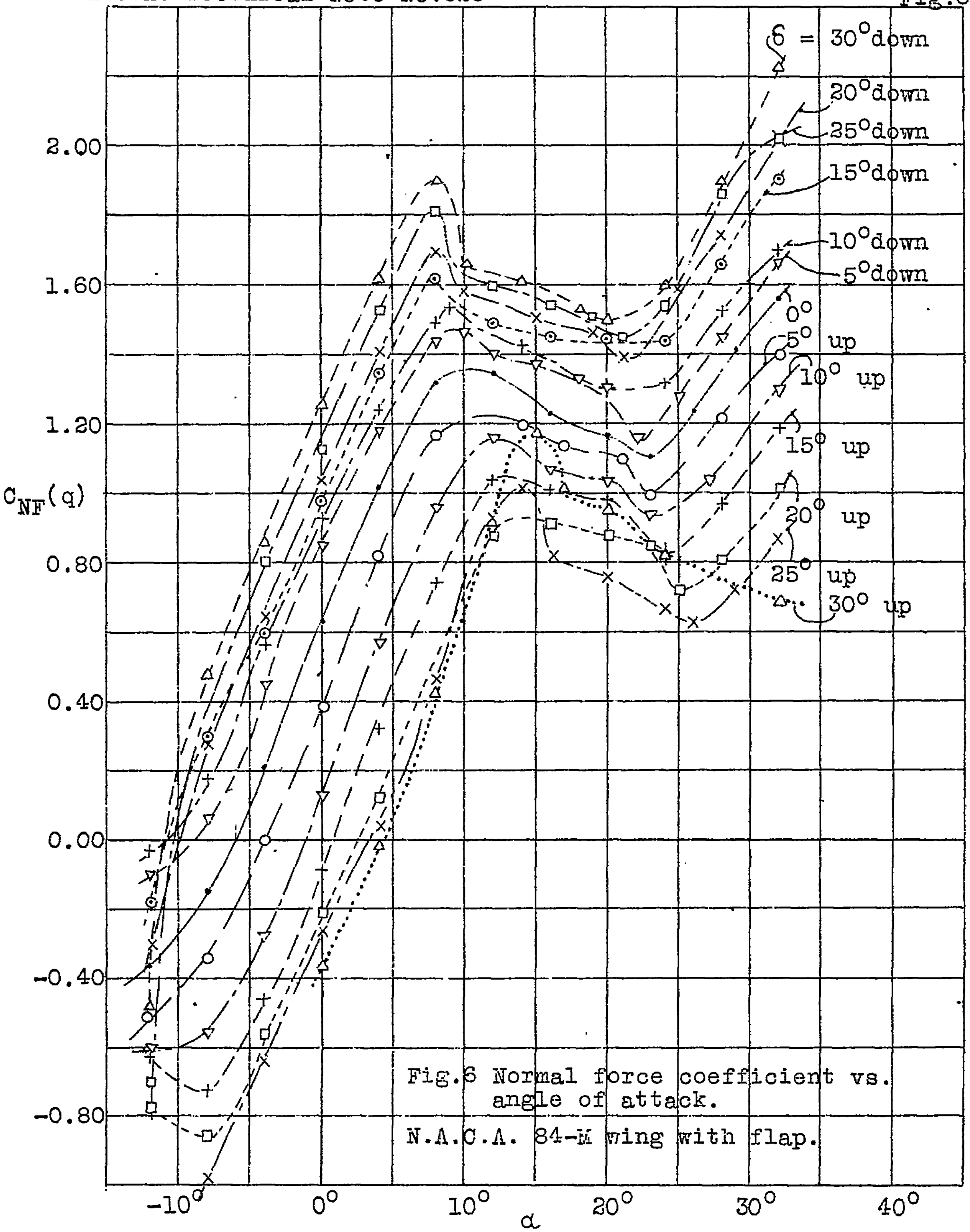

Fig.6 Normal force coefficient vs. angle of attack.

N.A.C.A. 84-M wing with flap.

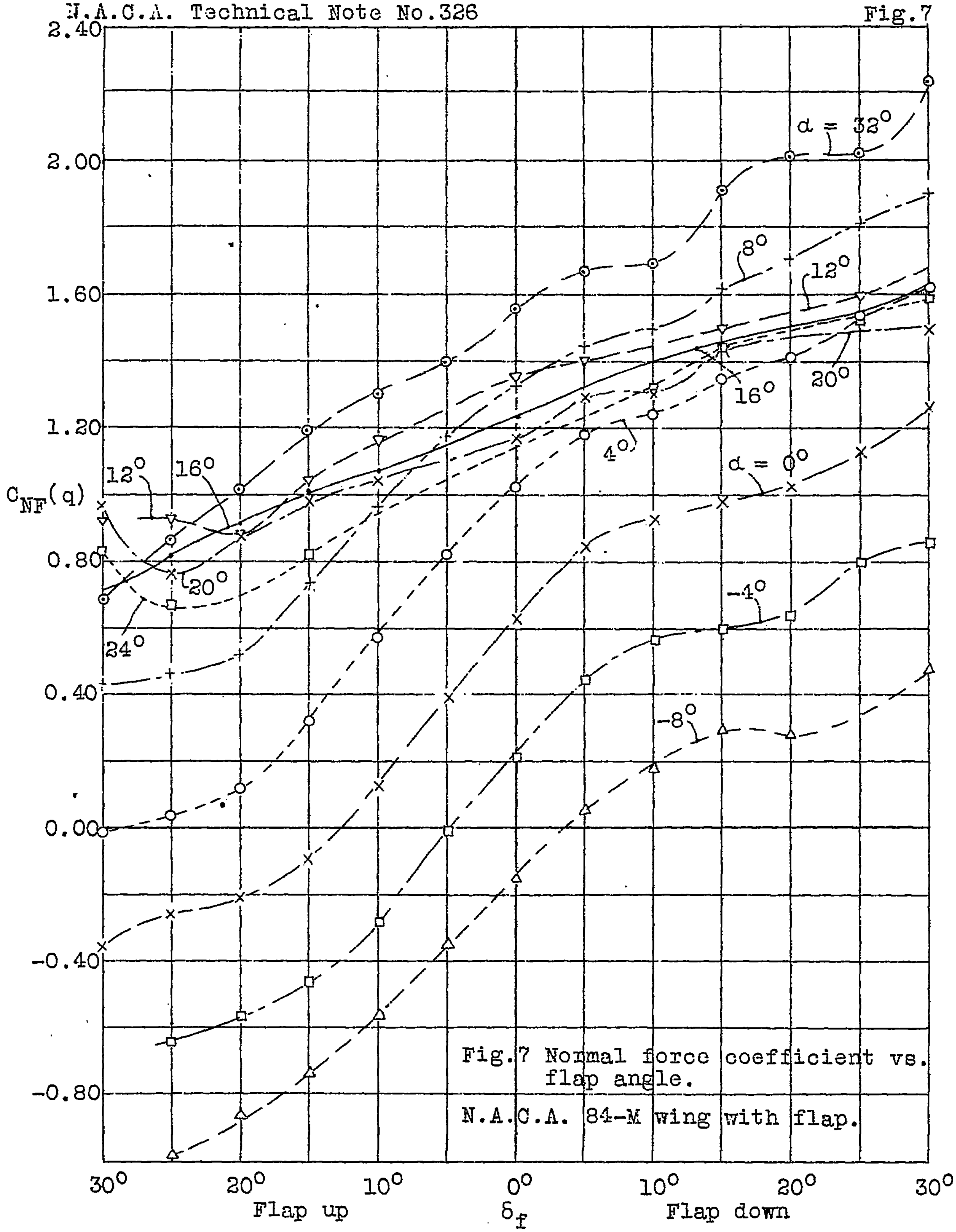

Fig.7 Normal force coefficient vs. flap angle.

N.A.C.A. 84-M wing with flap.

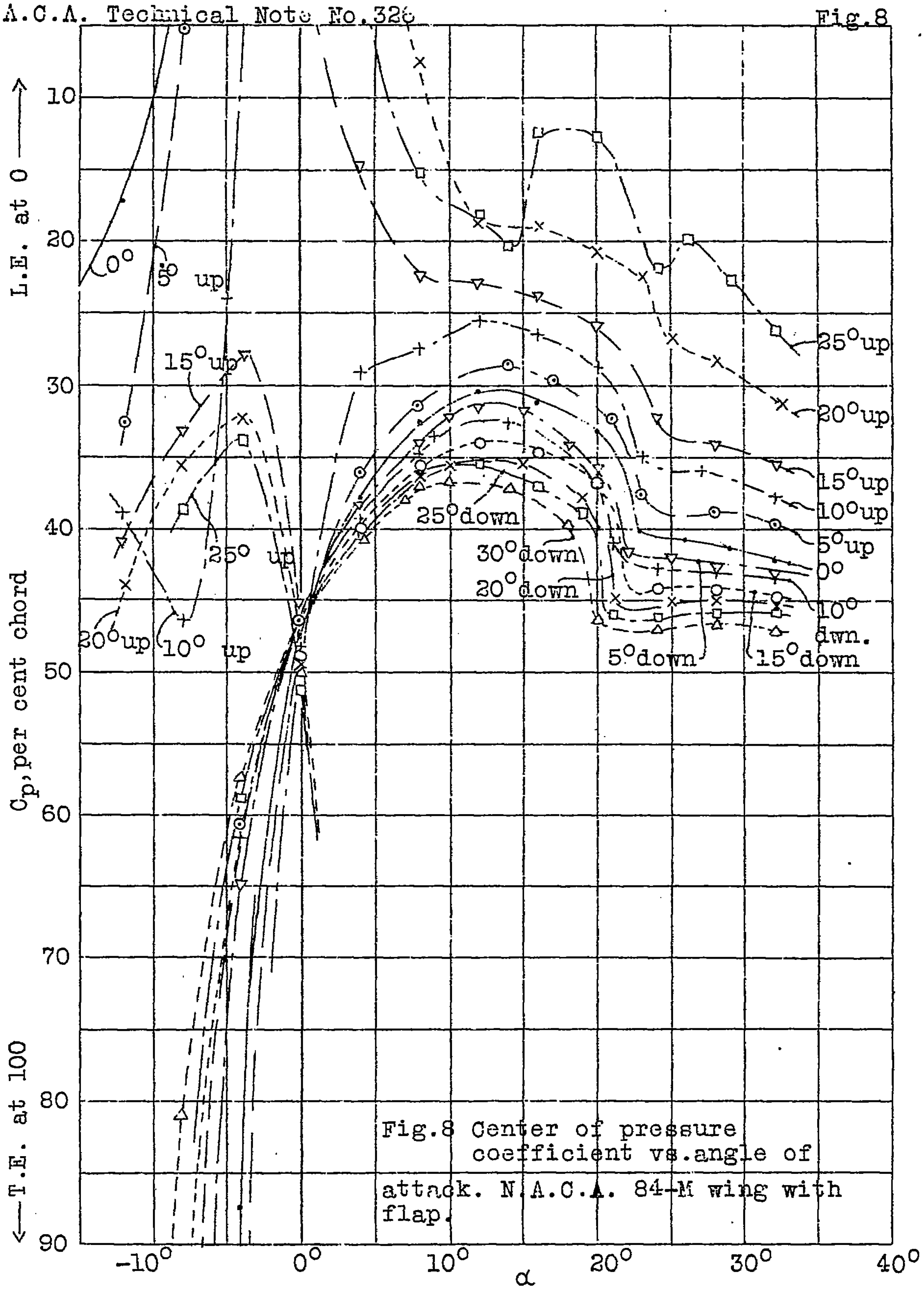

Fig.8 Center of pressure coefficient vs.angle of attack. N.A.C.A. 84-M wing with flap.

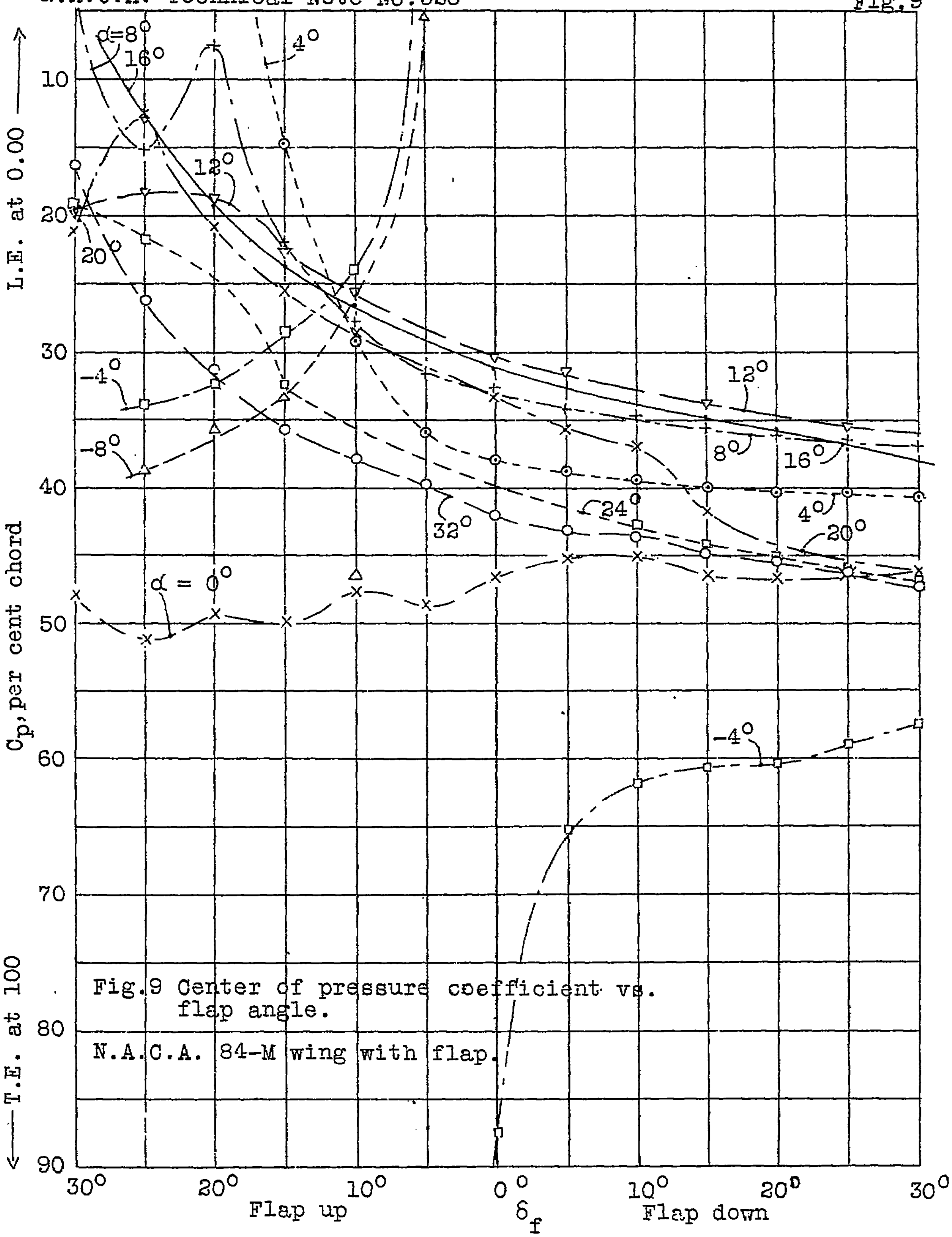

Fig. 9 Center of pressure coefficient vs. flap angle.

N.A.C.A. 84-M wing with flap.

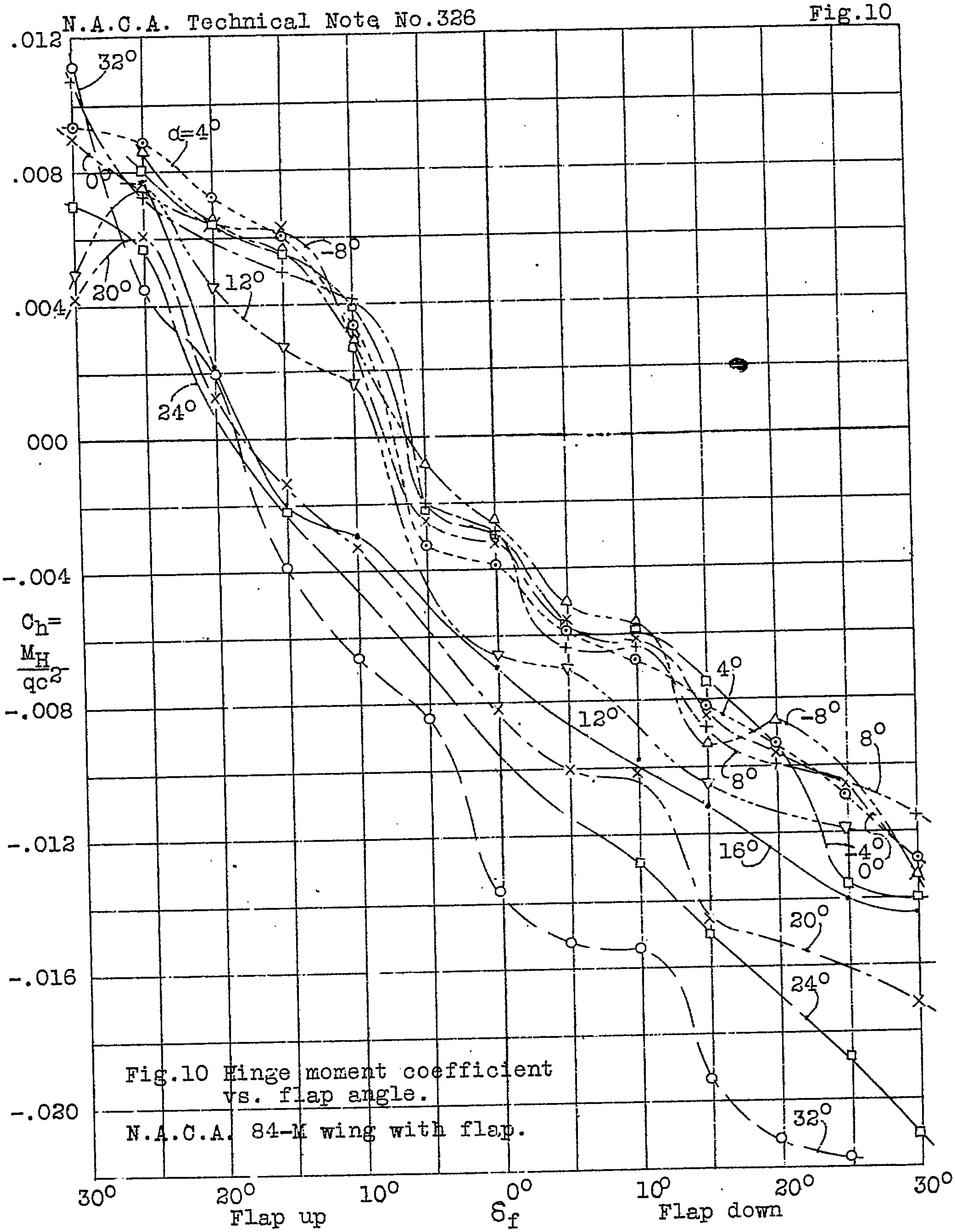

Fig.10 Hinge moment coefficient vs. flap angle.

N.A.C.A. 84-M wing with flap.