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RESEARCH MEMORANDUM

TESTS OF THE NACA 64_1-012 AND 64_1A012 AIRFOILS AT HIGH SUBSONIC MACH NUMBERS

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RESEARCH MEMORANDUM

TESTS OF THE NACA 64_1-012 AND 64_1A012 AIRFOILS AT HIGH SUBSONIC MACH NUMBERS

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SUMMARY

An investigation on NACA 64_1-012 and 64_1A012 airfoils at Mach numbers between 0.35 and 0.89 and at low Reynolds numbers indicated that the effect of increasing the trailing-edge angle from 9° (NACA 64_1-012) to 14° (NACA 64_1A012) was

(1) Inappreciable on the Mach number for normal-force break

(2) To decrease the normal-force-curve slope

(3) To reduce the effects of compressibility on $\frac{dc_{m_{c/4}}}{dc_n}$

(4) To decrease the minimum drag coefficient and to increase maximum normal-force to drag ratio.

INTRODUCTION

The shape of an airfoil at the trailing edge has been considered to have a large effect upon the aerodynamic characteristics encountered at high subsonic Mach numbers (for example, reference 1). Changes in trailing-edge angle, however, generally involved changes in other shape parameters; and, consequently, the effects of the trailing-edge shape alone were not determined.

Modifications to the NACA 6-series airfoil whereby the cusp was eliminated (reference 2), permitted trailing-edge angle effects to be studied on airfoils having essentially the same type of pressure distribution, thereby minimizing effects of other shape parameters. To determine the effects of this shape change, an investigation has been conducted at high subsonic Mach numbers on two 12-percent-thick NACA 64-series airfoils with and without cusp.

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APPARATUS AND TESTS

The tests were conducted in the Langley rectangular high-speed tunnel, an induction-type tunnel without return passages having an 18-inch by 4-inch test section. The airfoils were mounted to span the 4-inch dimension of the tunnel and were supported by large circular end plates which maintained the continuity of the tunnel walls.

The two airfoils investigated were the NACA 64_1-012 and 64_1A012, having chords of $2\frac{1}{2}$ inches. Forty-two static-pressure orifices were installed in each airfoil near the model center line. The locations of the orifices and the model contours are shown in figure 1. The ordinates for each airfoil are given in table I. Pressure-distribution measurements and wake surveys were made at Mach numbers between 0.35 and 0.89 for angles of attack from 0° to 8°. The Mach number range corresponded approximately to Reynolds number range from 4 to 9×10^5.

SYMBOLS

M	stream Mach number
c_n	section normal-force coefficient
$c_{m_{c/4}}$	section pitching-moment coefficient of normal force about quarter-chord location
c_d	section drag coefficient (determined from wake surveys)
α	angle of attack

TUNNEL-WALL EFFECTS

The data have been corrected for tunnel-constriction effects by the methods of reference 3. The basic data presented (figs. 2 and 3) do include a serious constriction effect that occurred near the maximum attainable Mach number for each configuration, that is, around choking, and are shown by the dashed portion of the curves in figures 2 and 3. This dashed portion of the curves corresponds to a Mach number increment of approximately 0.03, which previous investigations have indicated to be approximately the extent of influence of serious choking effects. Data subject to choking effects are not used in the analysis.

RESULTS

The variations of the aerodynamic characteristics with Mach number at a constant angle of attack represent the basic data and are presented in figures 2 and 3. The data of figures 2 and 3 have been cross-plotted to show the variation in normal-force coefficient with angle of attack and the variation in moment and drag with normal force in coefficient form at each of several Mach numbers. The cross-plotted results are presented in figures 4 and 5. Direct comparisons of the aerodynamic characteristics of the two airfoils for each of several high subsonic Mach numbers are presented in figure 6.

DISCUSSION

Inspection of the basic data (figs. 2(a) and 3(a)) shows that Mach numbers for the normal-force break are approximately the same for both profiles. The Mach number for normal-force recovery (the second normal-force reversal) occurs within the region of possible influence of choking effects and is therefore of questionable value. The drag rise (figs. 2(b) and 3(b)) occurs at the same Mach numbers for both airfoils within an increment of 0.03; the values being somewhat higher for the NACA 64_1A012 than for the NACA 64_1-012.

The characteristics of both airfoils (figs. 4 and 5) show no marked deviation from the accustomed effects of compressibility, particularly at Mach numbers below 0.75. The differences at the high Mach numbers are more clearly shown by the direct comparisons of the aerodynamic characteristics of the two airfoils. Inasmuch as the difference between the two airfoils is fundamentally a change in trailing-edge angle from approximately 9° for the NACA 64_1-012 airfoil to 14° for the NACA 64_1A012 airfoil (reference 2), the differences in characteristics shown in figure 6 will be attributed to change in trailing-edge angle.

The increase in trailing-edge angle resulted in a decrease in normal-force-curve slope throughout the angle of attack and Mach number ranges (fig. 6(a)). The decrease in slope is in agreement with the results of reference 2 obtained at low speeds and high Reynolds numbers.

The effect of trailing-edge angle on moment depended upon the range of angles of attack or normal-force coefficient concerned. At normal-force coefficient less than 0.2, the rate of change of moment coefficient with normal force became positive at high Mach numbers for both airfoils. The NACA $64_1$012 airfoil having the 9° trailing-edge angle had larger values of $\frac{dc_{m_{c/4}}}{dc_n}$ than did the other airfoil. At normal-force coefficients greater than 0.3, $\frac{dc_{m_{c/4}}}{dc_n}$ tended to become negative for both airfoils. The effect of compressibility on this trend was more severe for the airfoil having the 9° trailing-edge angle.

The comparison of the polars for the two airfoils (fig. 6(b)) shows that the airfoil having a 14° (NACA 64_1A012) trailing-edge angle had lower drag in the low normal-force coefficient range and, consequently, higher maximum ratios of normal force to drag.

CONCLUSIONS

The present investigation on NACA 64_1-012 and 64_1A012 airfoils, trailing-edge angles of 9° and 14°, respectively, at Mach numbers between 0.35 and 0.89 and low Reynolds numbers indicates the following conclusions:

1. Increasing the trailing-edge angle from 9° to 14° had an inappreciable effect on the Mach number for normal-force break.

2. The highest normal-force-curve slopes were obtained at all Mach numbers with the airfoil having the 9° trailing-edge angle.

3. The effects of compressibility on the variation of moment coefficient with normal-force coefficient were decreased by increasing the trailing-edge angle from 9° to 14°.

4. A favorable effect on minimum drag and maximum ratio of normal force to drag was obtained by increasing the trailing-edge angle.

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Langley Field, Va.

REFERENCES

1. Stevenson, David B., and Adler, Alfred A.: High-Speed Wind-Tunnel Tests of an NACA 009-64 Airfoil Having a 33.4-Percent-Chord Flap with an Overhang 20.1 Percent of the Flap Chord. NACA TN No. 1417, 1947.

2. Loftin, Laurence K., Jr.: Theoretical and Experimental Data for a Number of NACA 6A-Series Airfoil Sections. NACA TN No. 1368, 1947.

3. Allen, H. Julian, and Vincenti, Walter G.: The Wall Interference in a Two-Dimensional-Flow Wind Tunnel with Consideration of the Effect of Compressibility. NACA Rep. No. 782, 1944.

TABLE I.– ORDINATES OF AIRFOILS

[Stations and ordinates in percent of wing chord]

NACA 64_1–012	
Station	Upper or lower surface ordinate
0	0
.5	.978
.75	1.179
1.25	1.490
2.5	2.035
5.0	2.810
7.5	3.394
10.0	3.871
15.0	4.620
20.0	5.173
25.0	5.576
30.0	5.844
35.0	5.978
40.0	5.981
45.0	5.798
50.0	5.480
55.0	5.056
60.0	4.548
65.0	3.974
70.0	3.350
75.0	2.695
80.0	2.029
85.0	1.382
90.0	.786
95.0	.288
100.0	0
L.E. radius: 1.040	

NACA 64_1A012	
Station	Upper or lower surface ordinate
0	0
.5	.961
.75	1.158
1.25	1.464
2.5	2.018
5.0	2.788
7.5	3.364
10.0	3.839
15.0	4.580
20.0	5.132
25.0	5.534
30.0	5.809
35.0	5.965
40.0	5.993
45.0	5.863
50.0	5.605
55.0	5.244
60.0	4.801
65.0	4.289
70.0	3.721
75.0	3.118
80.0	2.500
85.0	1.882
90.0	1.263
95.0	.644
100.0	.025
L.E. radius: 0.994 T.E. radius: 0.028	

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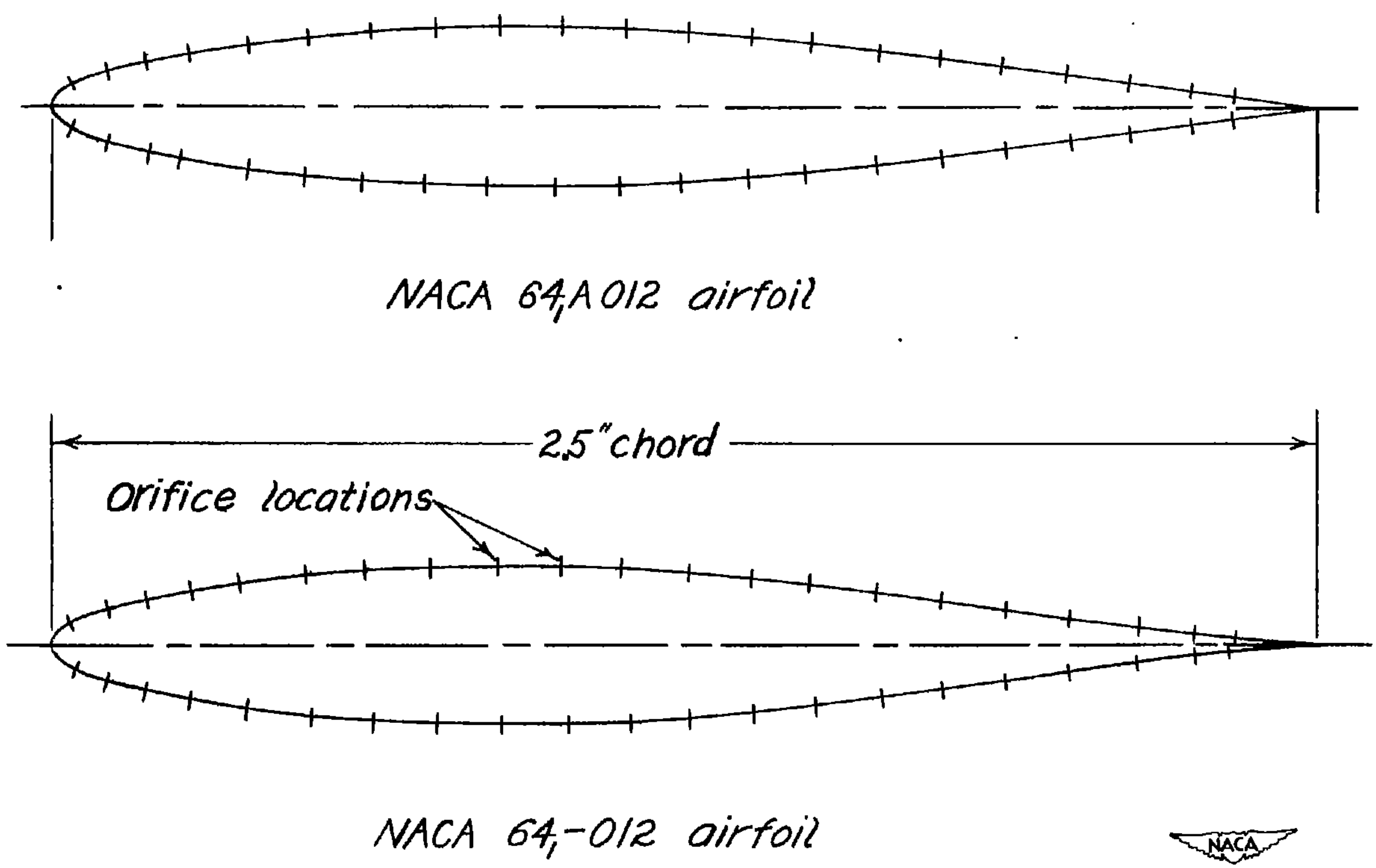

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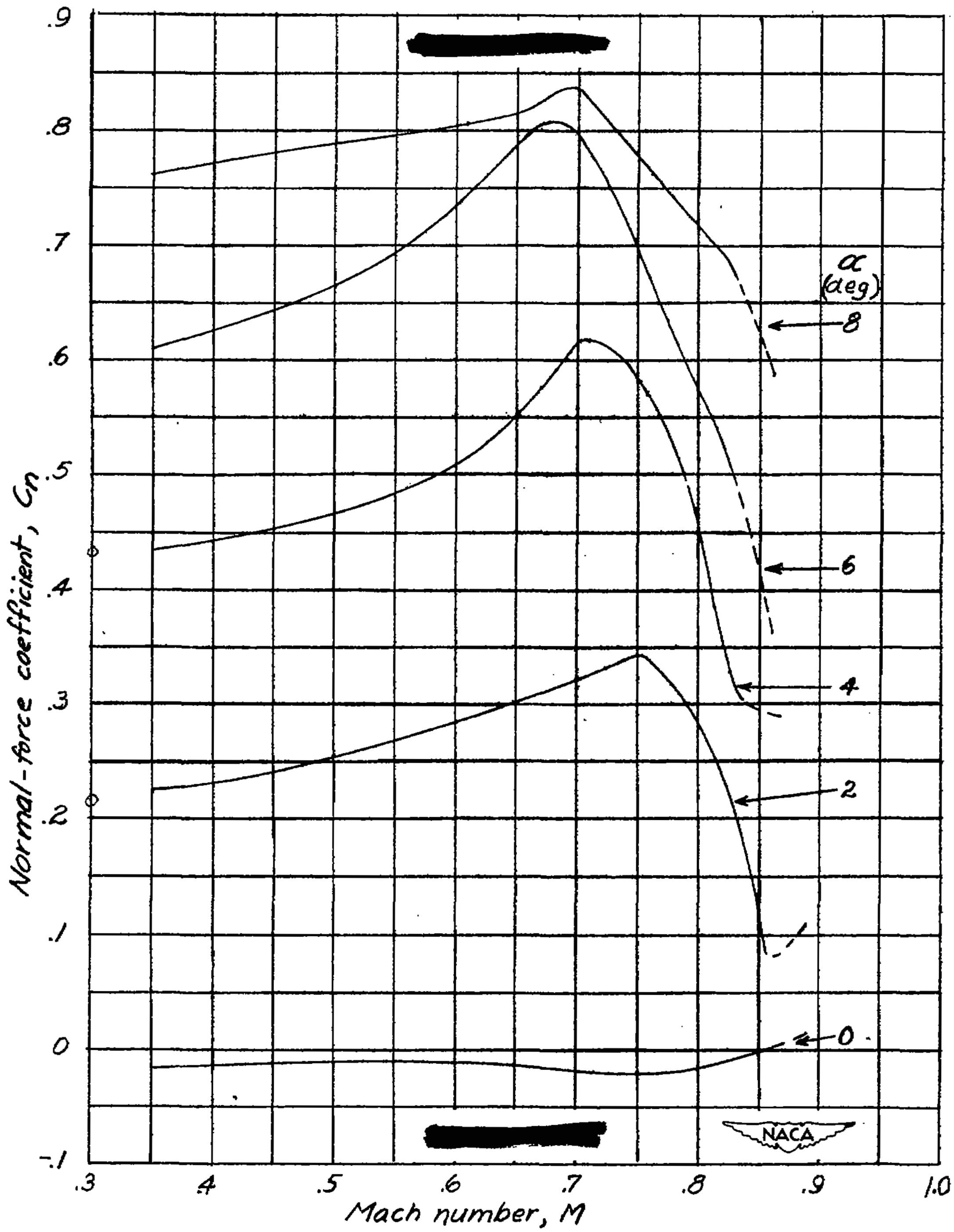
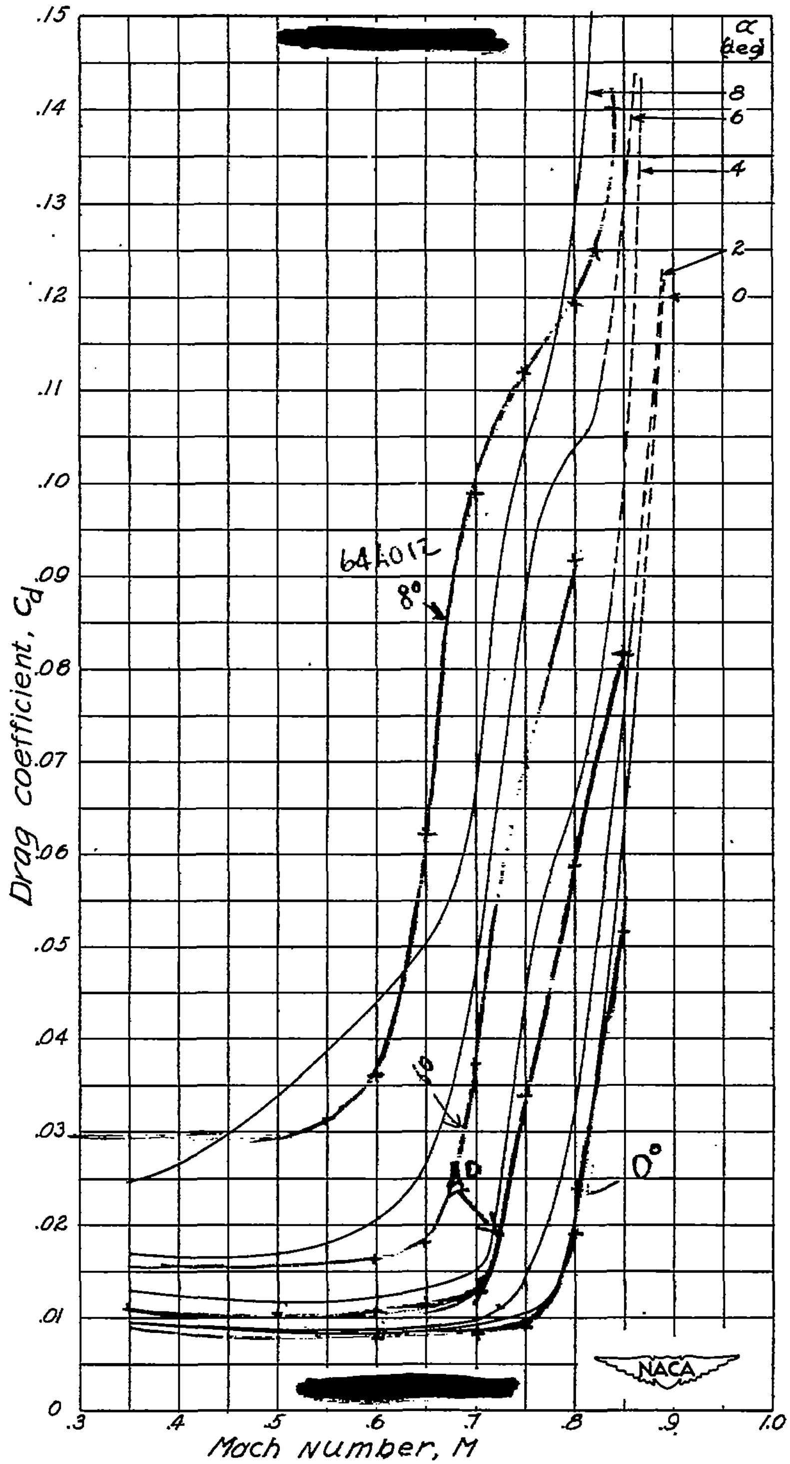
Figure 1.- Airfoil profiles and static-pressure-orifice locations.



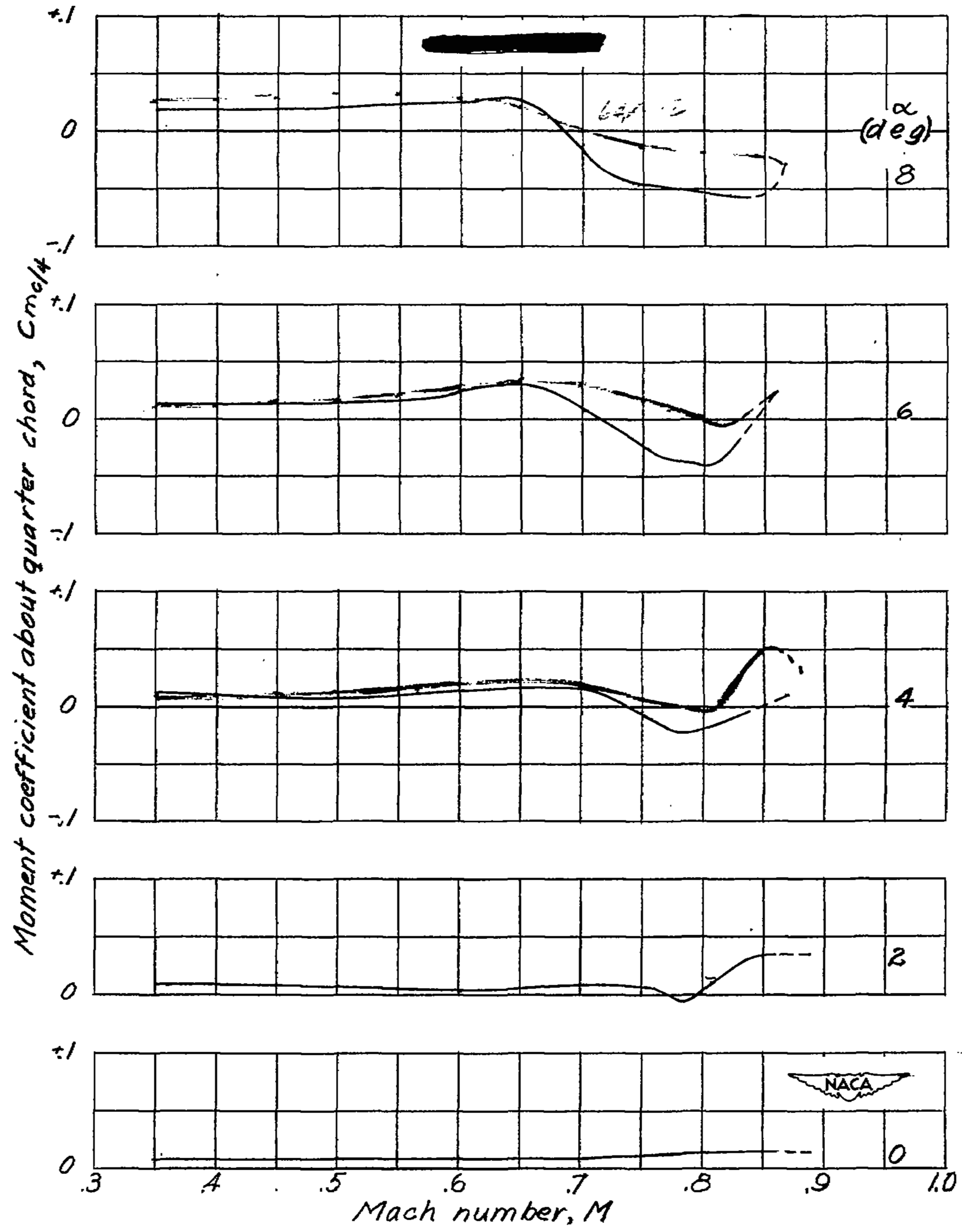
(a) Normal-force characteristics.

Figure 2.- Effect of compressibility on section aerodynamic characteristics of NACA 64_1-012 airfoil.



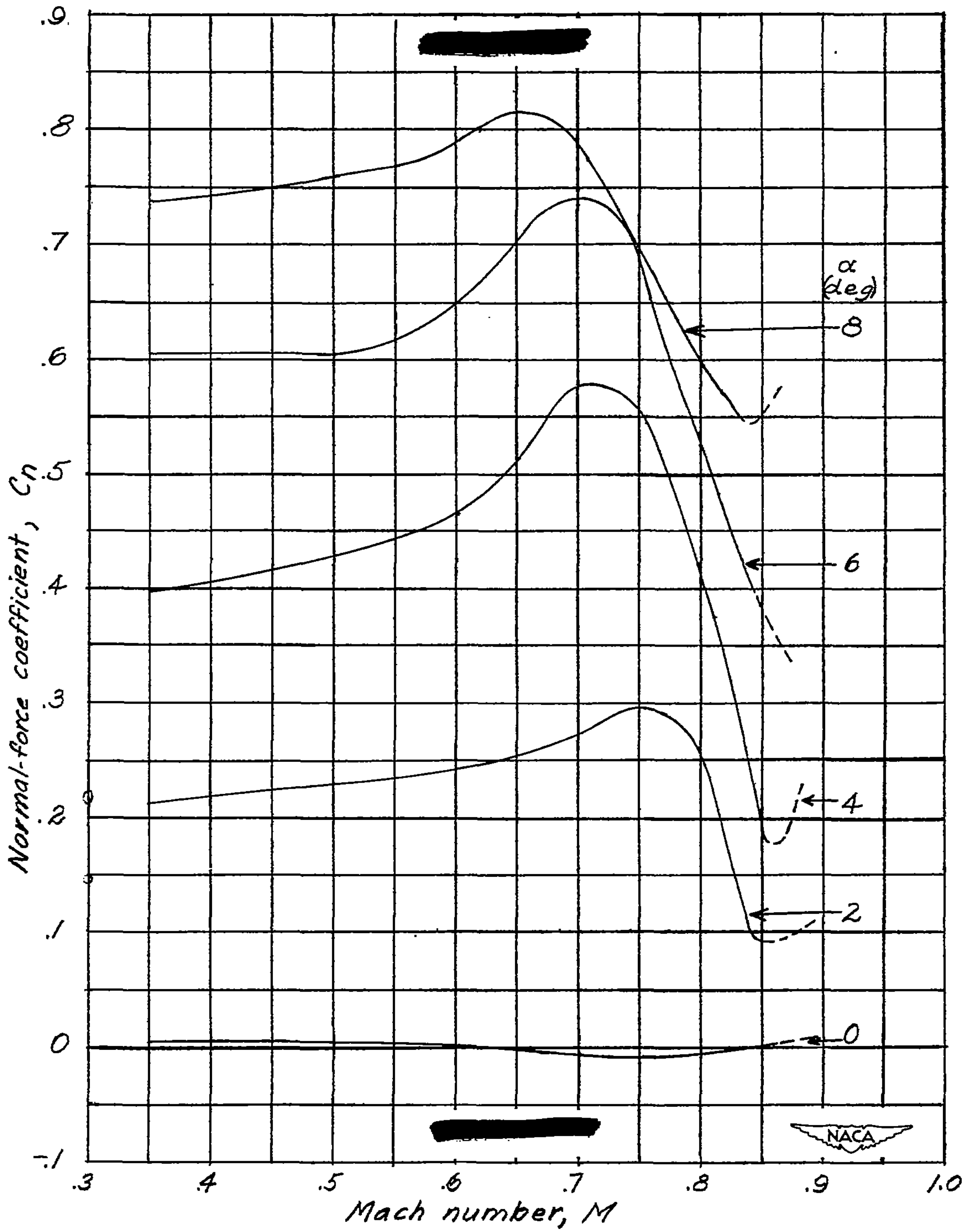
(b) Drag characteristics.

Figure 2.- Continued.



(c) Moment characteristics. [redacted]

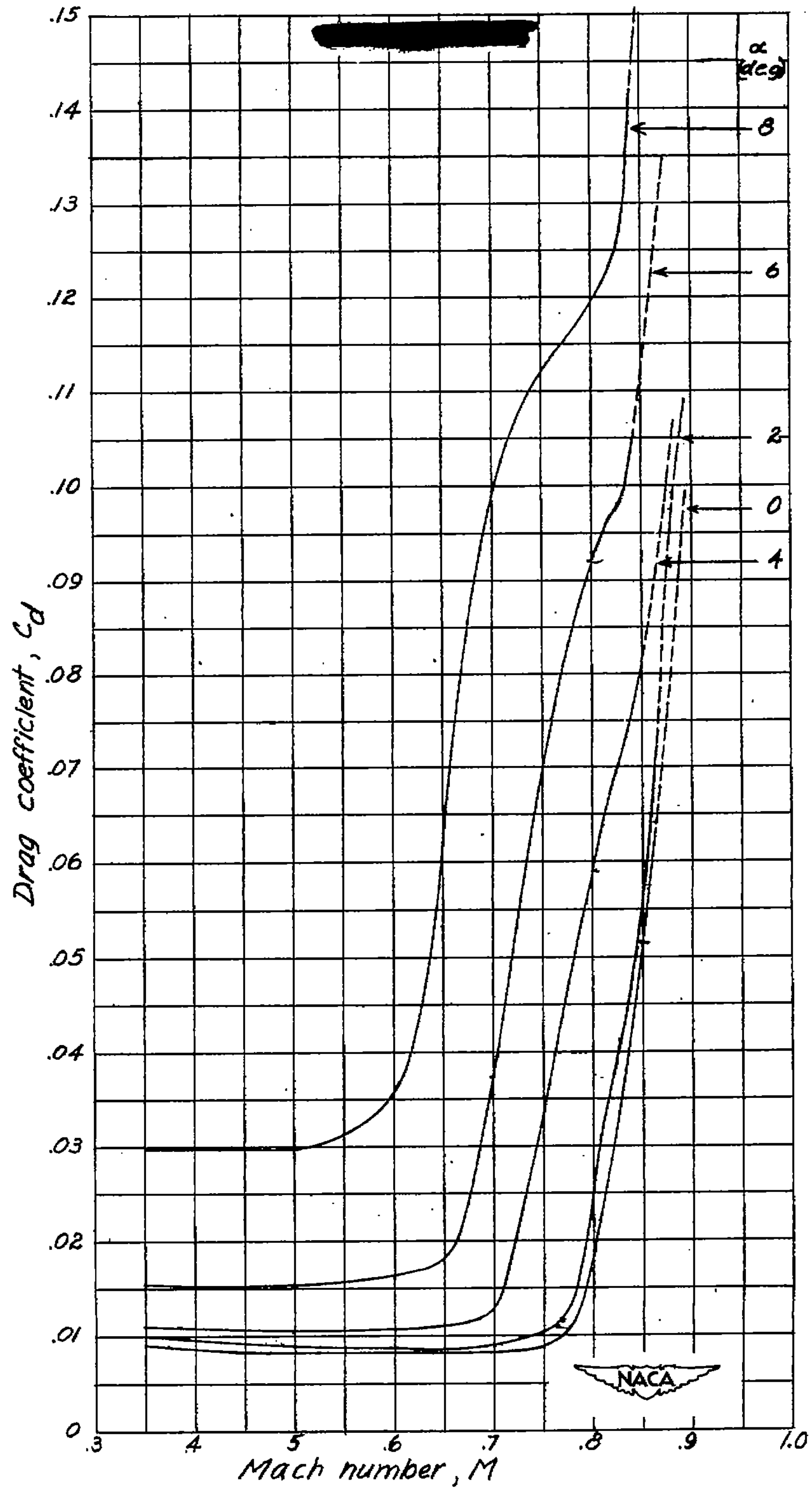
Figure 2.- Concluded.



(a) Normal-force characteristics.

Figure 3.- Effect of compressibility on section aerodynamic characteristics of the NACA 64_1A012 airfoil.

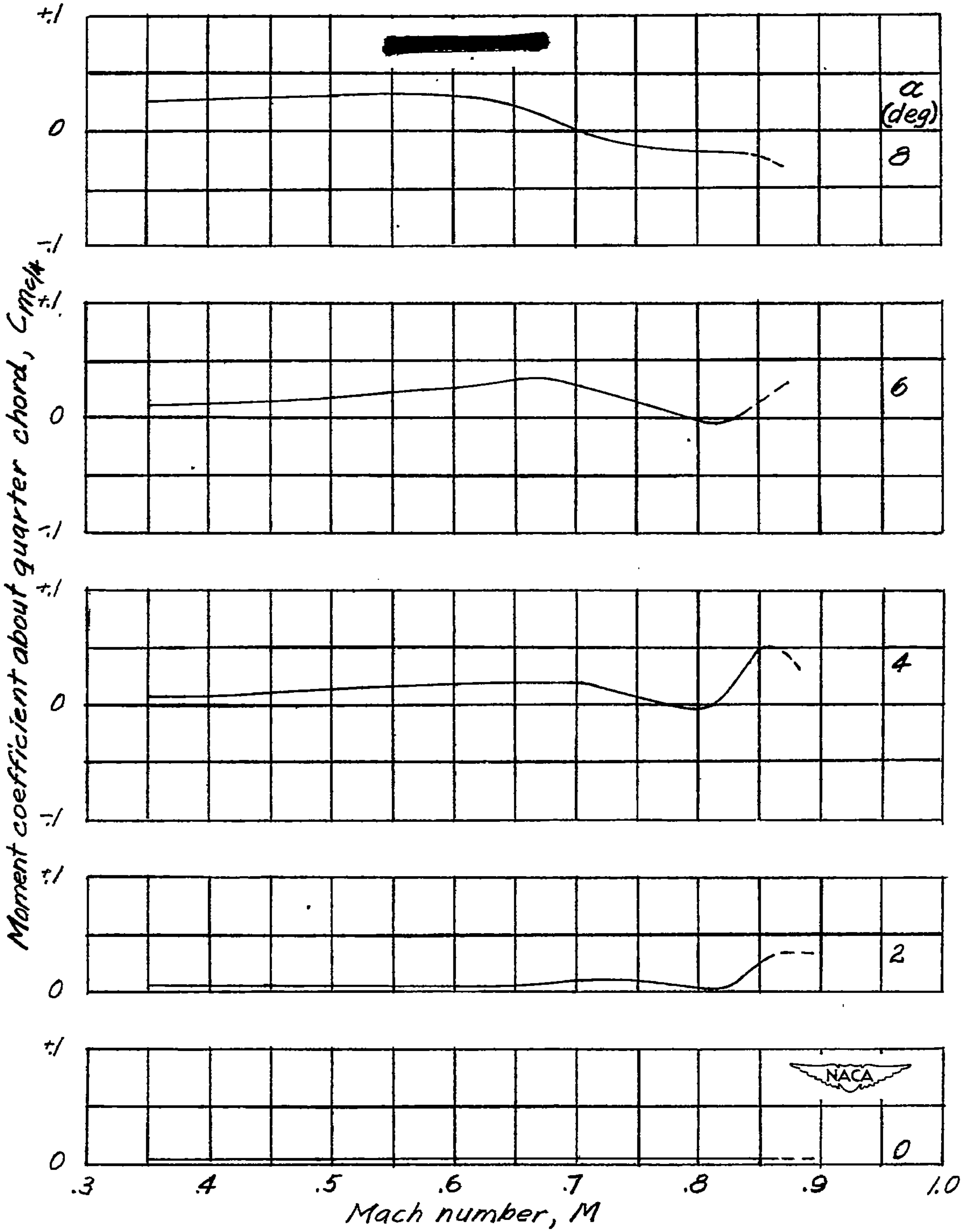
[redacted]



(b) Drag characteristics.

Figure 3.- Continued.

[redacted]

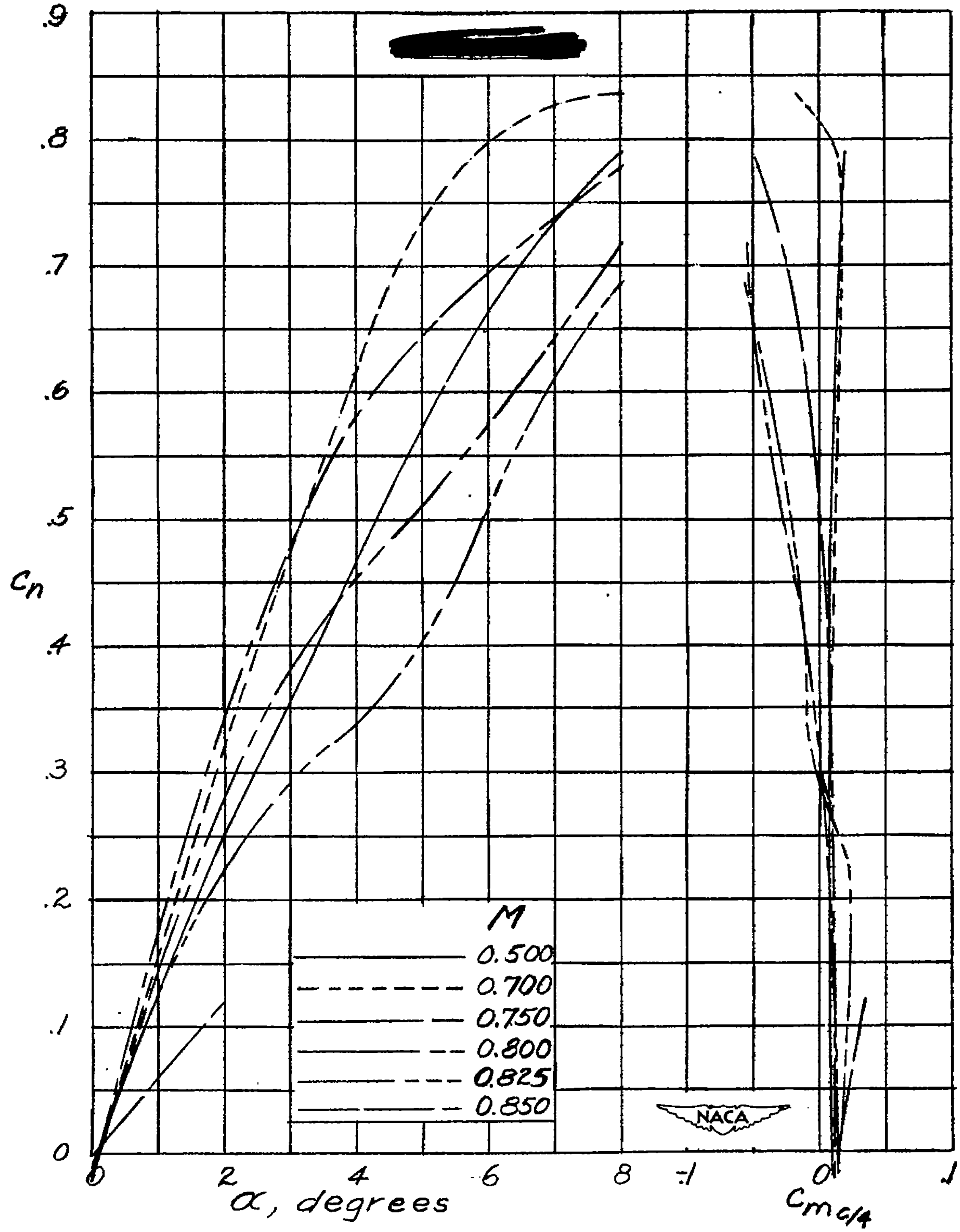


(c) Moment characteristics.

Figure 3.- Concluded.

[redacted]

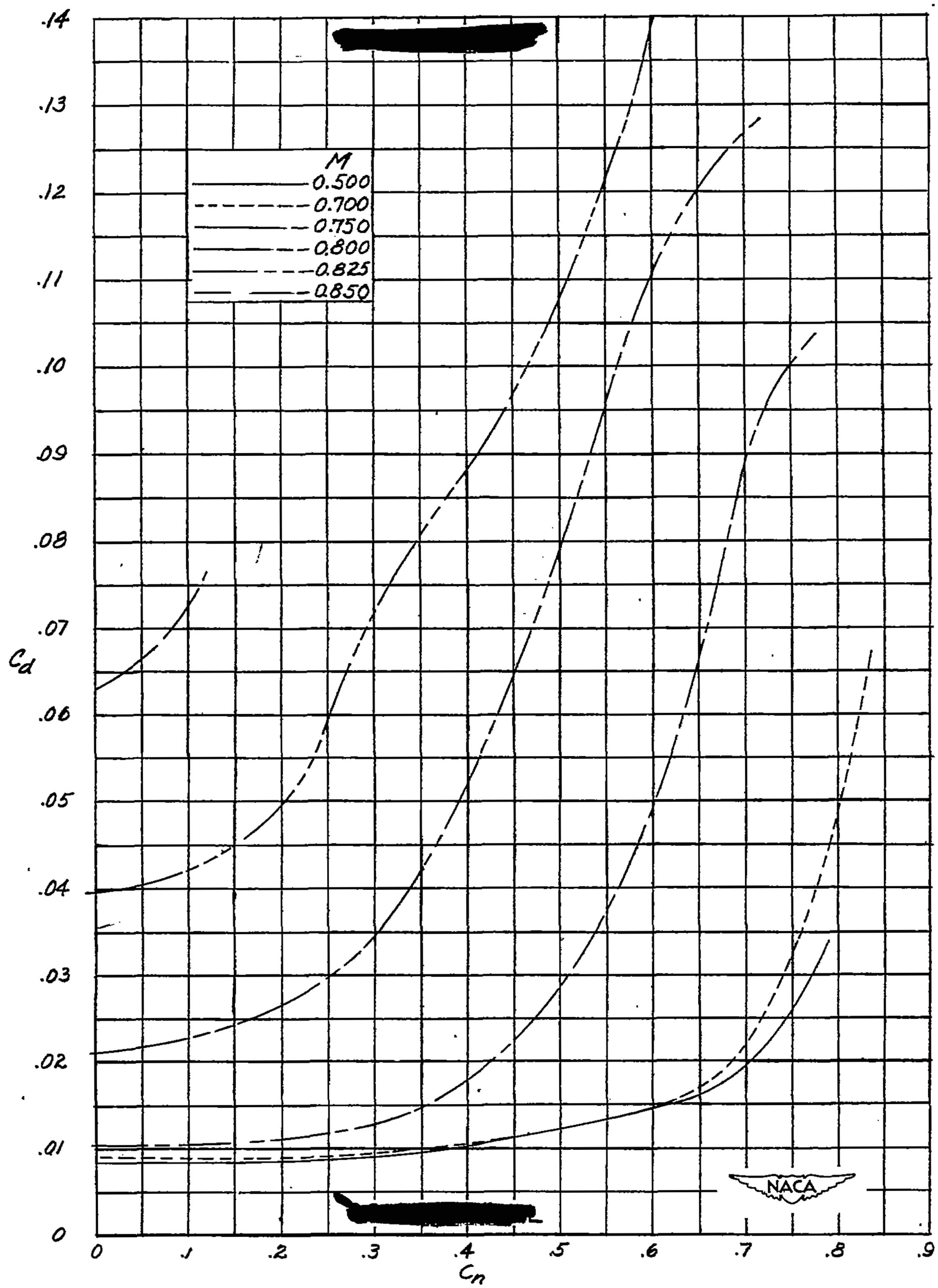
[redacted]



(a) Normal force and moment characteristics.

Figure 4.- Section characteristics for NACA 64_1-012 airfoil at constant Mach number.

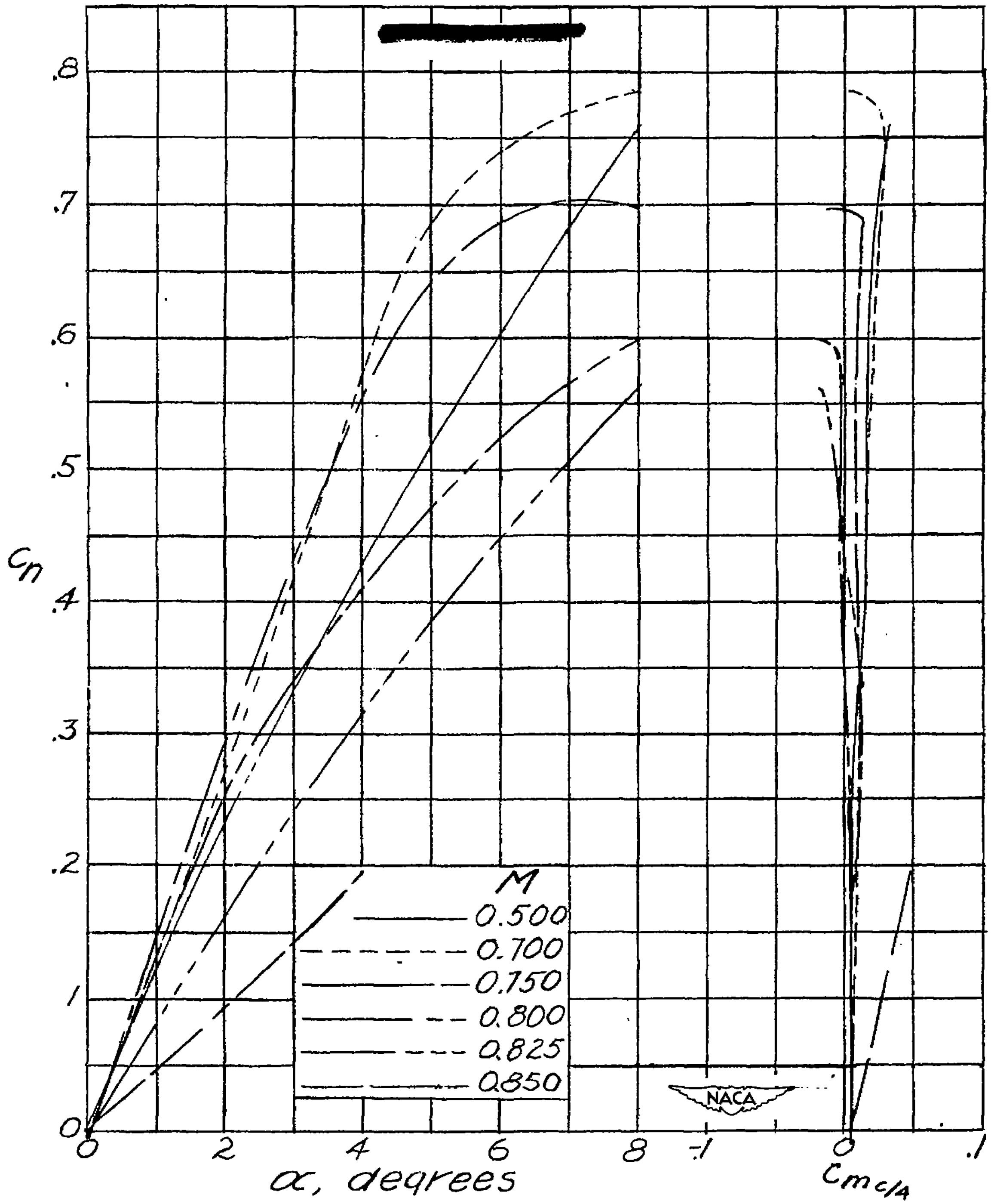
[redacted]



(b) Drag characteristics.

Figure 4.- Concluded.

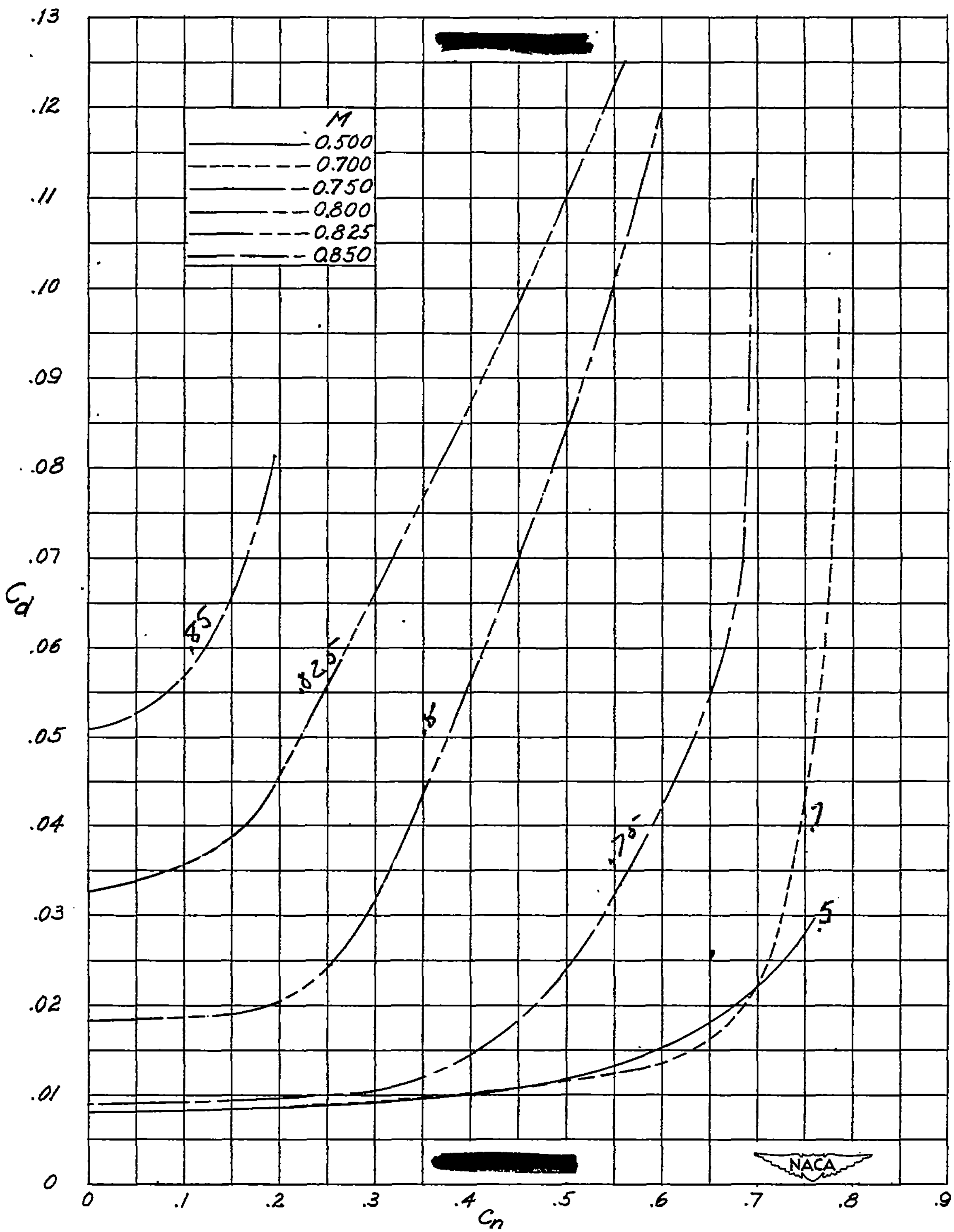
[redacted]



(a) Normal force and moment characteristics.

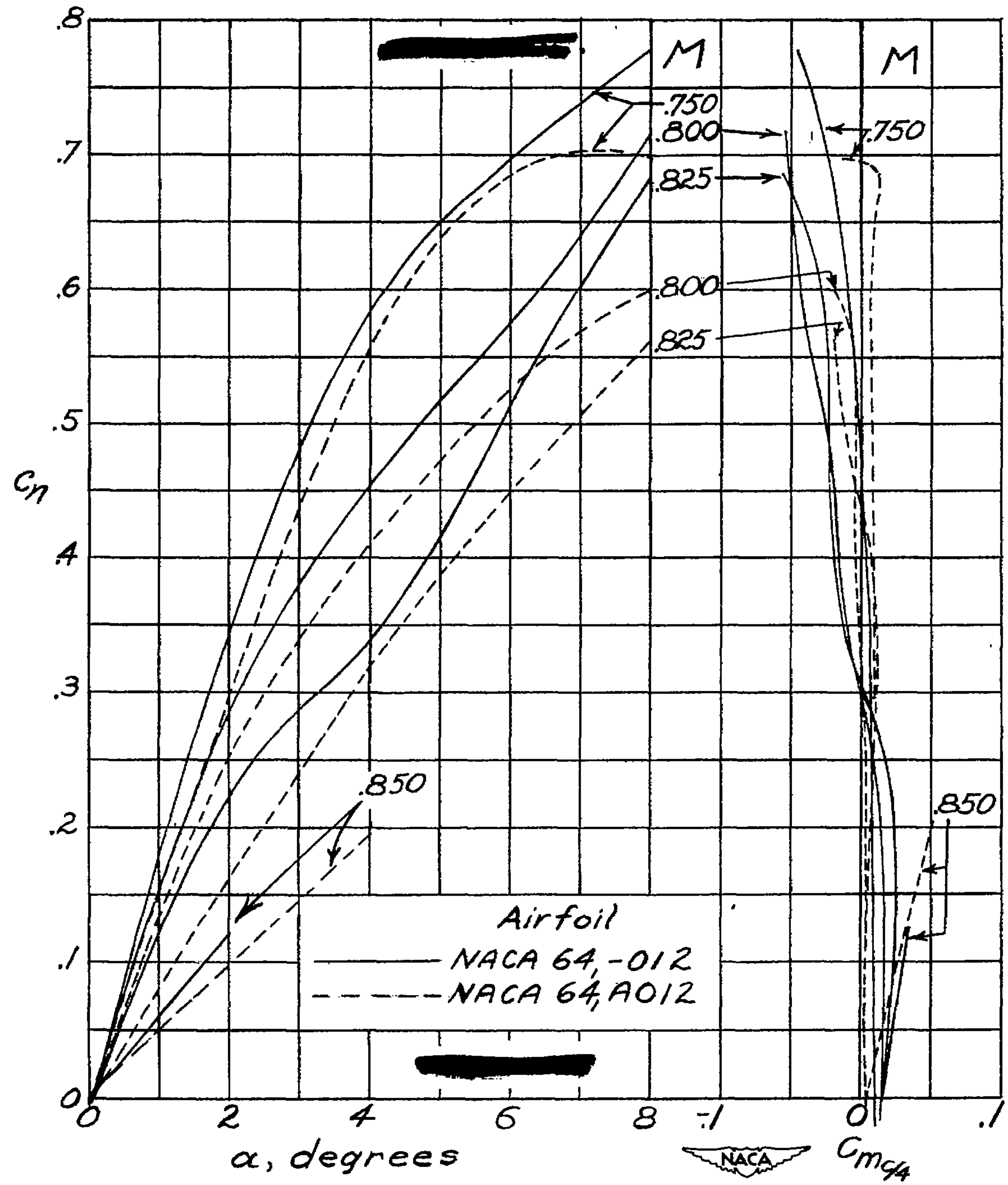
Figure 5.- Section characteristics for NACA 64_1A012 airfoil at constant Mach number.

[redacted]



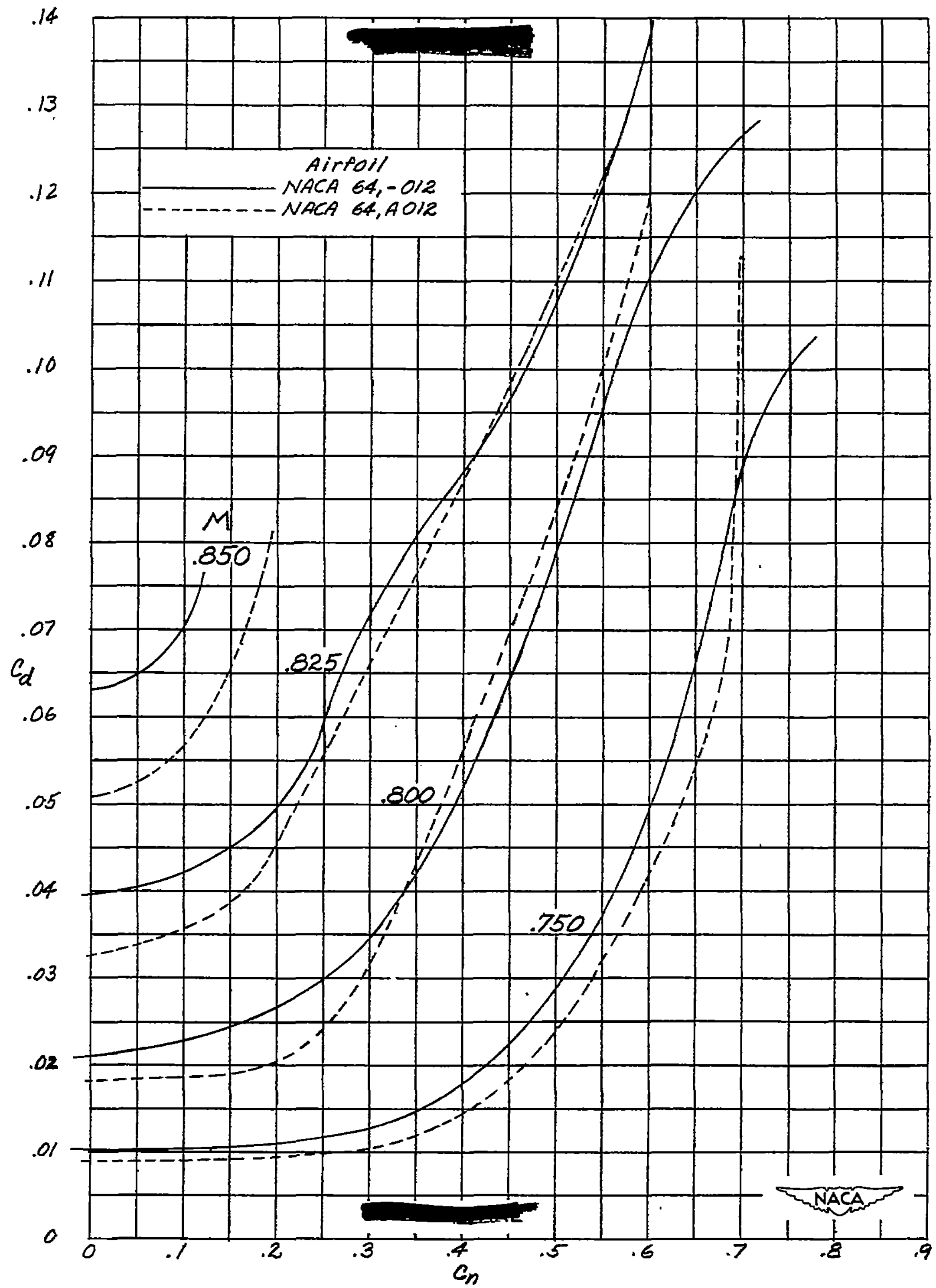
(b) Drag characteristics.

Figure 5.- Concluded.



(a) Normal-force characteristics.

Figure 6.- Section aerodynamic characteristics for NACA 64_1-012 and NACA 64_1A012 airfoils.



(b) Drag characteristics.

Figure 6.- Concluded.