NACA RM L51E08

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RESEARCH MEMORANDUM

LIFT AND DRAG COEFFICIENTS FOR THE BELL X-1 AIRPLANE

(8-PERCENT-THICK WING) IN POWER-OFF

TRANSONIC FLIGHT

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

June 25, 1951
Declassified May 8, 1957

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SUMMARY

Drag coefficients have been determined by the accelerometer method for the Bell X-1 airplane with 8-percent-thick wing and 6-percent-thick tail in power-off flight over a Mach number range of 0.64 to 1.14 and at lift coefficients from 0.1 to 1.2.

These data show that the angle of attack for maximum lift is approximately 6.5° at a Mach number of 0.77 and increases to approximately 17° at a Mach number of 0.95. Maximum lift coefficient increases from 0.79 at a Mach number of 0.77 to 1.2 at a Mach number of 0.95. A maximum in the lift-curve slopes of 0.095 occurs at a Mach number of about 0.77. The drag coefficients for low lift coefficients are approximately six times as high at sonic speeds as at Mach numbers below the drag rise. Maximum lift-drag ratio is approximately 15.5 at a Mach number of 0.75 and drops to slightly less than 4 at sonic speeds.

INTRODUCTION

A flight investigation to explore the lift-coefficient range of the Bell X-1 airplane at transonic speeds has been made at the NACA High-Speed Flight Research Station at Edwards Air Force Base, Calif., in cooperation with the Air Forces. The flights were made with power off at high altitudes where expected buffeting loads would be minimized and the load factors required for high lift would be reduced to a practical level. Instrumentation was included for the evaluation of the over-all buffeting characteristics of the airplane, the horizontal tail loads, the over-all drag of the airplane, and the wing loads. The results of the over-all drag investigation are included herein.

SYMBOLS

a	slope of lift curve per degree $(dC_L/d\alpha)$
a_X	longitudinal acceleration, g
C_D	drag coefficient
C_L	lift coefficient
C_N	normal-force coefficient
C_X	longitudinal-force coefficient
H_p	pressure altitude, feet
L/D	lift-drag ratio
M	Mach number
n	normal acceleration, g
q	dynamic pressure, pounds per square foot
S	wing area, square feet
W	airplane weight, pounds
α	angle of attack between flight path and airplane longitudinal axis, degrees

Subscript:

max	maximum

TEST EQUIPMENT AND PROCEDURE

Airplane

The general physical characteristics of the Bell X-1 airplane used in these tests are given in table 1. A three-view drawing of the airplane is shown in figure 1 and a photograph of the airplane in flight is shown in figure 2.

Instrumentation

The airplane was equipped to determine pressure altitude, Mach number, normal and longitudinal accelerations, and angle of attack with standard NACA photorecording instruments, synchronized by a common timer. The free-stream static and impact pressures used to compute Mach number were obtained with a Kollsman-type airspeed head located on the nose boom of the airplane (fig. 1). The vane-type angle-of-attack transmitter was supported by a strut on the nose boom so that the vane was approximately 17 inches forward of the zero-length station of the fuselage, and 9 inches below and 7 inches to the right of the fuselage center line (fig. 1).

Methods

Lift and drag data were obtained during level flight, pull-ups, turns, and push-overs at altitudes from 22,000 to 70,000 feet in the Mach number range from 0.64 to 1.14. A time history of the data obtained during a typical pull-up is presented in figure 3. The Reynolds number range for these tests was from 2.5×10^6 to 12×10^6 based on the mean aerodynamic chord.

The accelerometer method was used to determine normal- and longitudinal-force coefficients as expressed by the following equations:

$$C_N = \frac{Wn}{qS}$$

$$C_X = \frac{Wa_X}{qS}$$

Lift and drag coefficients were computed from:

$$C_L = C_N \cos \alpha - C_X \sin \alpha$$

$$C_D = C_X \cos \alpha + C_N \sin \alpha$$

A modified SCR 584 radar set and an Askania phototheodolite were used to obtain the data for airspeed calibrations using the method of reference 1.

ACCURACY

Mach numbers were accurate to within ±0.01.

Instrument accuracies for the remaining measurements were as follows:

Normal acceleration, g . . . . ±0.05
Longitudinal acceleration, g   . . . . ±0.005
Angle of attack, degrees . . . .   ±0.2

The angle-of-attack measurements were subject to errors caused by the upwash ahead of the wing and fuselage. Theoretical estimates of these errors were found to be a total of approximately 7 percent at a Mach number of 0.64. A constant error of -0.3° was similarly estimated for the vane in its offset position with respect to the axially symmetric position in the fuselage flow field. These errors all gradually decrease to zero at the speed of sound. Because of the uncertainties involved in these corrections, the angle-of-attack data were not corrected for any of these effects. Errors in pitching velocities were negligible.

The airplane weight was known to within ±1 percent.

RESULTS AND DISCUSSION

The variation of computed lift and drag coefficients with measured angle of attack is shown in figure 4 for various Mach numbers. These data are presented with a maximum spread of ±0.01 in Mach number at each Mach number shown. It can be seen that maximum lift occurs at angles of attack of approximately 6.5° at a Mach number of 0.77 and 17° at a Mach number of 0.95. At Mach numbers of 0.77, 0.81, and 0.87, lift coefficient is approximately constant after maximum lift occurs.

The variation of lift coefficient with Mach number for constant angle of attack is presented in figure 5. Maximum lift coefficient is 0.79 at Mach numbers from 0.77 to 0.81 and increases to 1.2 at a Mach number of 0.95. An increase of approximately 1.5° in angle of attack is required to maintain a lift coefficient of 0.3 between Mach numbers of 0.85 and 0.92. The angle of attack must be increased slightly more than 2° in order to maintain constant lift coefficients of 0.6 and 0.7 between Mach numbers of 0.77 and 0.92.

The slopes of the lift curves as measured between C_L of 0.2 to 0.4 and 0.4 to 0.6 are also presented in figure 5. A maximum slope of 0.095

in the former curve occurs at a Mach number of about 0.77. The lift-curve slopes are affected directly by the errors in angle-of-attack measurement mentioned in the section on accuracy. According to the theoretical estimates of these errors, the measured lift-curve slopes might be expected to be approximately 7 percent low at a Mach number of 0.64. This type of error should decrease to zero at sonic and supersonic speeds.

In figure 6 the cross plot of the variation of drag coefficient with Mach number for constant lift coefficient is shown. The drag rise occurs at Mach numbers of about 0.75 to 0.85 depending on the lift coefficient. The C_D values at low C_L for Mach numbers below the drag rise are approximately one-sixth of the C_D for the same C_L at sonic speeds. The highest drag coefficient measured during this investigation was $C_D = 0.48$ near $C_{L_{max}}$ at a Mach number of 0.95 as previously shown in figure 4(g). This is approximately seven times the drag coefficient at a C_L of 0.2. The dashed line representing the drag coefficient for maximum lift may be considered a practical operating limit for the airplane, above which the drag increases while the lift remains constant or decreases.

The effect of Mach number on lift-drag ratio at constant lift coefficient is shown in figure 7. Values of L/D as high as 15.5 are found at Mach numbers below the drag rise while at sonic speeds maximum L/D is less than 4. The value of C_L for $(L/D)_{max}$ is approximately 0.4 at Mach numbers up to 0.9 and increases to a C_L value of approximately 0.6 at sonic speeds.

CONCLUSIONS

From lift and drag data obtained with the Bell X-1 airplane (8-percent-thick wing and 6-percent-thick tail) in power-off transonic flight, the following conclusions may be drawn:

1. The lift curves are flat-topped at Mach numbers of 0.77, 0.81, and 0.87.

2. The angle of attack for maximum lift is approximately 6.5° at a Mach number of 0.77 and increases to approximately 17° at a Mach number of 0.95.

3. Maximum lift coefficient increases from 0.79 at a Mach number of 0.77 to 1.2 at a Mach number of 0.95.

4. A maximum value of 0.095 in the lift-curve slope occurs at a Mach number of about 0.77.

5. The drag coefficients at low lift coefficients are approximately six times as high at sonic speeds as at Mach numbers below the drag rise. The highest drag coefficient measured during the investigation was approximately 0.48 at a Mach number of 0.95.

6. Maximum lift-drag ratio is approximately 15.5 at a Mach number of 0.75 and drops to slightly less than 4 at sonic speeds.

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    National Advisory Committee for Aeronautics
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REFERENCE

1. Zalovcik, John A.: A Radar Method of Calibrating Airspeed Installations on Airplanes in Maneuvers at High Altitudes and at Transonic and Supersonic Speeds. NACA Rep. 985, 1950. (Formerly NACA TN 1979.)

TABLE 1.- PHYSICAL CHARACTERISTICS OF THE BELL X-1 AIRPLANE

WITH 8-PERCENT WING AND 6-PERCENT TAIL

Engine . . . . Reaction Motors Inc.
Model 6000C4

Rated sea-level thrust, each of the four rocket
cylinders, lb 1500

Propellants:
  Fuel
    Ethyl alcohol, percent 75
    Water, percent 25
  Oxidant . . . . Liquid oxygen

Propellant flow (approx.), lb/sec/cylinder 7.9

Fuel feed . . . . High-pressure nitrogen gas

Weight
  Full, lb 12,400
  Empty, lb 7,340

Center-of-gravity travel, percent
  mean aerodynamic chord . . . . Maximum: 22.1 percent full
                                             load to 25.3 percent empty

Wing:
  Airfoil section . . . . NACA 65-108(a = 1)
  Area (including section through fuselage), sq ft 130
  Span, ft 28
  Aspect ratio 6
  Mean aerodynamic chord, in. 57.71
  Location aft of leading edge of root chord, in. 6.58
  Root chord, in. 74.2
  Tip chord, in. 37.1
  Taper ratio 2:1
  Incidence, deg
    Root 2.5
    Tip 1.5
  Sweepback (leading edge), deg 5.05
  Dihedral (chord plane), deg 0

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TABLE 1.- PHYSICAL CHARACTERISTICS OF THE BELL X-1 AIRPLANE

WITH 8-PERCENT WING AND 6-PERCENT TAIL - Concluded

Horizontal tail:
  Airfoil section . . . . NACA 65-006
  Area, sq ft 26.0
  Span, ft 11.4

Vertical tail
  Area (excluding dorsal fin), sq ft 25.6
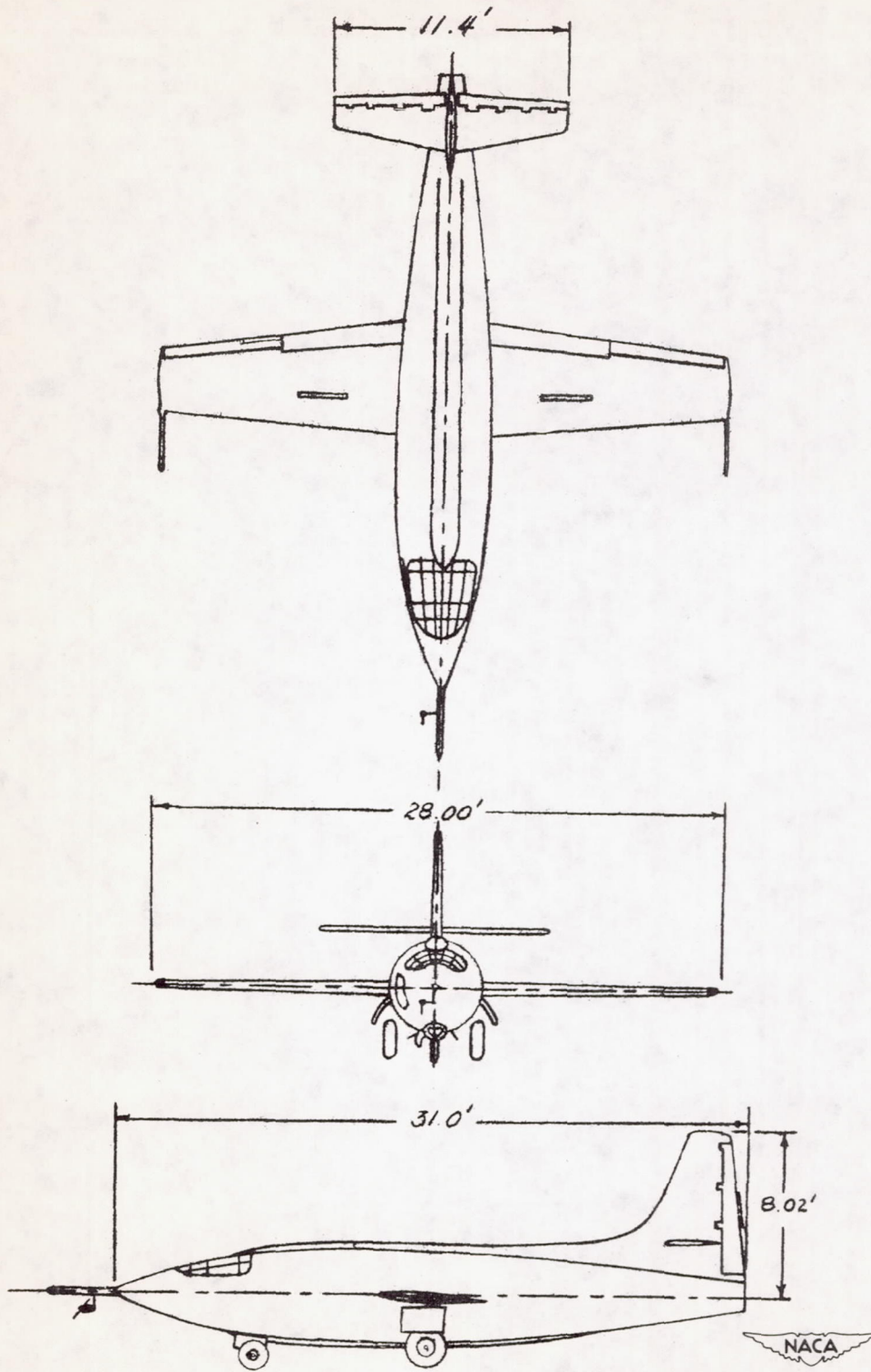
Figure 1.- Three-view drawing of X-1 airplane showing location of angle-of-attack vane.
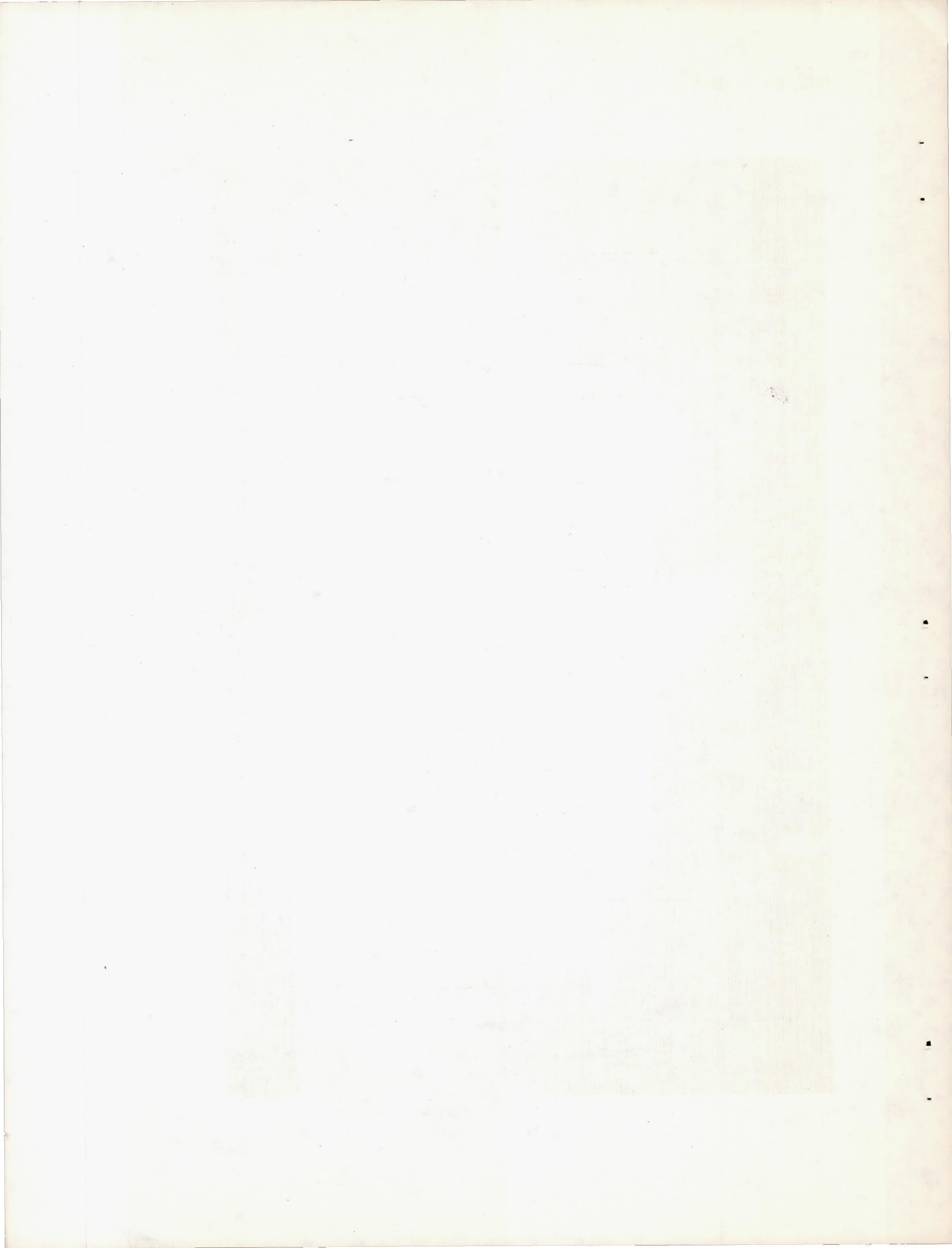
Figure 2.- Photograph of the X-1 airplane in flight.
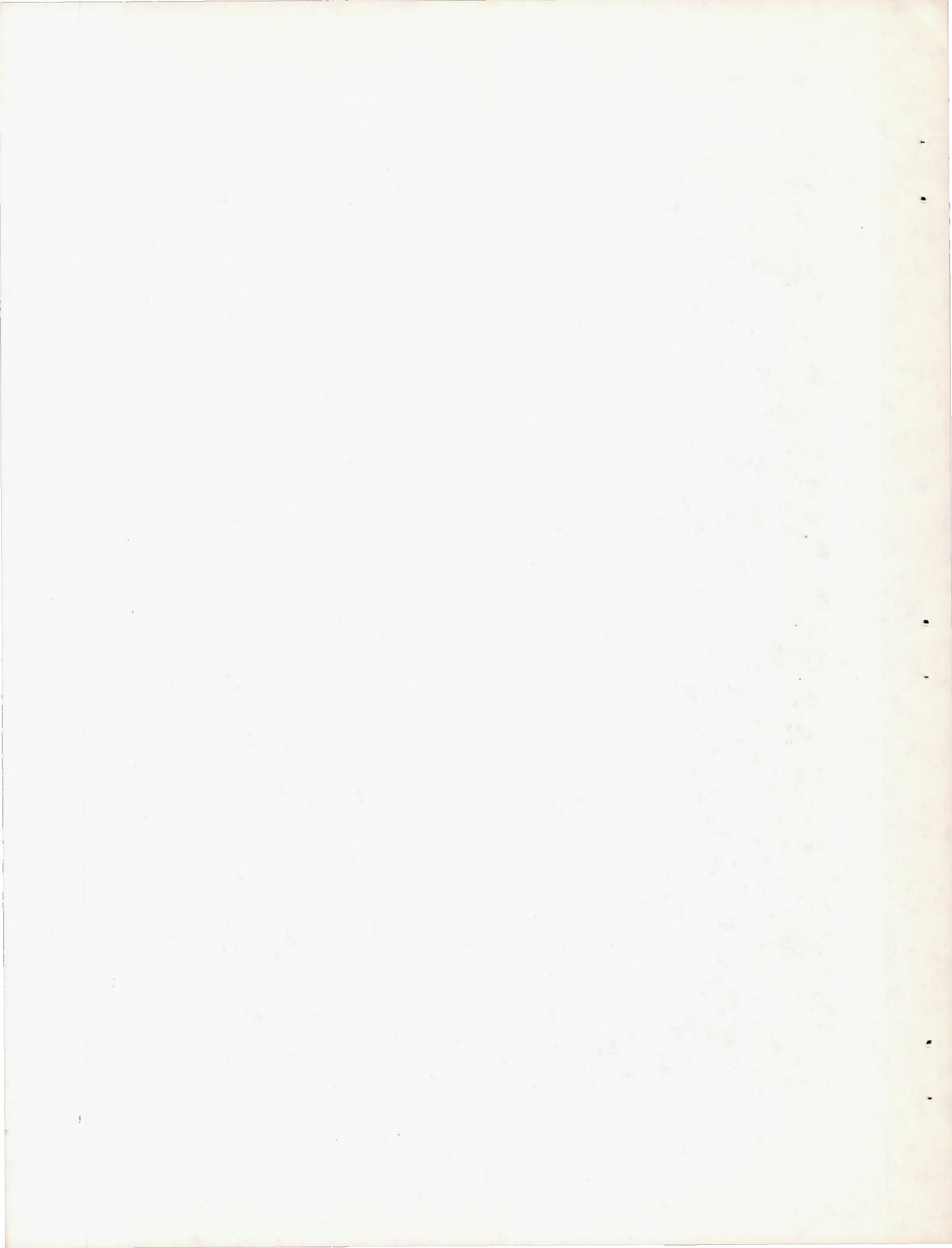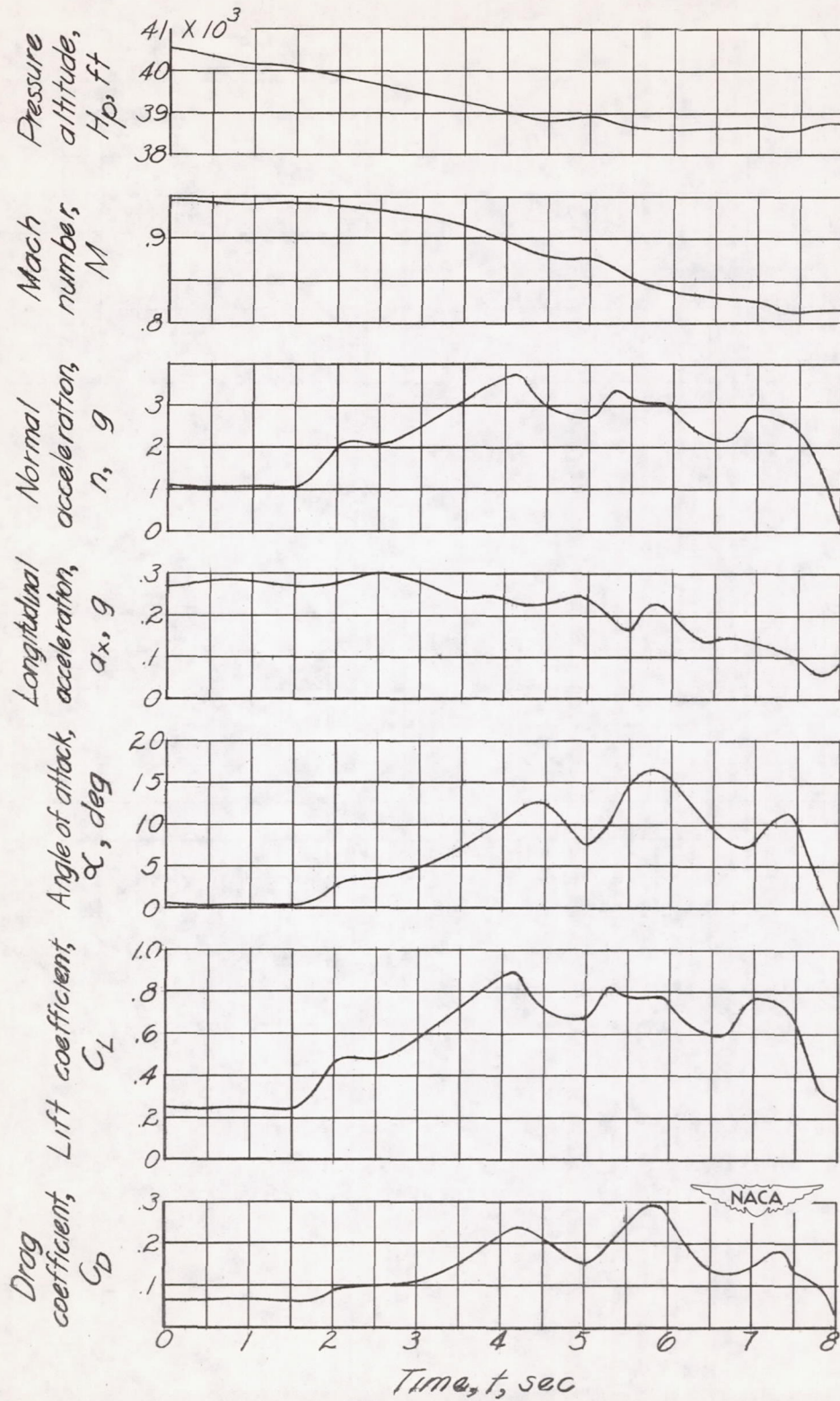
Figure 3.- Time history of a typical power-off pull-up at transonic Mach numbers.

(a) M = 0.64.   (b) M = 0.73.
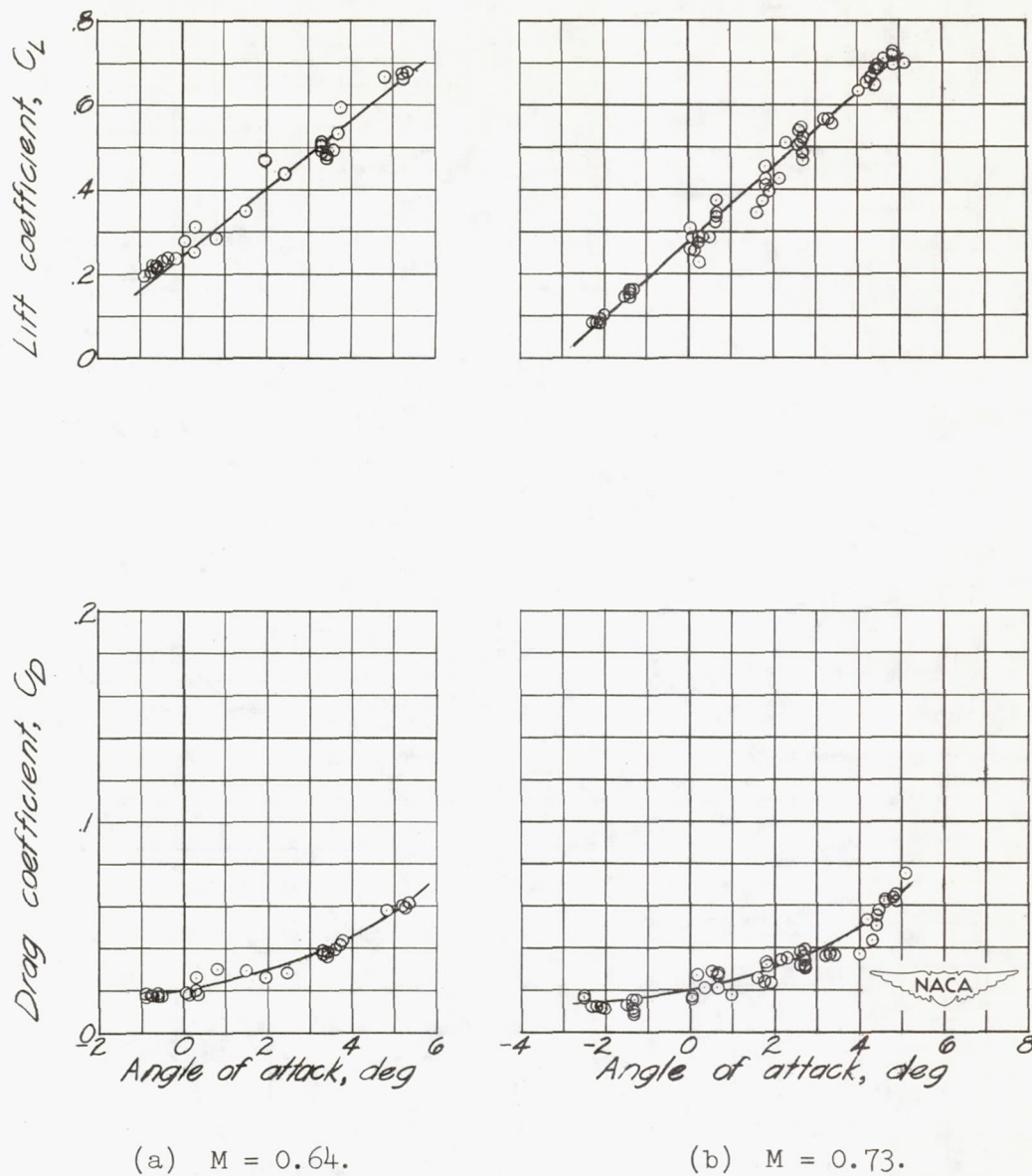
Figure 4.- Variation of lift coefficient and drag coefficient with angle
of attack for constant Mach number.
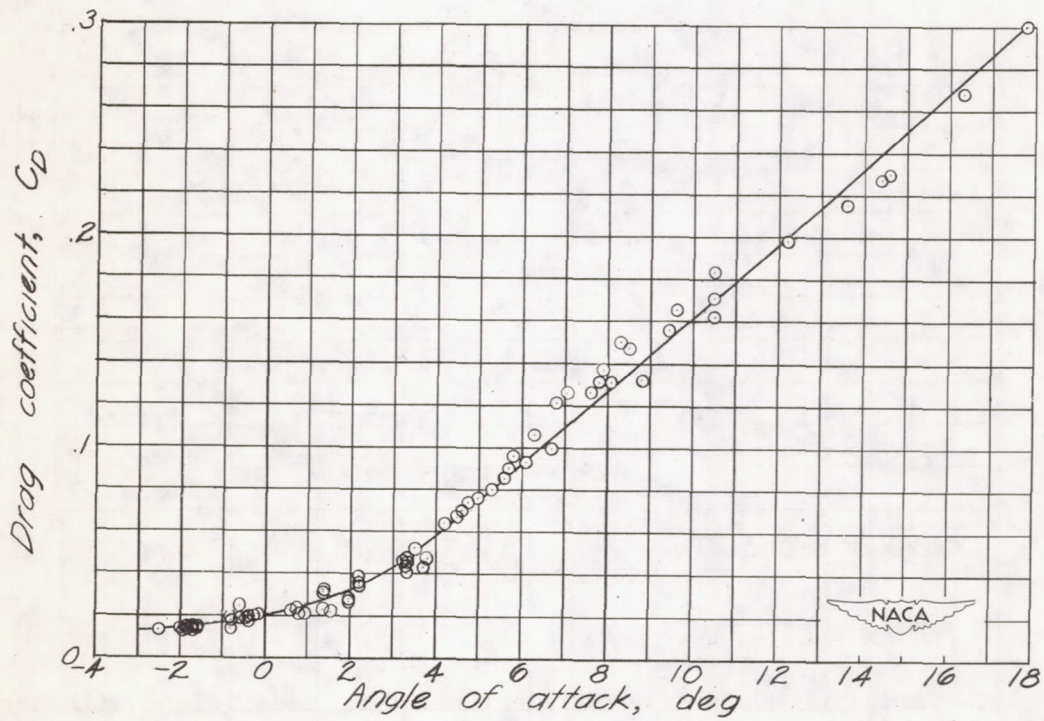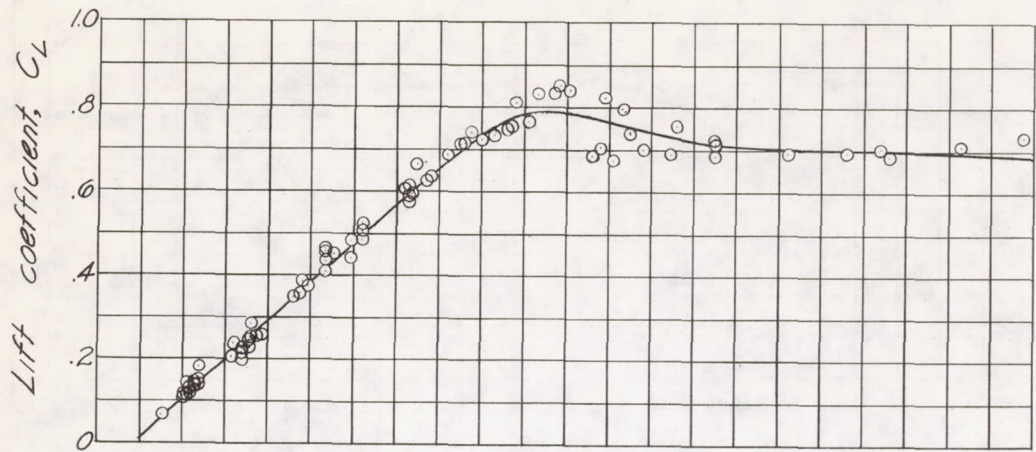
(c) M = 0.77.

Figure 4.- Continued.
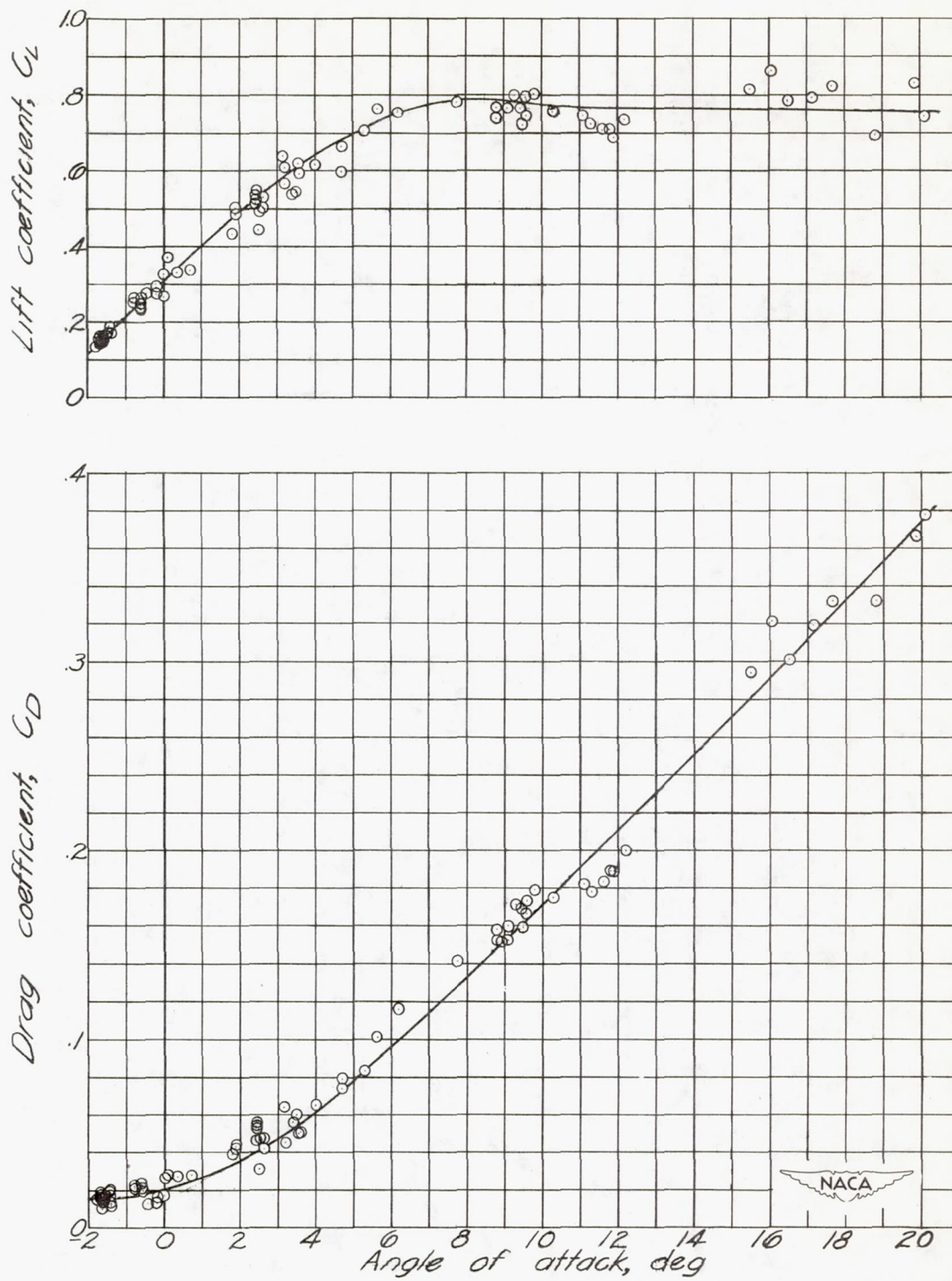
(d) M = 0.81.

Figure 4.- Continued.
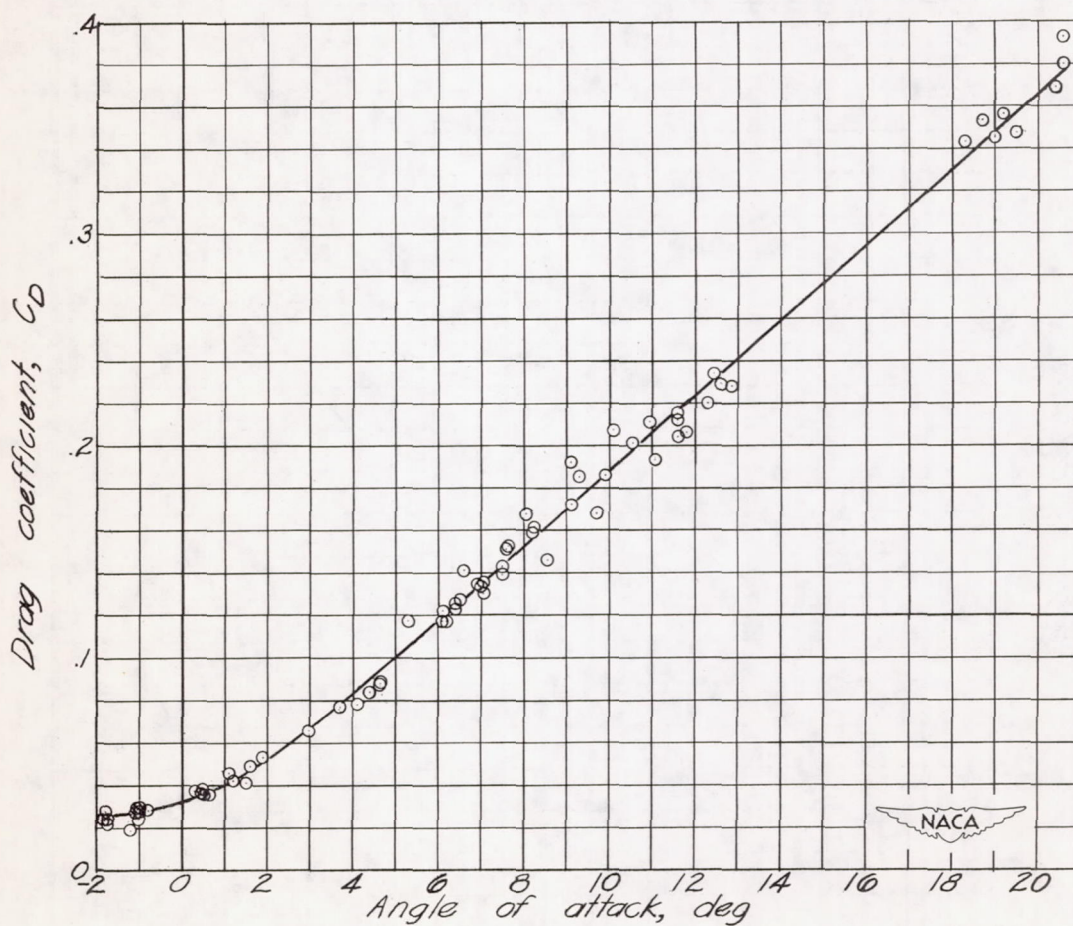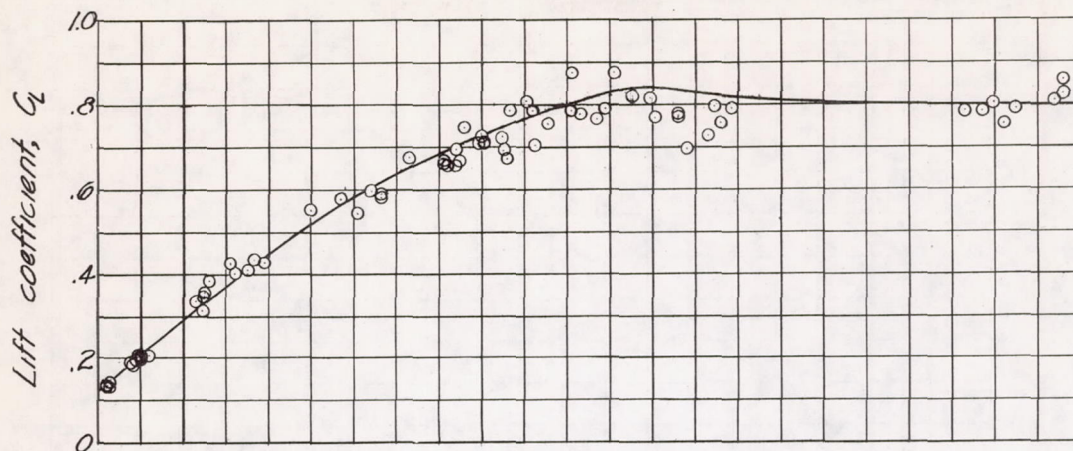
(e)   M = 0.87.

Figure 4.- Continued.
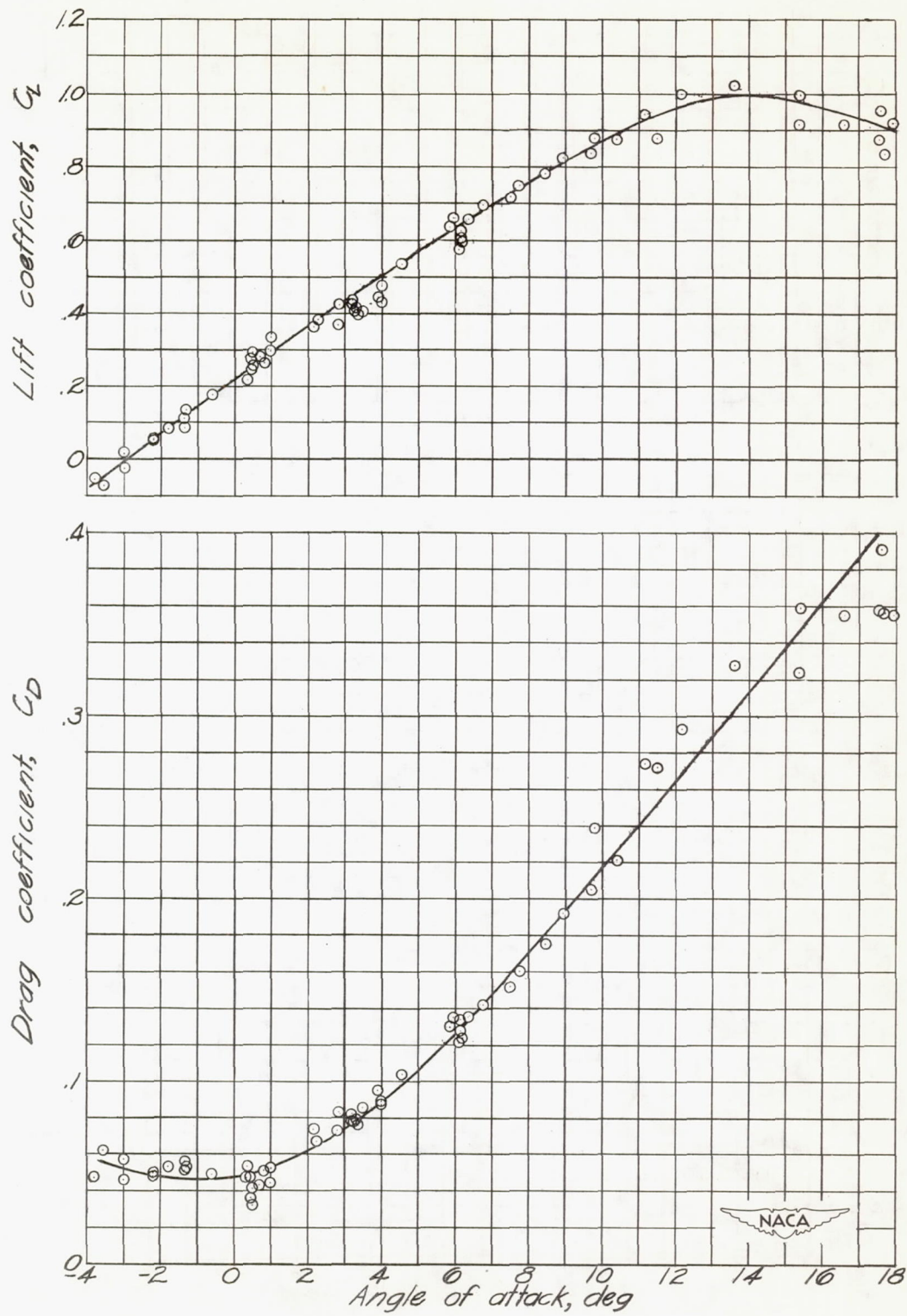
(f)   M = 0.91.

Figure 4.- Continued.
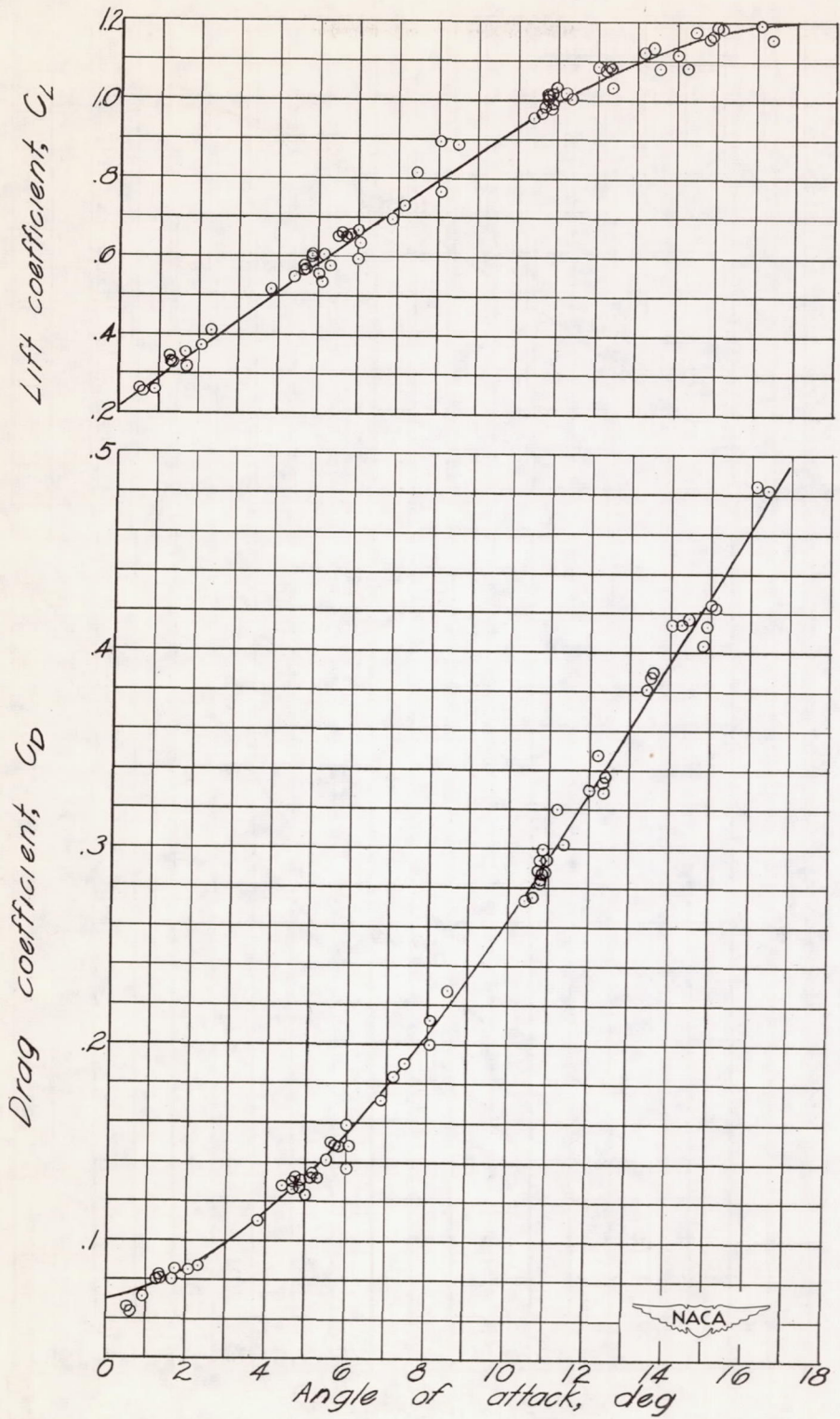
(g) M = 0.95.

Figure 4.- Continued.
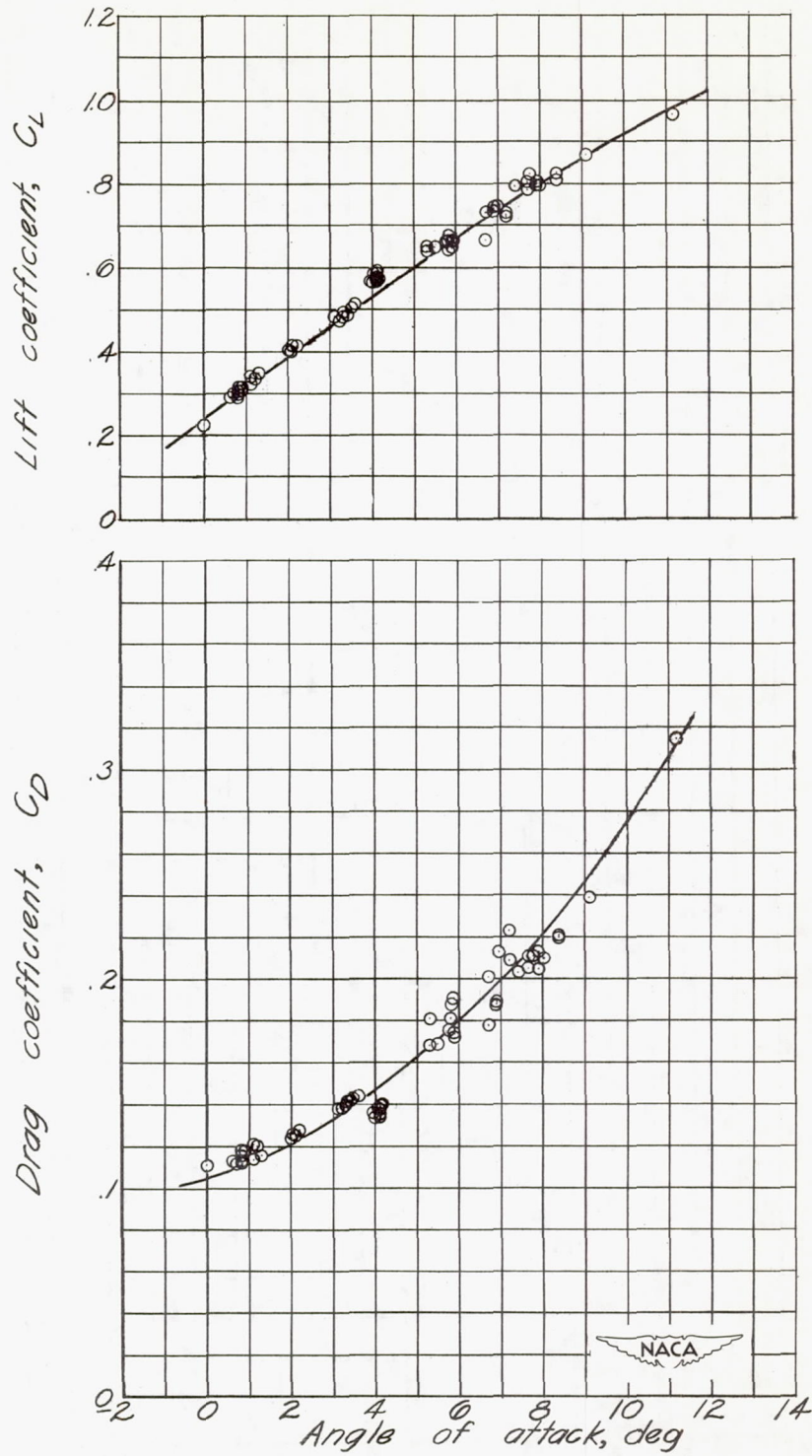
(h)   M = 1.01.

Figure 4.- Continued.
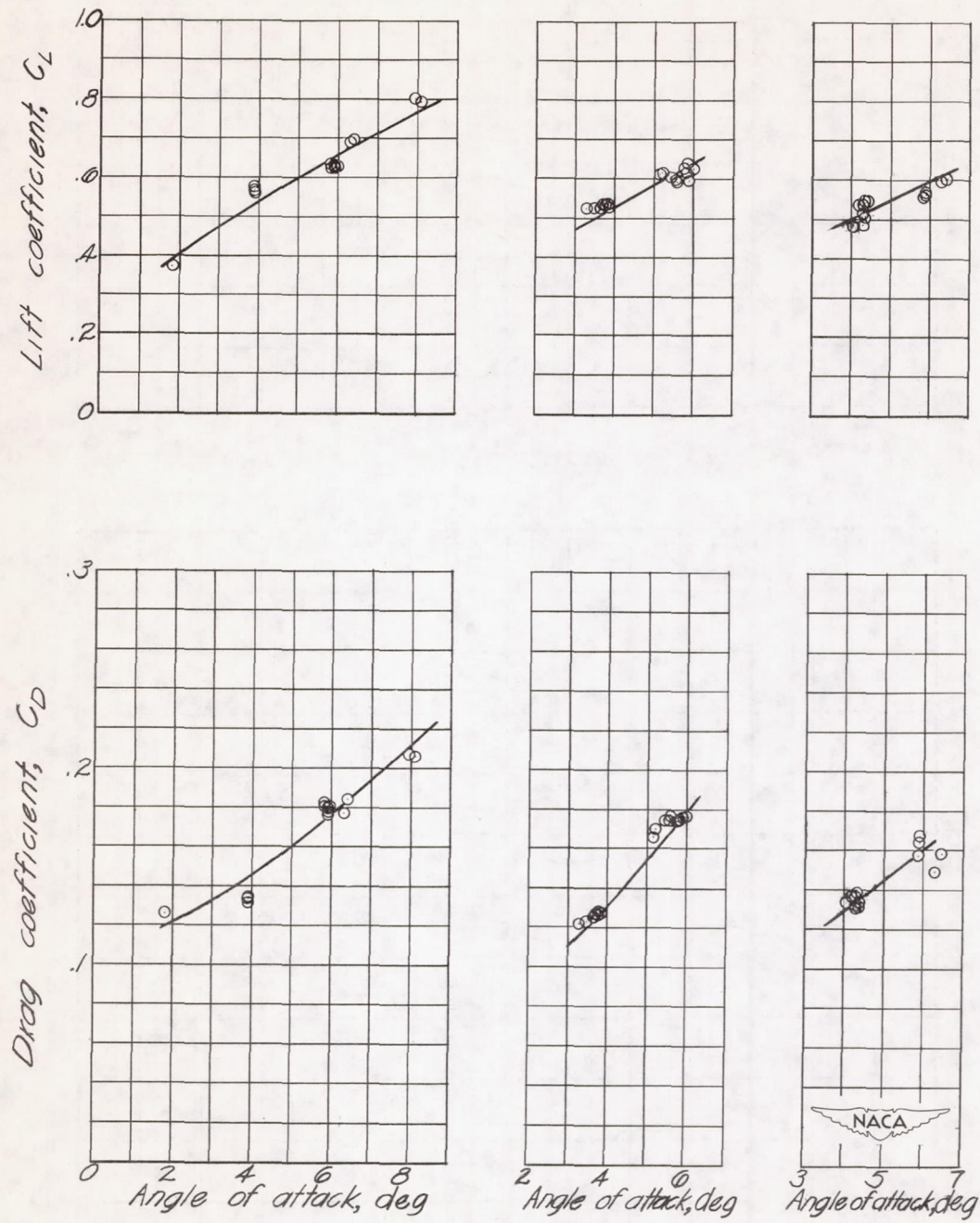
(i) M = 1.05.   (j) M = 1.10.   (k) M = 1.14.
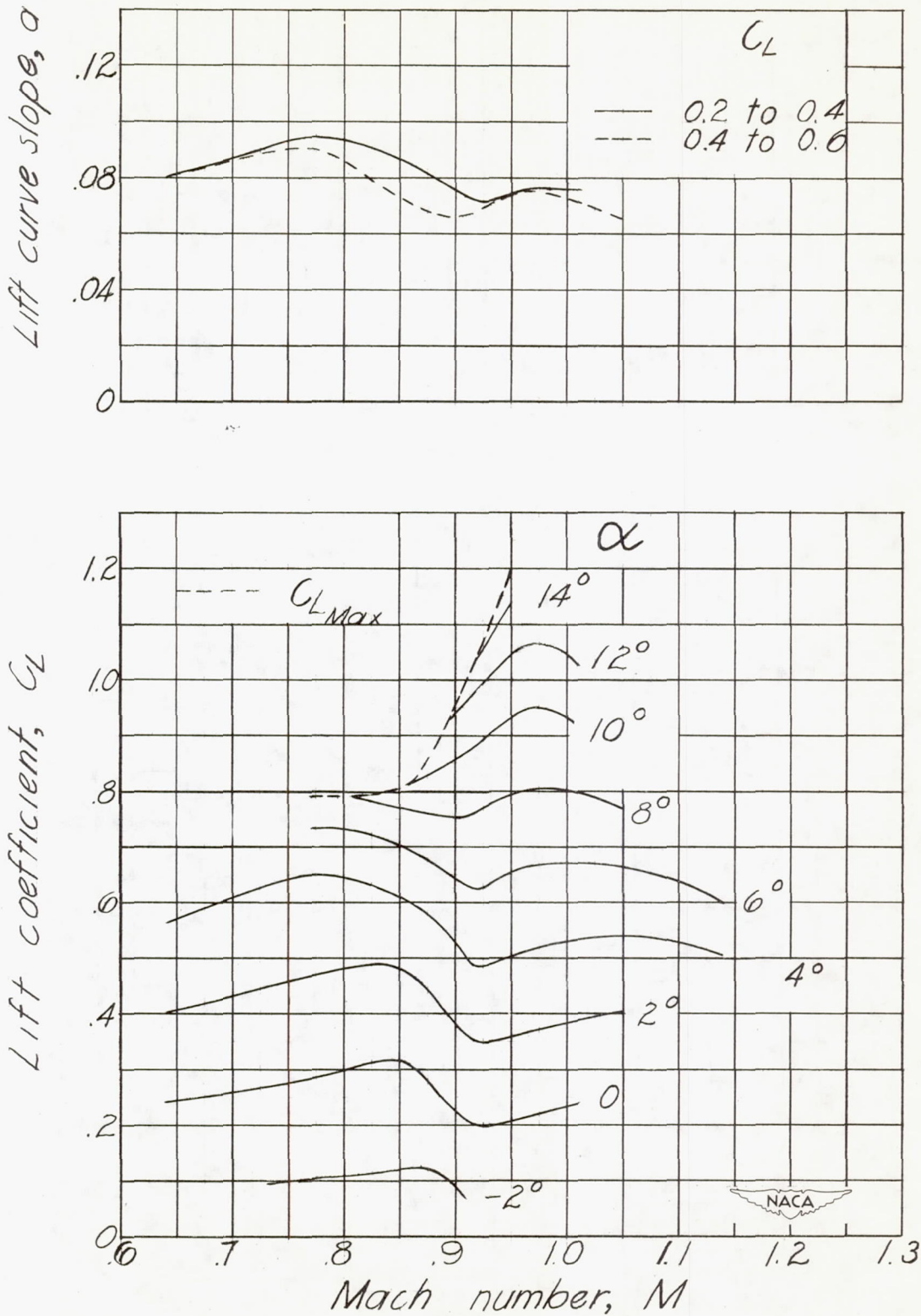
Figure 4.- Concluded.

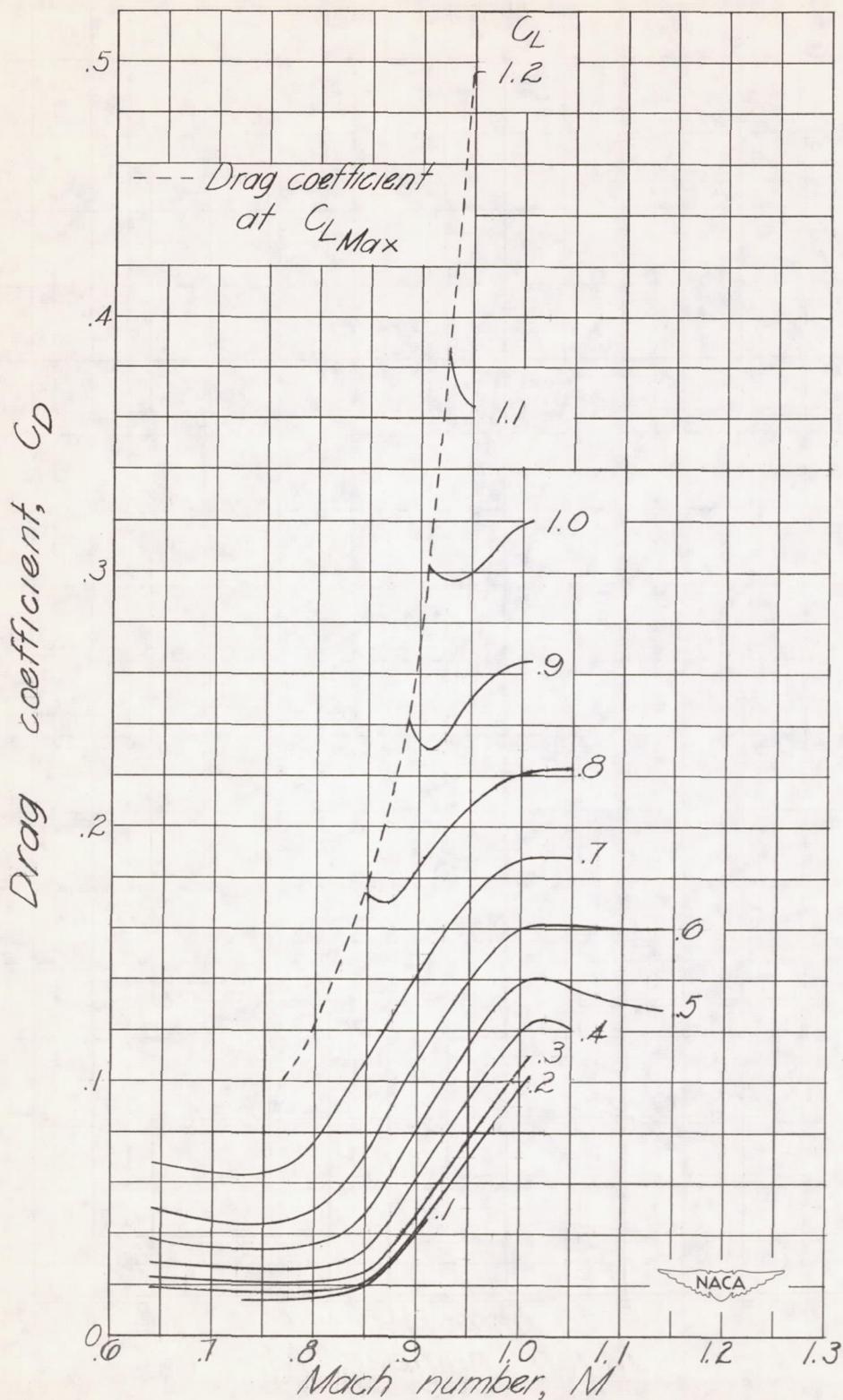Figure 5.- Variation of lift coefficient and lift-curve slope with
Mach number.

Figure 6.- Variation of drag coefficient with Mach number for constant
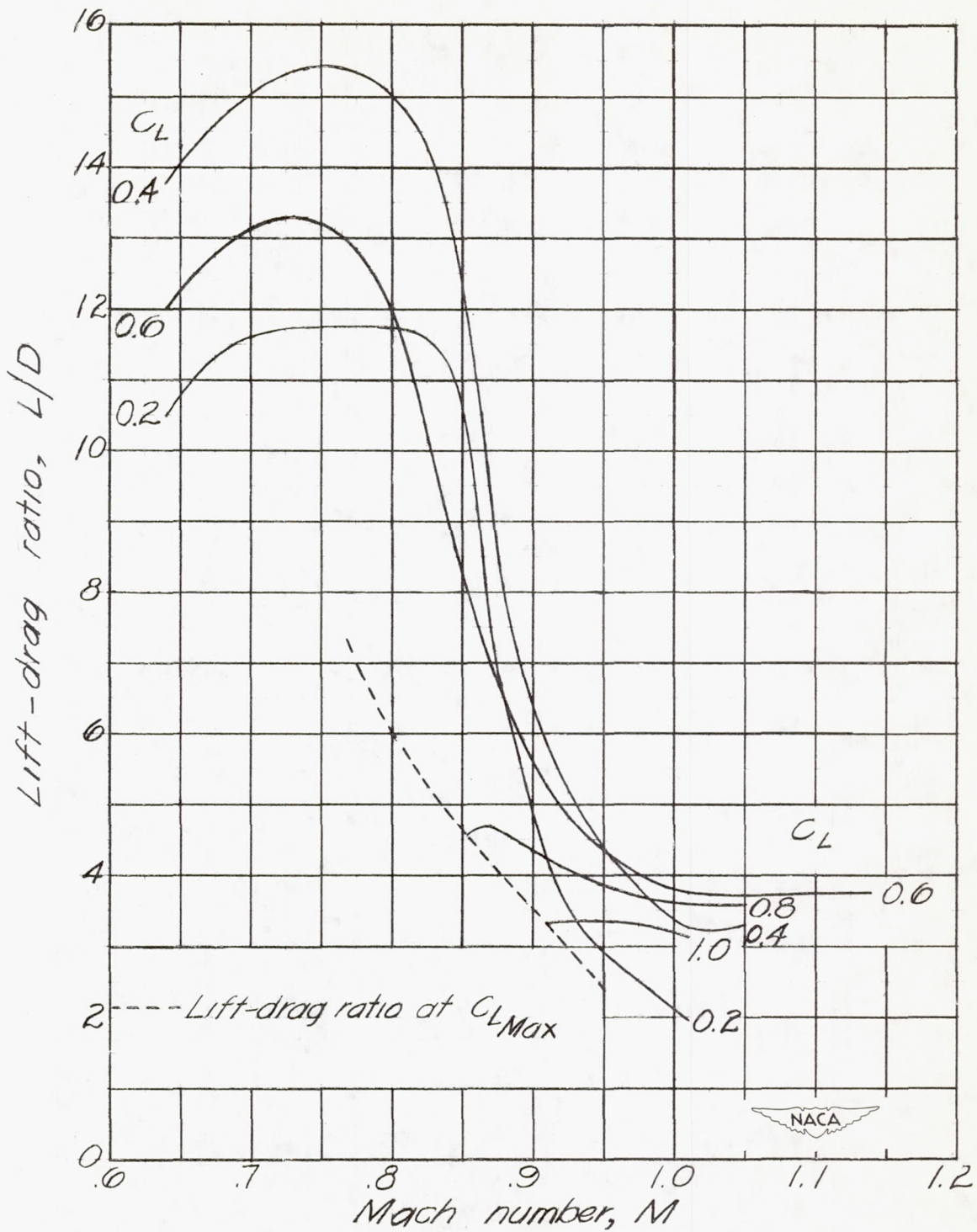lift coefficient.

Figure 7.- Variation of lift-drag ratio with Mach number for constant
lift coefficient.