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RESEARCH MEMORANDUM

FLIGHT MEASUREMENT OF THE STABILITY CHARACTERISTICS OF THE DOUGLAS D-558-1 AIRPLANE (BUAERO NO. 37971) IN SIDESLIPS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
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SUMMARY

Measurements have been made of the stability characteristics of the D-558-1 airplane in steadily increasing sideslips at various Mach numbers from 0.50 to 0.80 at an altitude of 10,000 feet and at Mach numbers from 0.50 to 0.84 at an altitude of 30,000 feet. The results of these tests show that the apparent directional stability of the airplane is high and increases with increasing Mach number and dynamic pressure. The dihedral effect is positive at all speeds, there is little or no change in pitching moment with sideslip, and the cross-wind force is positive.

INTRODUCTION

The NACA is engaged in a flight-research program in the transonic speed range utilizing two Douglas D-558-1 airplanes which were procured for use by the NACA in high-speed flight research. One of these airplanes (BuAero No. 37971) is being used for the investigation of stability and control characteristics and over-all aerodynamic loads. The other airplane (BuAero No. 37972) is being used for detailed measurements of the pressure distribution over the wing and horizontal tail. The present report covers results of measurements of the static directional and lateral stability in sideslips made with the D-558-1 airplane (BuAero No. 37971) as part of the stability and control program.

SYMBOLS

q_c impact pressure, pounds per square foot

M Mach number

V_i indicated airspeed, miles per hour

δ_r rudder position, degrees

β sideslip angle, degrees

AIRPLANE

The Douglas D-558-1 airplane is a single-place low-wing monoplane powered by a single General Electric TG-180 turbojet engine. General views of the airplane are given in figures 1(a), (b), and (c). A three-view layout of the airplane is given in figure 2. Detailed specifications of the airplane are given in reference 1.

INSTRUMENTATION

Standard NACA recording instruments were used to measure the various quantities necessary to determine the stability and control characteristics of the subject airplane. In addition, a Consolidated oscillograph was installed to record the loads as measured by the strain gages installed in the wing and horizontal tail. All records were synchronized by means of a common timing circuit. The instruments used and the quantities measured follow:

Recording Instrument	Quantity Measured
Airspeed-altitude recorder	Indicated airspeed, pressure altitude
Three-component accelerometer	Normal, longitudinal, and transverse acceleration
Angular velocity recorder	Rolling velocity
Yaw-angle recorder	Sideslip angle
Wheel-force recorder	Aileron and elevator force
Pedal-force recorder	Rudder-pedal force
Control-position recorder	Aileron, elevator, rudder, and stabilizer position
Consolidated oscillograph	Wing bending moment and shear load, horizontal-tail shear load
Timer	Time

The yaw vane used with the yaw-angle recorder was mounted a distance of 1 chord ahead of the left wing tip. The airspeed head was mounted on a boom on the right wing tip of such length that the static orifices were at a distance of 1 chord ahead of the wing leading edge.

TESTS, RESULTS, AND DISCUSSION

The results of the airspeed calibration flights made on the D-558-1 airplane have not been completely evaluated as yet. The results of a calibration of the error in static pressure by flying past a reference landmark indicate, however, that the error in measured static pressure is of the order of $0.01q_c$ up to a Mach number of approximately 0.78. Results of the airspeed calibration of the XS-1 which has a similar installation indicate that the error in Mach number up to $M = 0.84$, the limit of the present tests, is of the order of 1 percent or less (reference 2).

The static directional stability of the D-558-1 airplane was measured in gradually increasing sideslips which were made by slowly deflecting the ailerons and using sufficient rudder and elevator to maintain straight flight. Tests were made at pressure altitudes of approximately 10,000 and 30,000 feet and covered a Mach number range from 0.50 to 0.80 at 10,000 feet and from 0.50 to 0.84 at 30,000 feet.

The results of the tests made at 10,000 feet are given in figures 3(a) to 3(f) whereas results obtained at 30,000 feet are in figures 4(a) to 4(g). In these figures, rudder, aileron, and elevator position and force and angle of bank are plotted as functions of sideslip angle. The values of bank angle were obtained from measurements of the transverse acceleration. No measurements of rudder force were obtained, however, at 10,000 feet altitude. The variation of rudder position and force with sideslip angle gives a measure of the static directional stability, control fixed and free. A measure of the dihedral effect, control fixed and control free, is afforded by the variation of aileron position and force with sideslip angle. The pitching moment due to sideslip is illustrated by the variation of elevator position and force with sideslip angle and the variation of angle of bank with sideslip angle gives a measure of the cross-wind-force characteristics.

The data given in figures 3 and 4 show that the directional stability of the D-558-1 is high throughout the speed range tested. The dihedral effect of the airplane is positive, although low, throughout the speed range. There are some discontinuities in the variation of aileron force and position with sideslip angle near zero sideslip. It is believed that these discontinuities are caused by the friction in the control system in the case of the force measurements and caused by some play in the aileron linkage between the aileron and the point of measurement in the case of position measurements. The slopes of these curves, however, should afford a good measure of the dihedral effect. There appears to be little or no change in pitching moment with sideslip angle for all sideslips presented. The cross-wind force was positive; that is, right bank accompanied right sideslip.

A comparison of the directional stability data presented in figures 3 and 4 shows that there is a variation in the directional stability parameter $d\delta_r/d\beta$ with Mach number and indicated airspeed. To illustrate this fact, figure 5 was prepared to show the variation of $d\delta_r/d\beta$ with Mach number and indicated airspeed for the two test altitudes (10,000 and 30,000 ft). In this figure, it can be seen that the increase in the apparent directional stability with increasing speed is a function of Mach number. The increase in apparent directional stability at any given Mach number as the altitude is decreased is probably caused by a decrease in rudder effectiveness. This decrease in rudder effectiveness is probably caused by distortion of the vertical tail and fuselage at the higher values of dynamic pressure encountered at the lower altitude.

CONCLUSIONS

The results of measurements of the stability characteristics of the D-558-1 airplane in steadily increasing sideslips at various Mach numbers from 0.5 to 0.80 at 10,000 feet altitude and from 0.5 to 0.84 at 30,000 feet altitude show the following:

1. The apparent directional stability of the D-558-1 airplane is high throughout the speed range tested, but is greater at low altitude than at high altitude at any given Mach number. There is also an increase in directional stability with increasing Mach number.

2. The dihedral effect was positive but low throughout the speed range tested.

3. There was little or no change in pitching moment with sideslip and the cross-wind force was positive.

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REFERENCES

1. Williams, Walter C.: Limited Measurements of Static Longitudinal Stability in Flight of Douglas D-558-1 Airplane (BuAero No. 37971). NACA RM No. L8E14, 1948.

2. Drake, Hubert M., McLaughlin, Milton D., and Goodman, Harold R.: Results Obtained During Accelerated Transonic Tests of the Bell XS-1 Airplane in Flights to a Mach Number of 0.92. NACA RM No. L8A05a, 1948.

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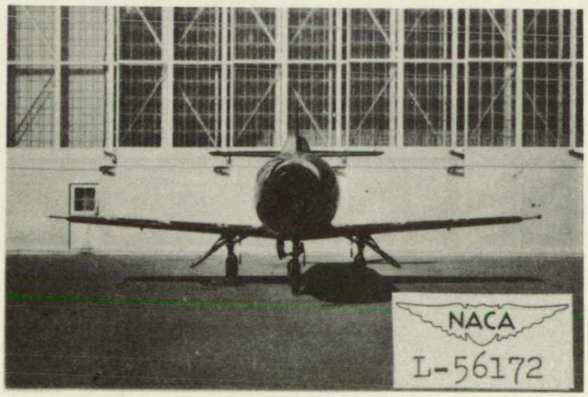
(a) Side view.

(b) Three-quarter front view.



(c) Front view.

Figure 1.- Photographs of D-558-1 airplane.

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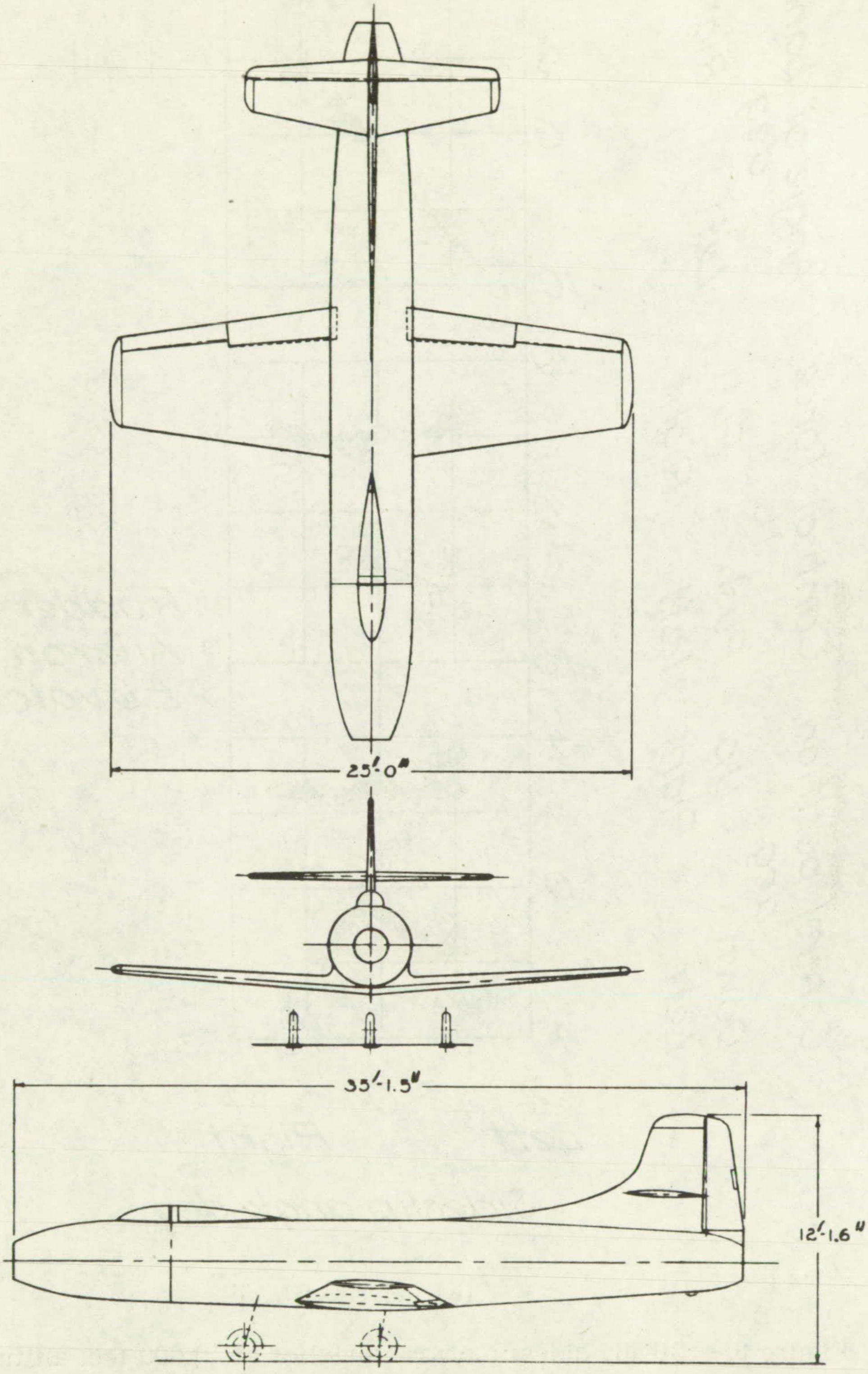

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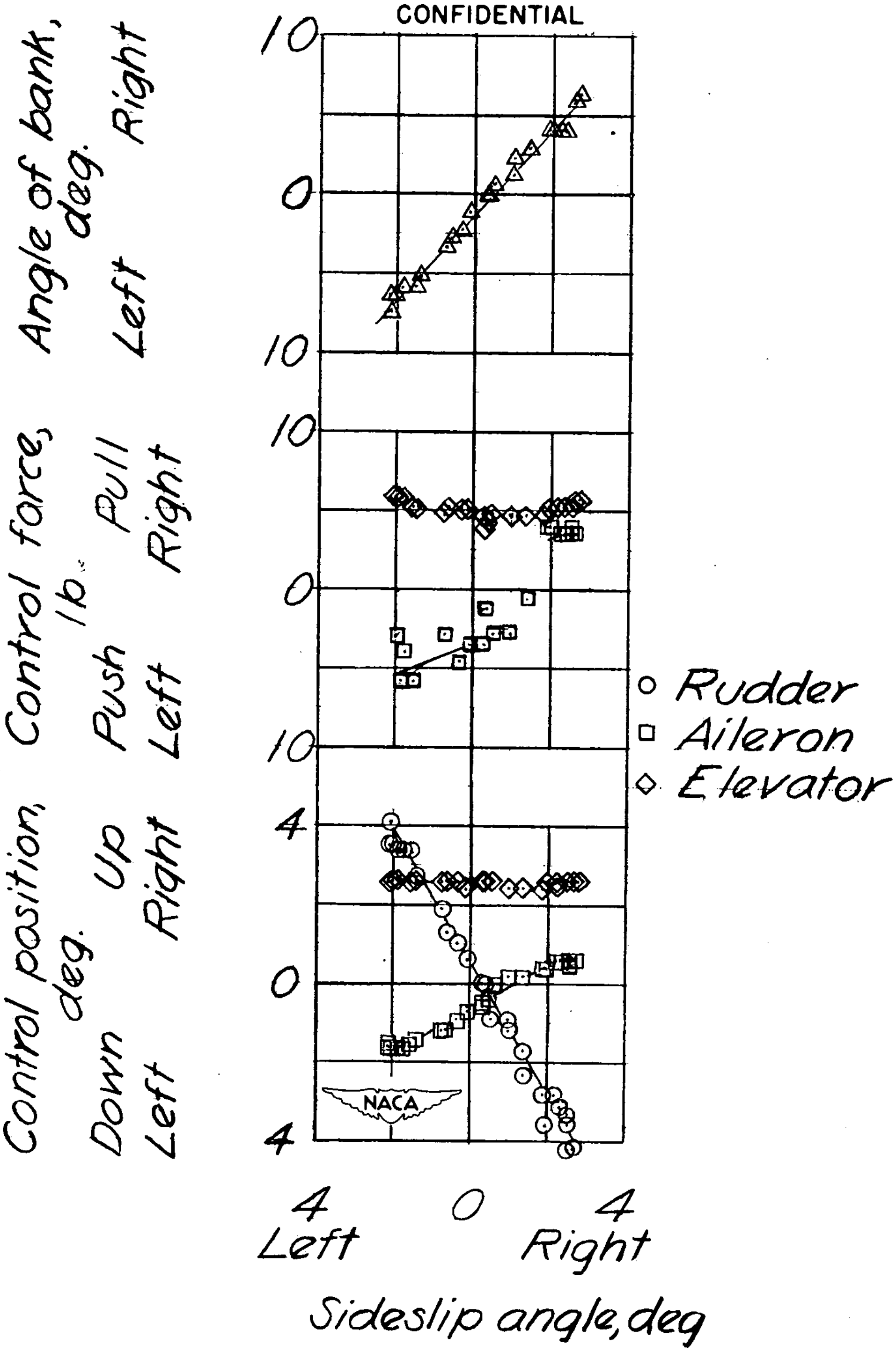
Figure 2.- Three-view drawing of D-558-1 airplane.



(a) M = 0.50.

Figure 3.- Steady sideslip characteristics at 10,000 feet altitude. D-558-1 airplane.

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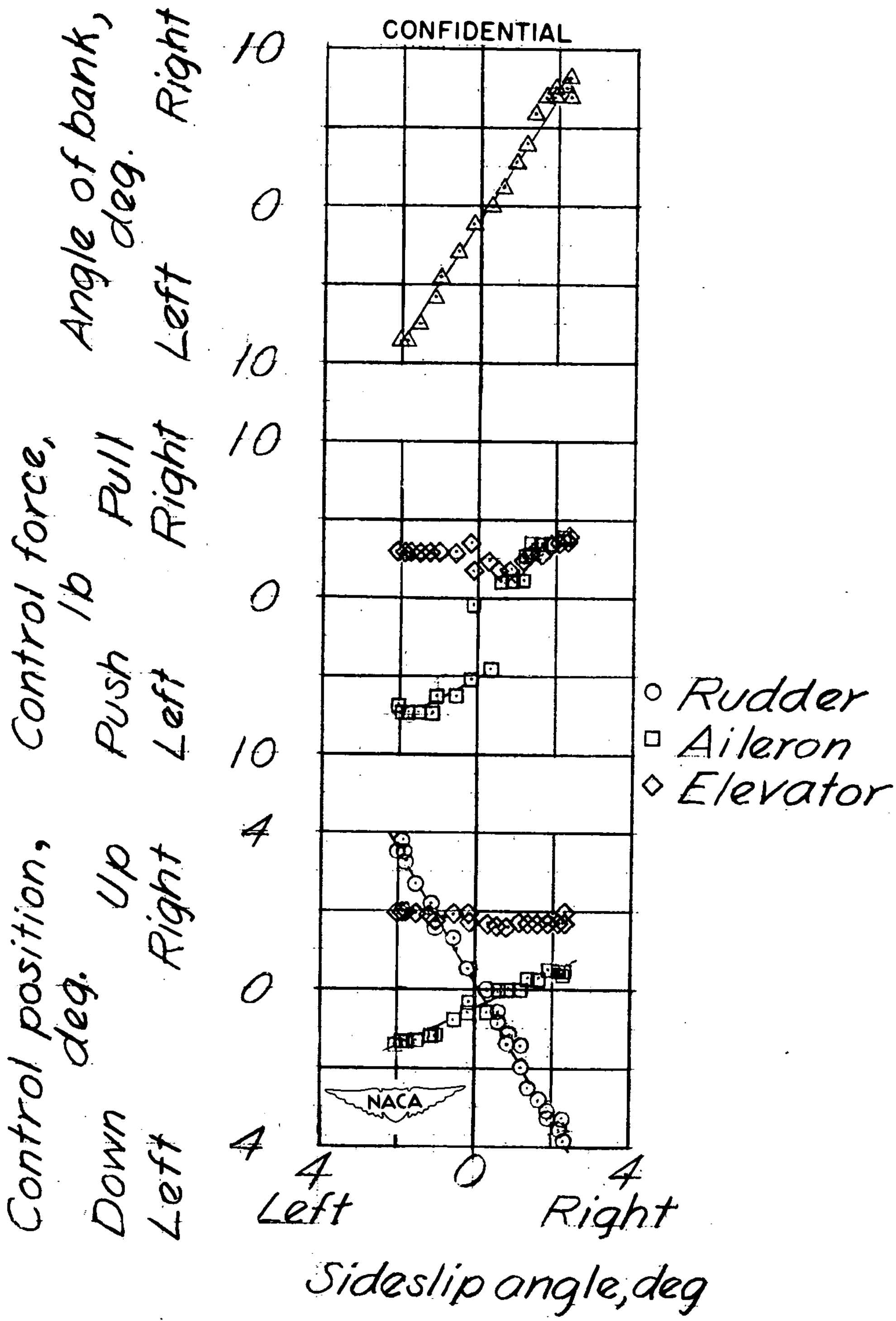

(b) M = 0.59.

Figure 3.- Continued.

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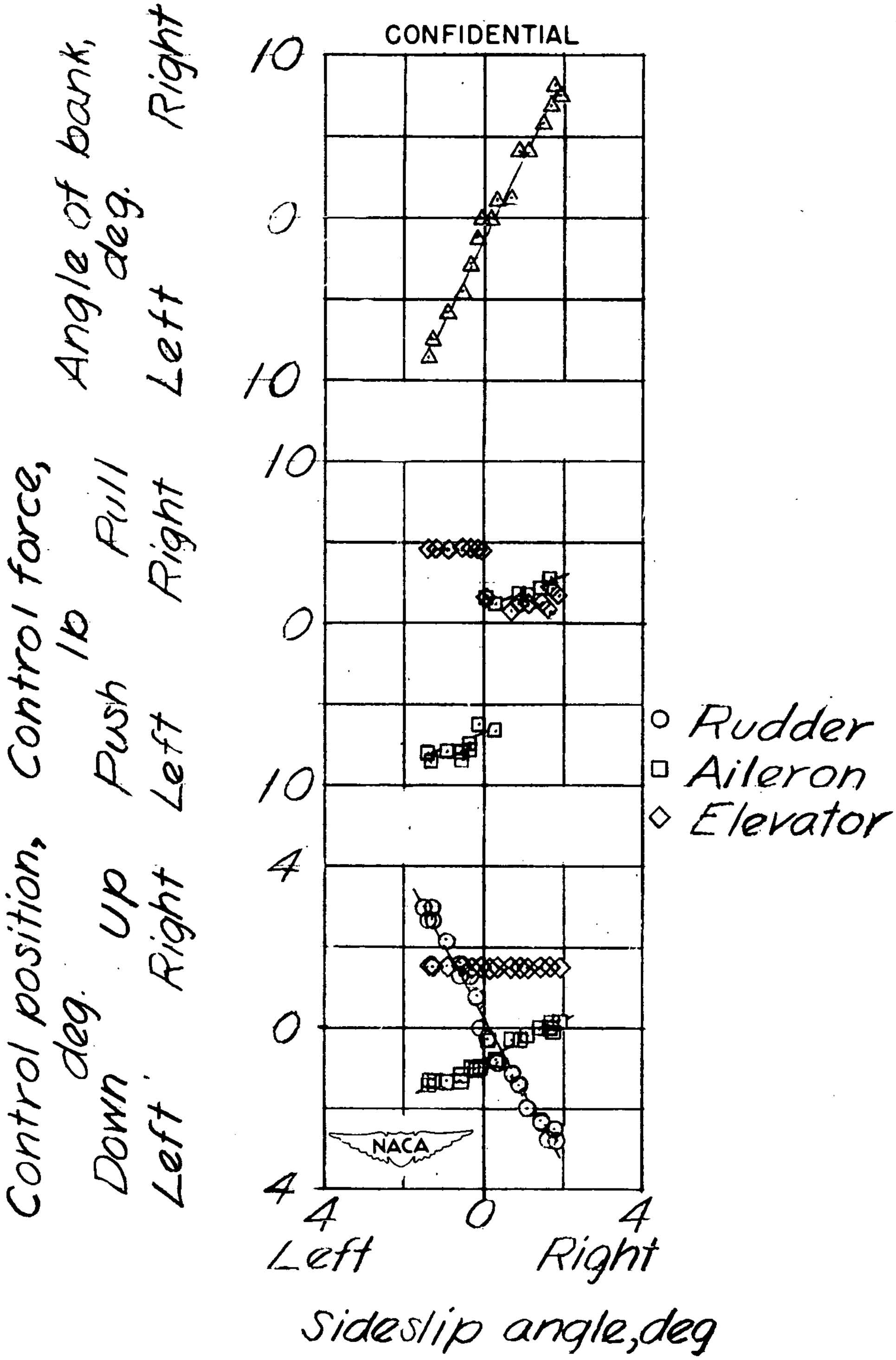

(c) M = 0.65.

Figure 3.- Continued.

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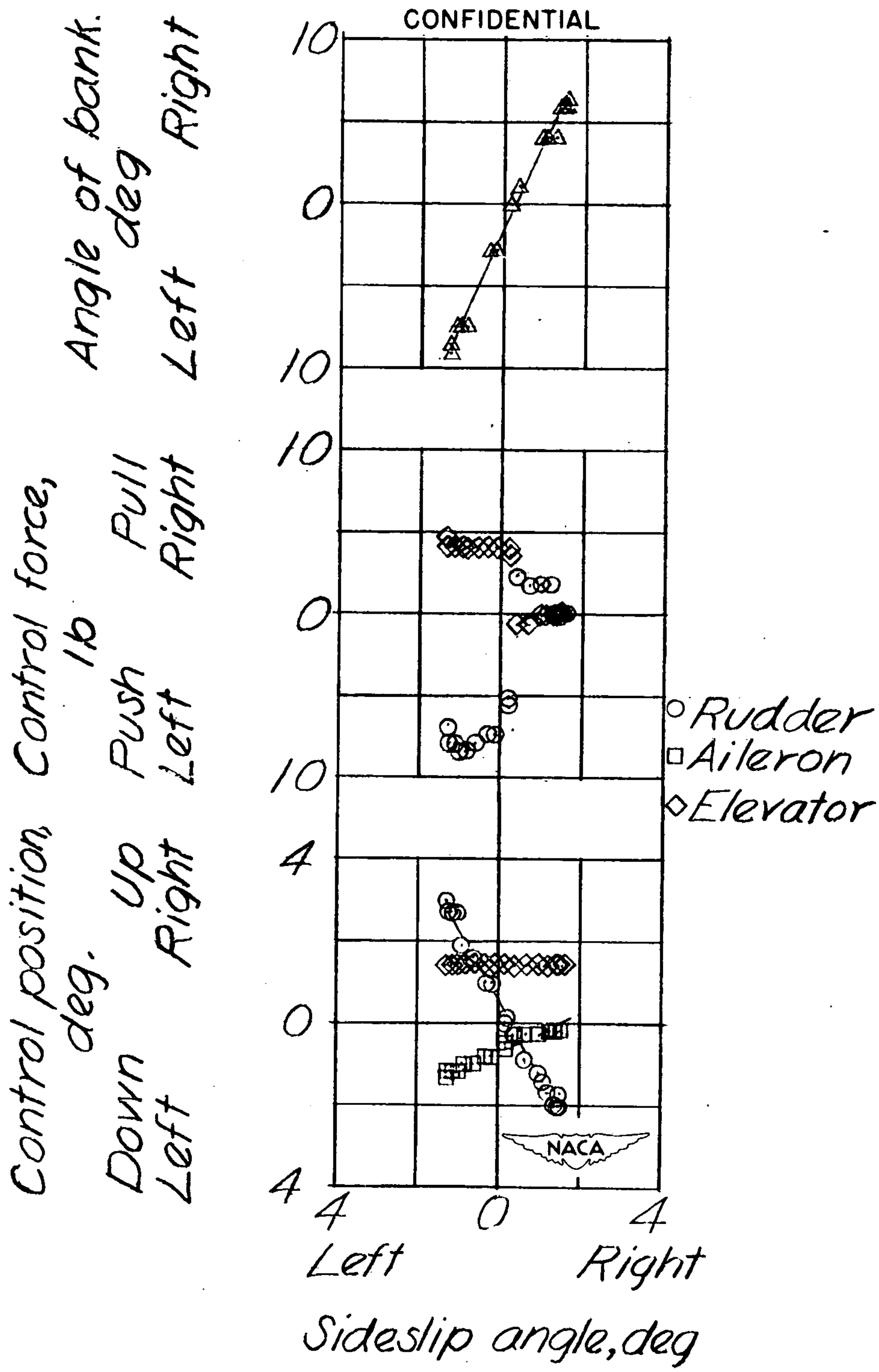

(d) M = 0.71.

Figure 3.- Continued.

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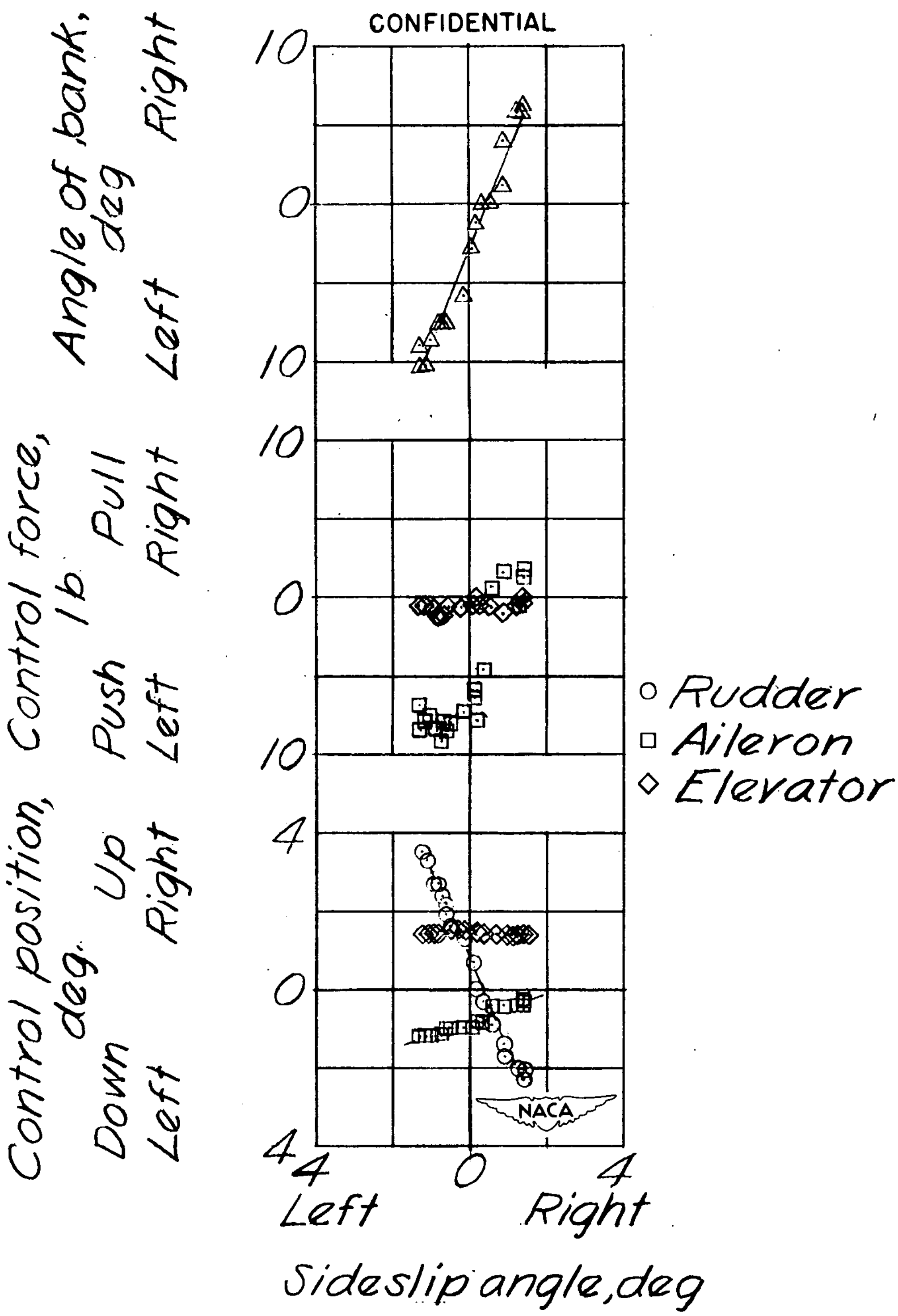

(e) M = 0.74.

Figure 3.- Continued.

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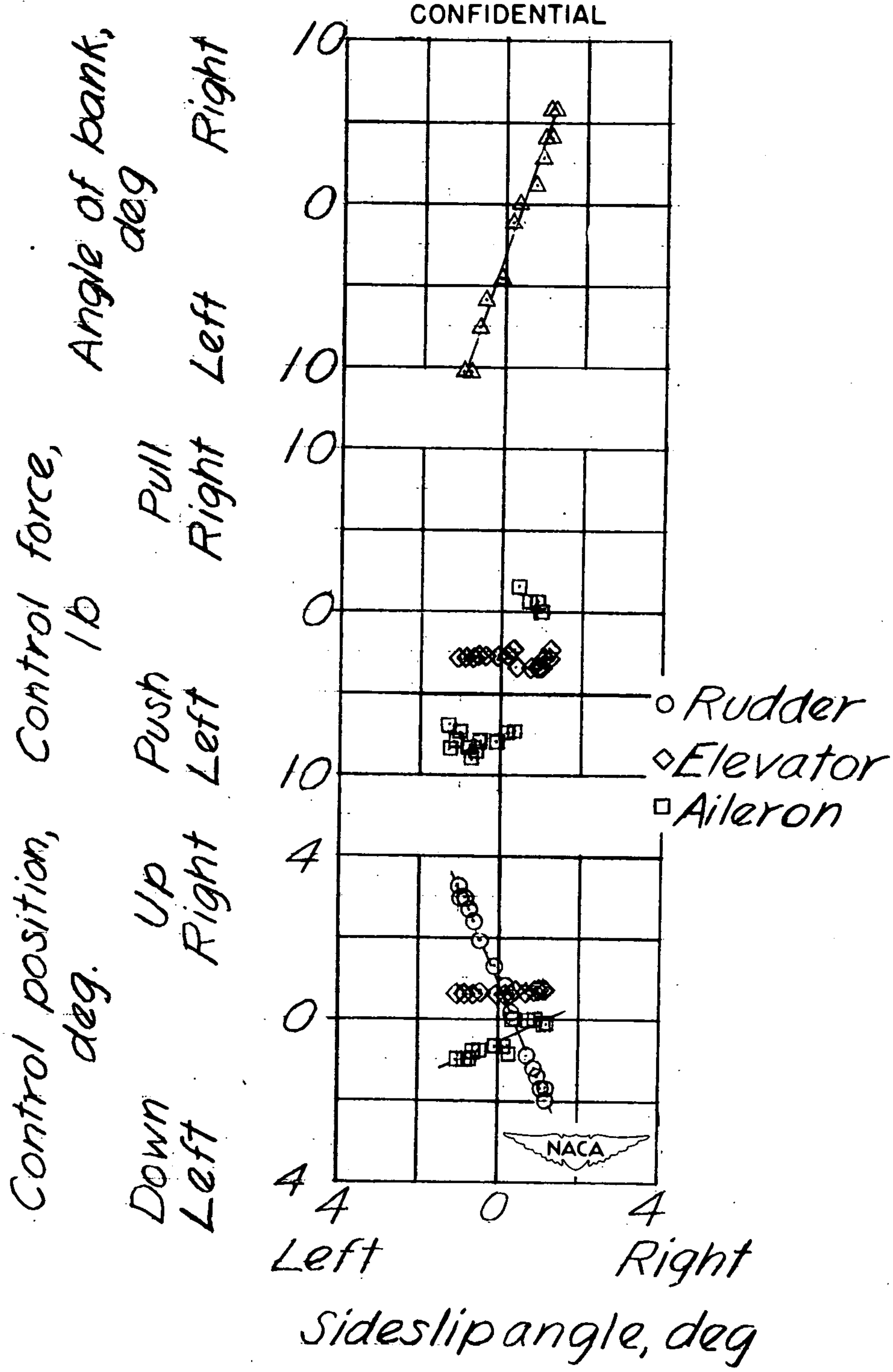

(f) M = 0.80.

Figure 3.- Concluded.

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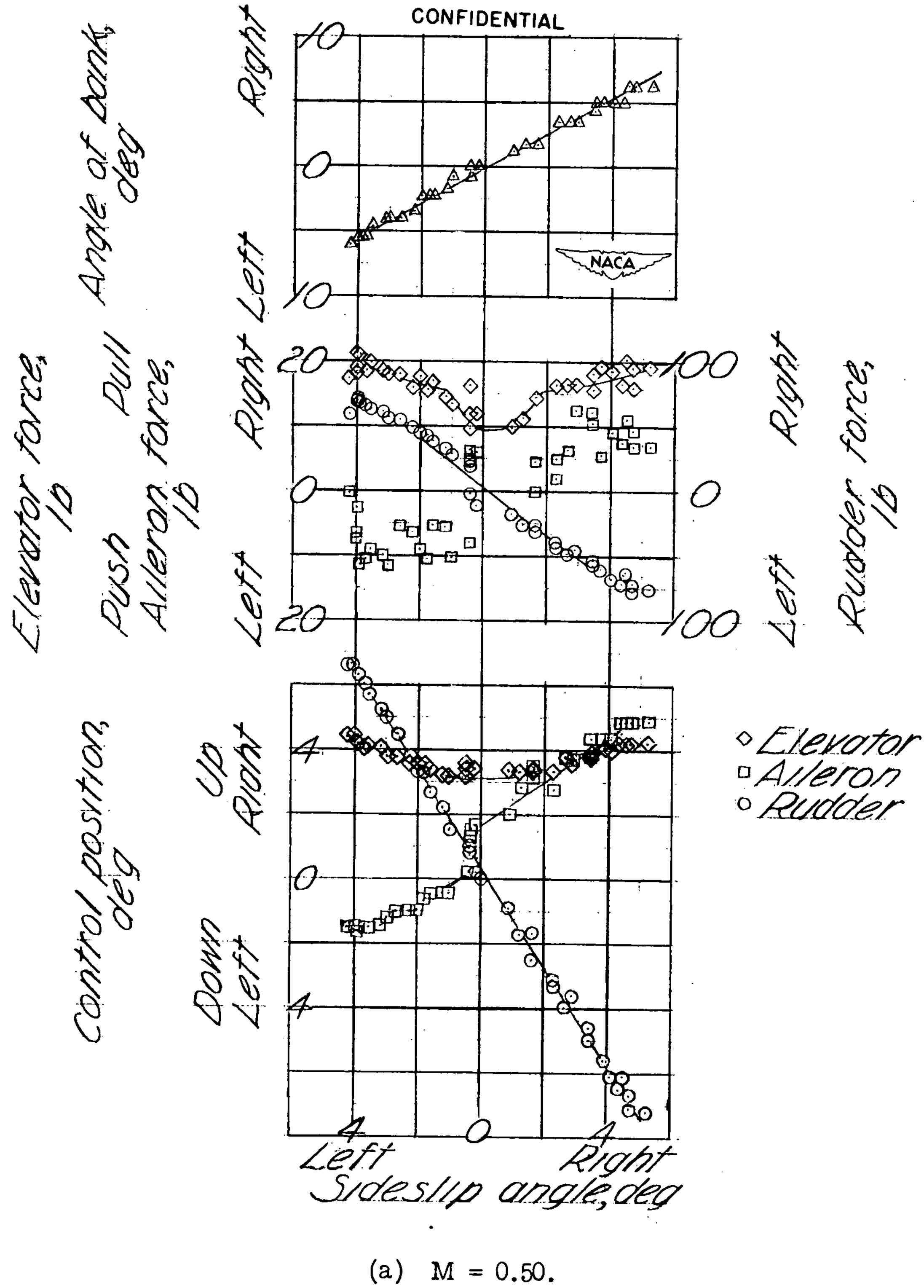

(a) M = 0.50.

Figure 4.- Steady sideslip characteristics at 30,000 feet altitude. D-558-1 airplane.

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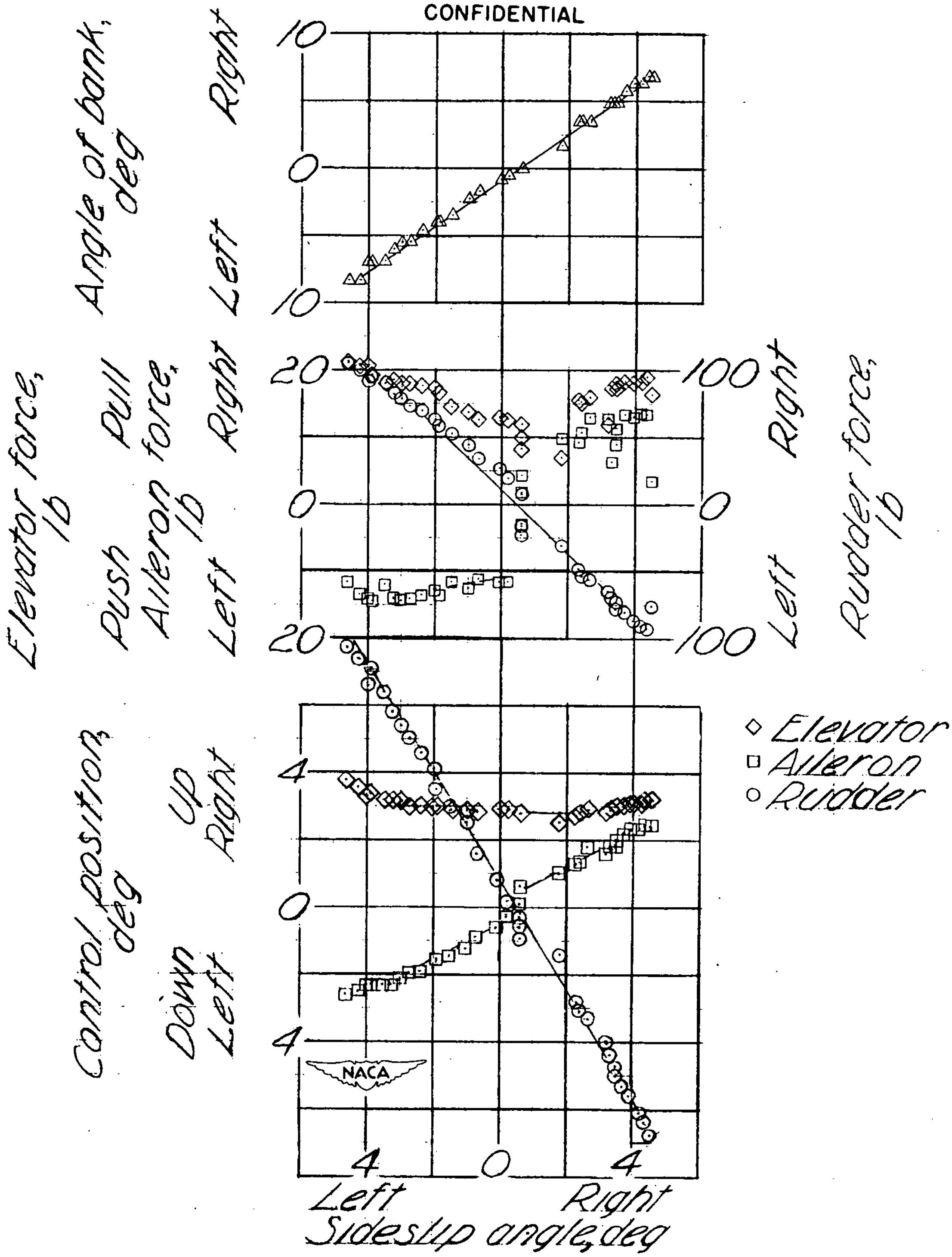

(b) M = 0.58.

Figure 4.- Continued.

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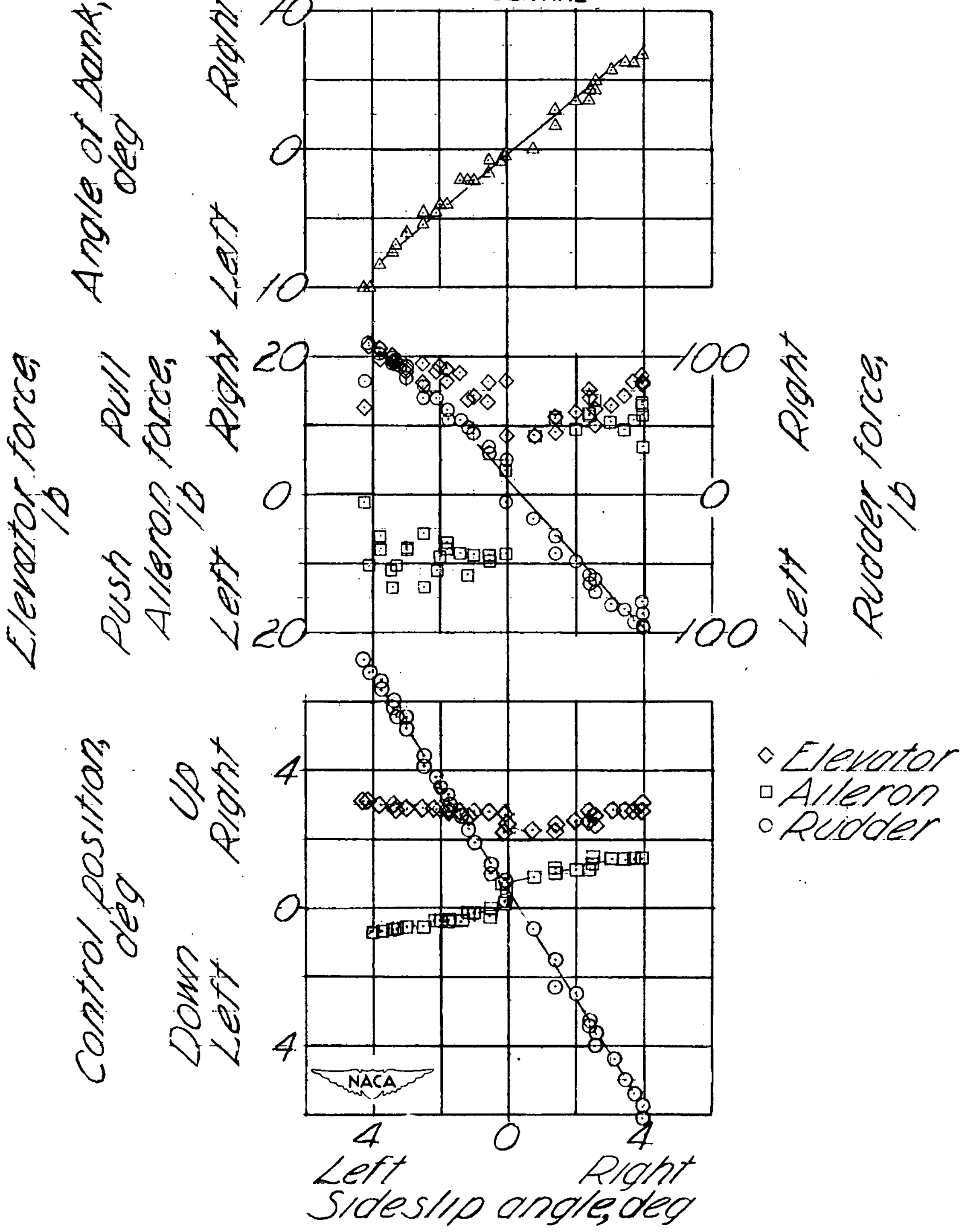

(c) M = 0.61.

Figure 4.- Continued.

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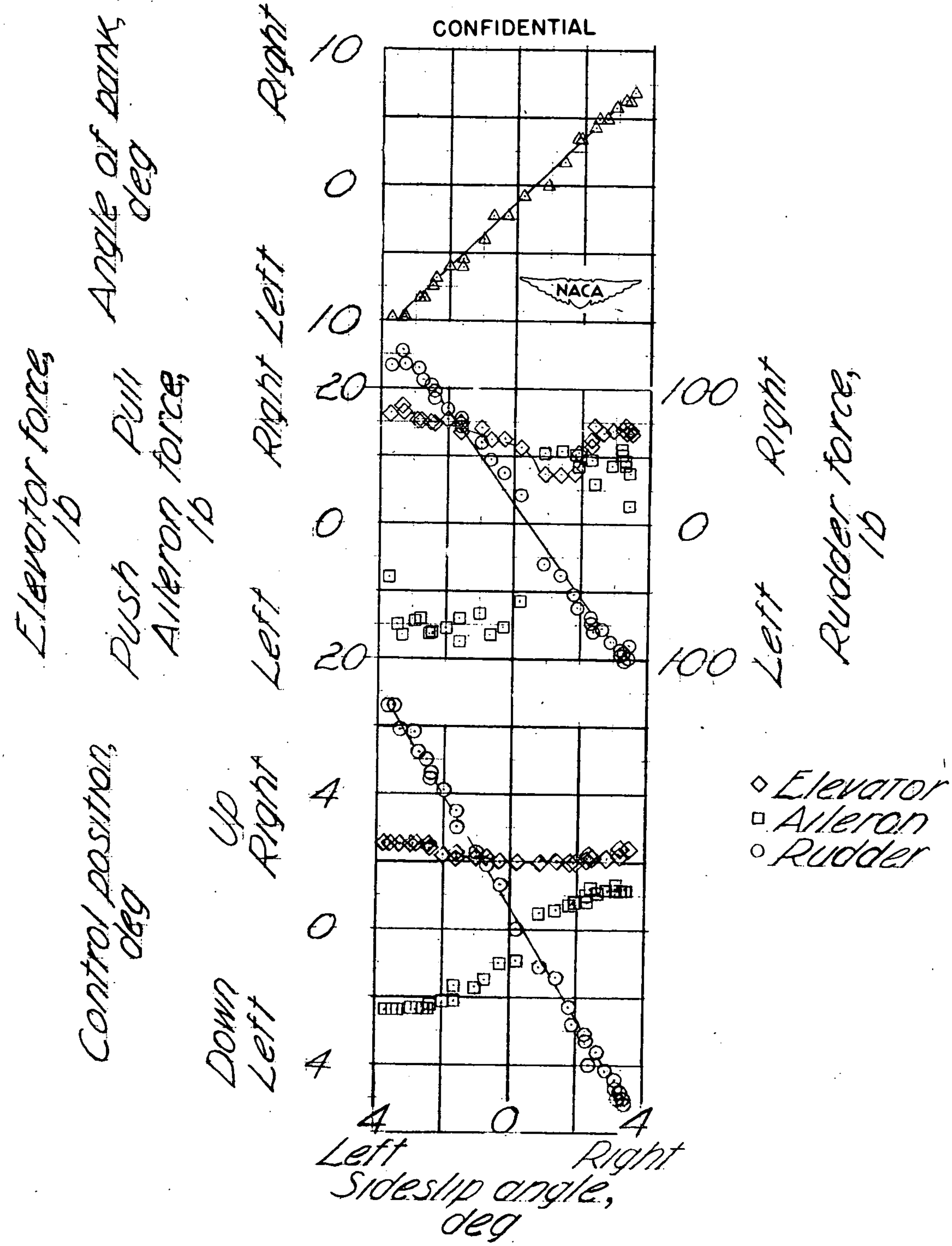

(d) M = 0.69.

Figure 4.- Continued.

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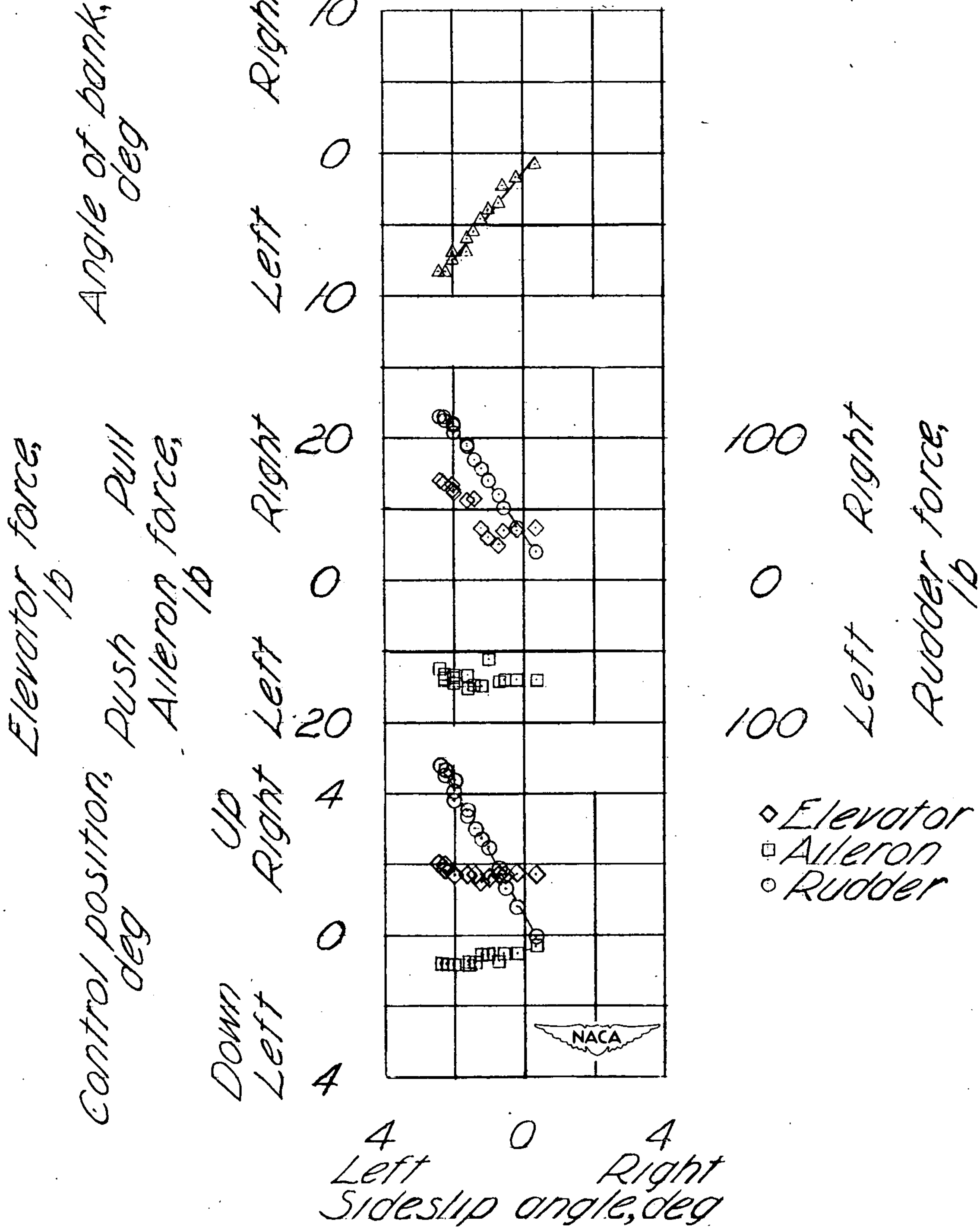

(e) M = 0.76.

Figure 4.- Continued.

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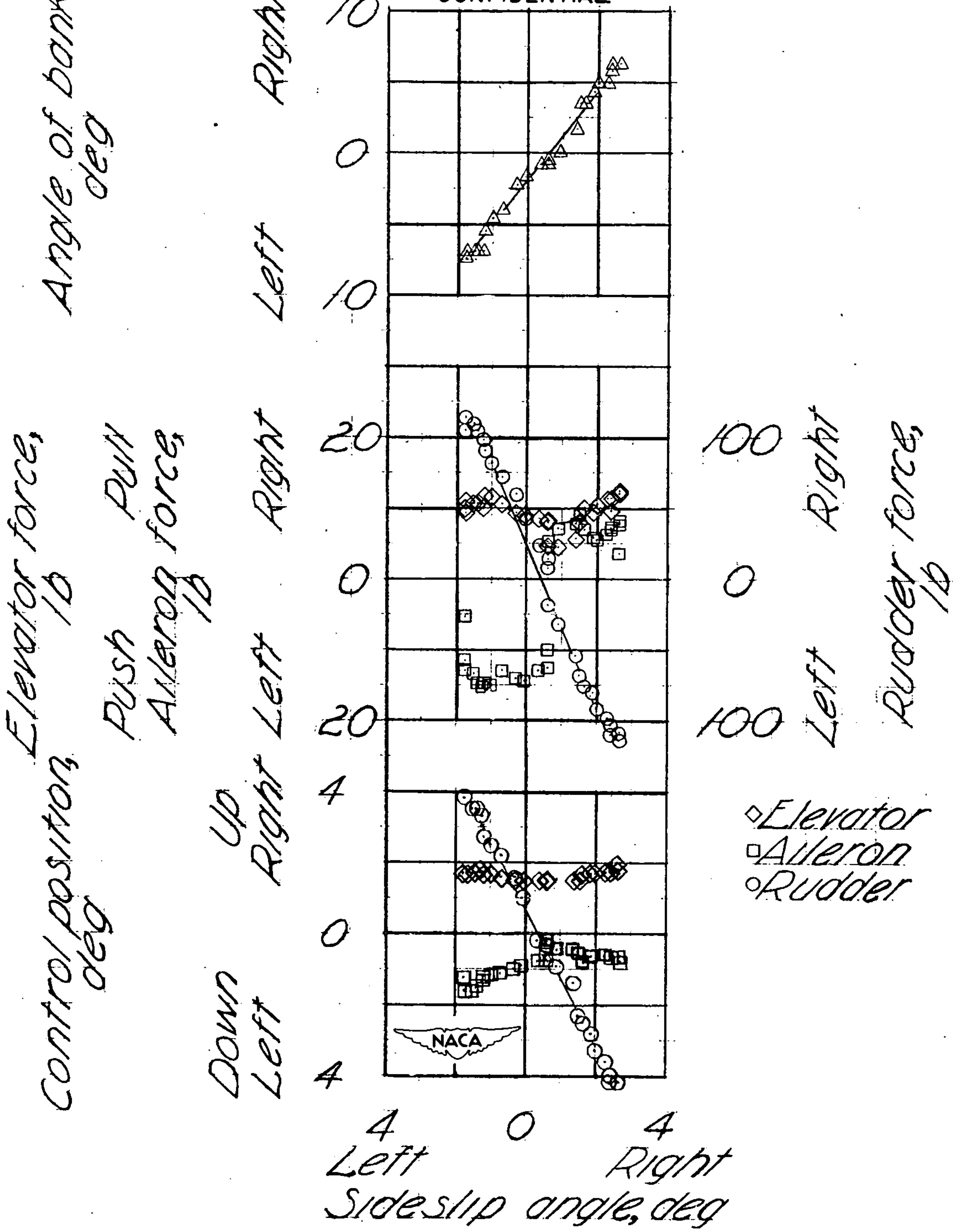

(f) M = 0.80.

Figure 4.- Continued.

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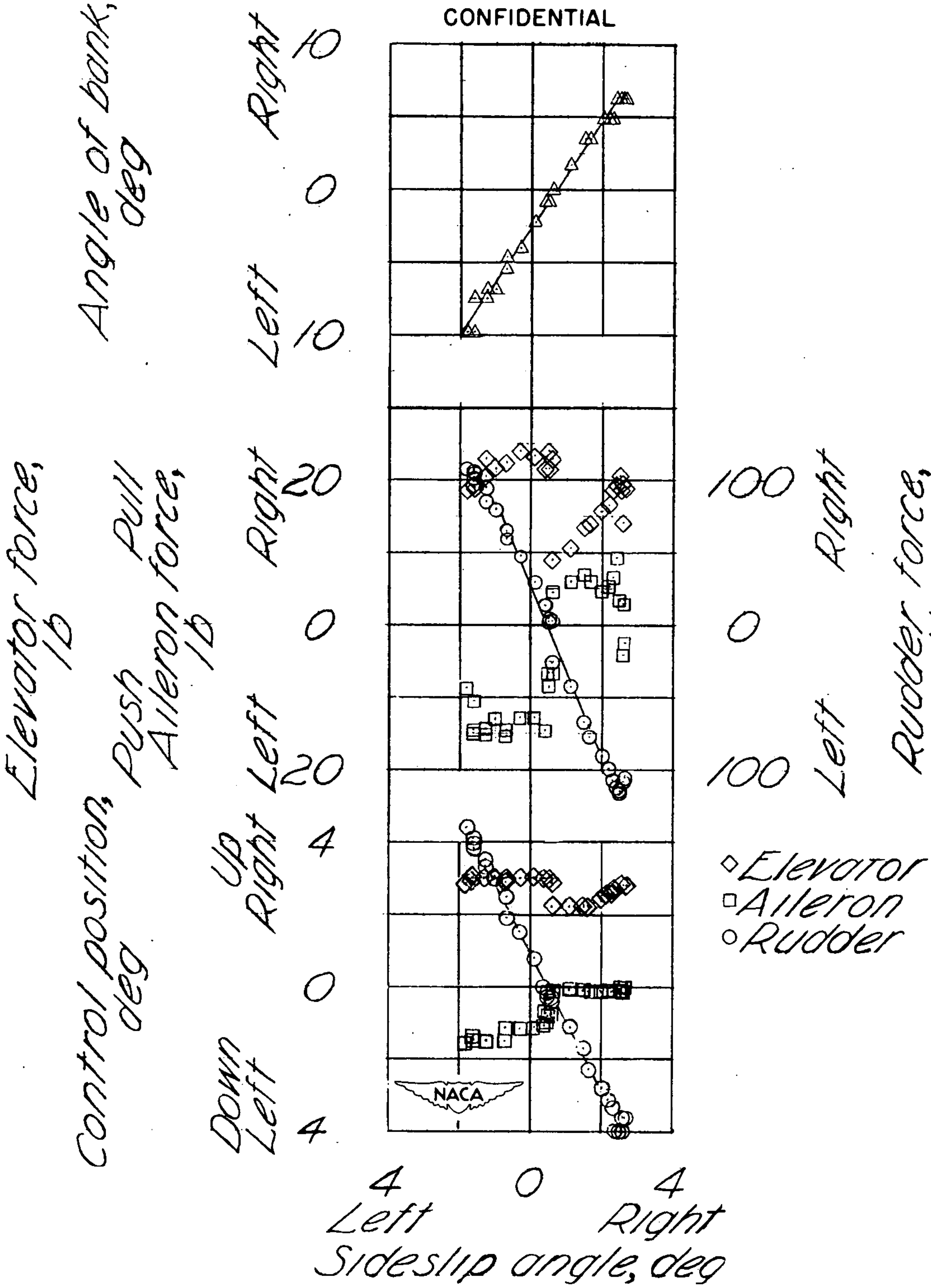

(g) M = 0.84.

Figure 4.- Concluded.

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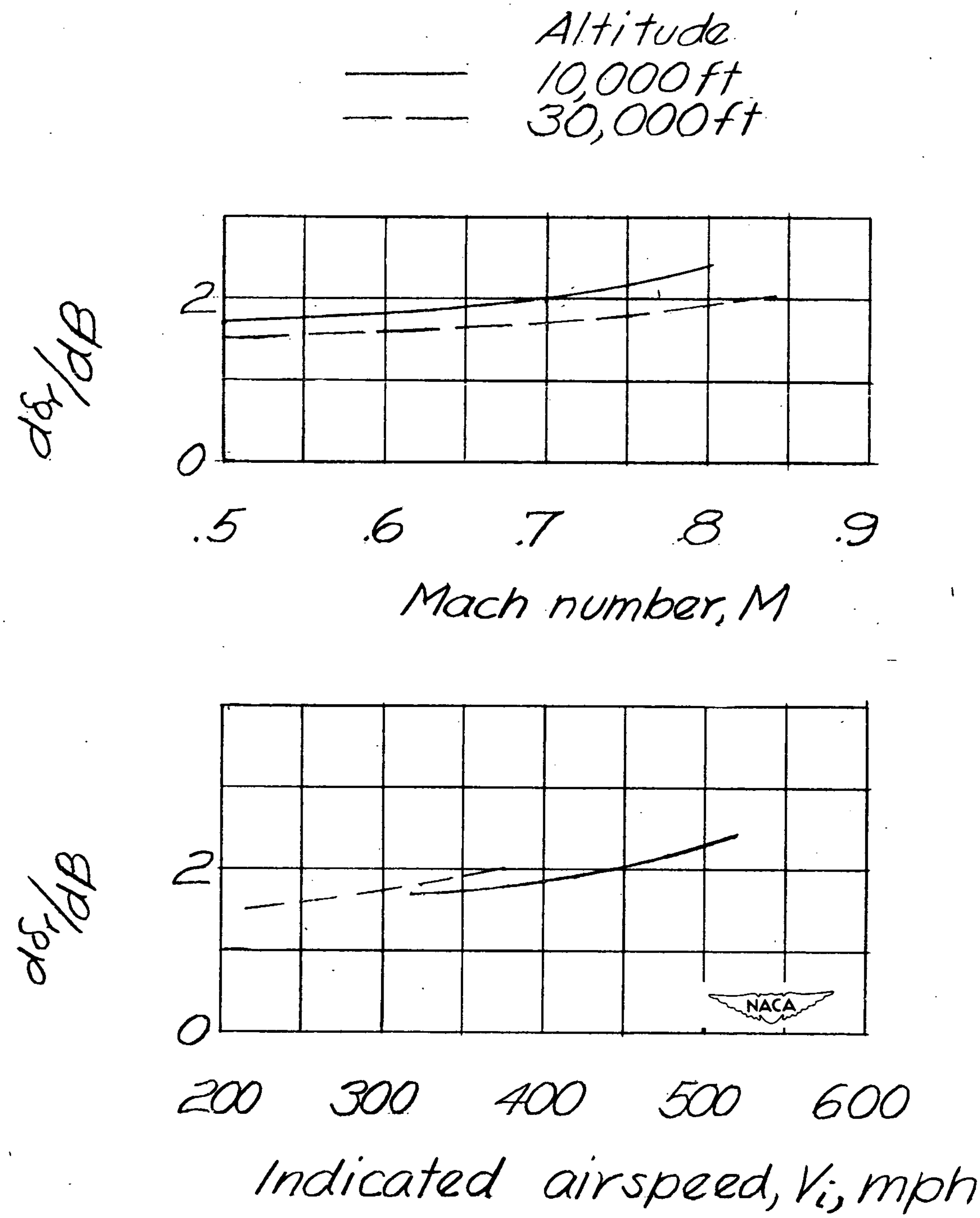

Figure 5.- Variation of $d\delta_r/d\beta$ with Mach number and indicated airspeed. D-558-1 airplane.

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