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# RESEARCH MEMORANDUM

## RESULTS OF PRELIMINARY FLIGHT TESTS OF THE XS-1 AIRPLANE (8-PERCENT WING) TO A MACH NUMBER OF 1.25

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# RESULTS OF PRELIMINARY FLIGHT TESTS OF THE XS-1 AIRPLANE (8-PERCENT WING) TO A MACH NUMBER OF 1.25

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## INTRODUCTION

Upon completion of acceptance tests on the XS-1 airplanes by the Bell Aircraft Corporation, one of these airplanes (XS-1-1 which has the thin wing and horizontal tail, 8 percent and 6 percent thick, respectively) was taken over by the Air Forces' Wright Field Flight Test Division for use in an accelerated transonic flight research program. The purpose of these flight tests was to fly at speeds in excess of the speed of sound in as short a test program as possible. No detailed investigations are being made and as large an increase in Mach number as compatible with safety is made in each flight. If necessary, flight will be made at extreme altitudes (50,000 to 60,000 feet). This program is a cooperative endeavor between the U. S. Air Force and NACA. NACA instrumentation is used in all flights. Data reduction and analysis are performed by NACA personnel. The flying is done by a Wright Field Flight Test Division pilot.

The purpose of this report is to present data from the first flight tests of the XS-1 to speeds beyond a Mach number of 1.0. The data presented herein cover a Mach number range from 0.70 to 1.25 and an altitude range from 30,000 feet to 49,000 feet.

## AIRPLANE AND INSTRUMENTATION

The XS-1 airplane flown in these tests incorporates an 8-percent-thick wing and 6-percent-thick tail. Pertinent dimensions of the airplane are shown in the three-view layout given in figure 1. Flight conditions of the airplane during the tests were as follows:

| | |
|---|---|
| Launching weight, pounds | 12,365 |
| Launching center-of-gravity position (percent M.A.C.) | 22.1 |
| Landing weight, pounds | 7115 |
| Landing center-of-gravity position (percent M.A.C.) | 25.3 |
| Fuel consumption of each rocket, pounds per second | 7.87 |
| Engine, four-cylinder RMI-liquid rocket thrust, pounds per cylinder | 1500 |

Measurements of airspeed, altitude, normal acceleration, elevator position, and tail shear loads have been obtained from standard NACA recording instruments installed in the airplane. Measurements of aileron position, stabilizer position, and elevator wheel force were telemetered to a ground station.

## SYMBOLS

$M$ free-stream Mach number corrected for position error of pitot-static head

$M'$ free-stream Mach number uncorrected for position error of pitot-static head

$C_{L_A}$ airplane lift coefficient (measured normal-force component is assumed to be equal to lift component $(nW/qS)$)

$q$ dynamic pressure, pounds per foot$^2$

$S$ wing area, 130 feet$^2$

$S_t$ horizontal-tail area, 26 feet$^2$

$L_T$ aerodynamic shear load of right tail, pounds

$i_t$ stabilizer incidence, degrees

$\delta_e$ elevator position, degrees

$\alpha_t$ angle of attack of horizontal tail, degrees

$C_{N_t}$ tail normal-force coefficient $\left(L_T/S_t q\right)$

## TESTS, RESULTS, AND DISCUSSION

A calibration of the position error of the Kollsmann type D-1 pitot-static head located 1 chord length ahead of the wing tip has been made up to a corrected Mach number of 1.25. The static-pressure errors have been obtained from a survey of true static pressure within the test altitude range with the test airplane and using radar to obtain geometric altitude. The test airplane was flown during the survey at speeds where the static error was known. The test airplane is tracked by radar during the test run and the static-pressure error is determined from a comparison of the true static pressure and that pressure recorded from the airspeed head of the test airplane. The total-head pressure errors have been determined from a theoretical consideration of the total head loss behind a detached bow wave. The calibration curve including only the static-pressure errors and the curve including both the static and total-head errors are noted in figure 2. It is estimated that the calibration is accurate to a M of ±0.01 up to a Mach number of approximately 1.02 and to a M of ±0.04 above a corrected Mach number of 1.02.

In figure 3 is shown an envelope of the buffeting region established from lift and Mach number combinations obtained within the buffet region. The boundaries of the envelope have been identified as the buffet boundary and limit lift. The buffet boundary is defined by the first indication of buffet as shown by records of acceleration and wing and tail loads. Limit lift is determined during gradual turns where the lift ceased to increase although increasing up-elevator is being applied. The stabilizer incidence angle was approximately 2.2°. These data were obtained in level flight and in gradual turns. An evaluation of the measured tail buffeting loads occurring within the envelope shown in figure 3 was made. The maximum buffeting loads for altitudes above 30,000 feet were obtained at limit lift from a Mach number of 0.76 to 0.80 and were of the order of ±400 pounds. At Mach numbers greater than 0.80, buffet loads were less than ±250 pounds. As indicated by these low buffeting tail loads, the buffeting was mild above 30,000 feet. The pilot did not consider the buffeting a serious problem in negotiating the transonic speed zone.

Figure 4 shows the variation of measured quantities with Mach number obtained in tests made at approximately 30,000 feet pressure altitude for a Mach number range from 0.7 to 0.94. Included on this figure are the variations with Mach number of elevator position and force, balancing tail-load coefficient, and relative elevator effectiveness $\Delta\alpha_t/\Delta\delta_e$. Tests were made with two stabilizer settings. The data given in this figure and subsequent figures are for essentially constant lift coefficient. With the stabilizer set at an incidence angle of 1.0° the pilot did not fly beyond a Mach number of 0.876 because it was difficult to hold steady flight due to the elevator forces required for trim, the relatively far forward position of the wheel with this stabilizer setting, and because of buffeting expected at the higher Mach numbers. Data were obtained for

a stabilizer incidence of $+2.2^{\circ}$ up to a Mach number of 0.934. From these data of elevator required for trim for the two stabilizer settings a variation of relative elevator effectiveness $\Delta\alpha_t/\Delta\delta_e$ was obtained up to a Mach number of 0.876 and is shown in this figure. It should be noted that the relative elevator effectiveness is reduced by more than 50 percent between a Mach number of 0.70 and 0.87. This reduction in effectiveness of the elevator will affect the magnitude of the elevator angles required for trim. It can also be seen from the variation of the balancing tail load that a part of the trim change is caused by a change in the wing-fuselage moment for the Mach number range covered by this figure. These data are in qualitative agreement with tests made in Langley 8-foot tunnel and wing-flow tests of an XS-1 model.

In figure 5, the variation of elevator position and force, right aileron position, and balancing tail load with Mach number is shown for a test run made at 37,000 feet pressure altitude. The maximum value of Mach number reached was approximately 1.00. It should be noted that trim changes occurred above a Mach number of 0.94 which were in addition to those predicted from model tests in the Mach number range from 0.8 to 0.94. In the comparison of the variation of balancing tail load and the variation of elevator position with Mach number, several interesting points are noted. The changes in elevator position and in balancing tail load are similar indicating that the largest effect is the change in wing-fuselage moment with Mach number. Also, it should be noted that the change in tail load, indicating change in wing-fuselage moment between 0.87 and 0.91, corresponds to a $1^{\circ}$ change in elevator position. For the change in tail load occurring near a Mach number of 1.0, which is approximately the same magnitude as the earlier change in tail load, a change in elevator position of approximately $11\frac{1}{2}^{\circ}$ was measured. These data indicate a probable further decrease in elevator effectiveness beyond the change shown in figure 4. It is also possible that some of this elevator deflection is being used to offset changes in downwash. The variation of right aileron deflection with Mach number shows that the airplane is becoming right wing-heavy as the Mach number increases. The pilot reported that this wing heaviness was most apparent to him between Mach numbers of 0.90 and 0.92.

The variation of elevator position and balancing tail load with Mach number at 43,000 feet pressure altitude up to a Mach number of approximately 1.055 is shown in figure 6. The curves on this figure are discontinuous because data were selected at two different values of lift coefficient. It can be seen that the tail load and elevator position follow in the same manner as shown in figure 5 for the same Mach number range. It should be noted, however, that at the highest Mach number shown on this figure (1.055), there is an appreciable reversal in the direction of the elevator motion with little or no change in the tail load, indicating possible changes in the elevator effectiveness or downwash.

Figure 7 gives the variation of elevator position and force with Mach number as obtained in tests made at a pressure altitude of 49,000 feet up to a Mach number of approximately 1.25. It should be noted that above a Mach number of 1.0, there is a continuing trim change in the nose-down direction. The maximum elevator control force required in flying the XS-1 in the transonic speed zone is shown on this figure and occurs just past a Mach number of 1.0. The force measured was 25 pounds. It should be remembered, however, that these data were obtained at 49,000 feet altitude. At lower altitudes, the forces involved in transonic flight with the XS-1 may be greater than the pilot can exert. It should also be pointed out that the XS-1 has a very small elevator. The elevator chord is 20 percent of the horizontal-tail chord, and the root-mean-square chord of the elevator is only 5.6 inches. With a larger airplane of similar design the control forces may be unreasonably large.

In order to show the effects of altitude and stabilizer position on the longitudinal trim characteristics, the variation of elevator position with Mach number from figures 4, 5, 6, and 7 is given in figure 8. Although the changes in stabilizer position are small, it should be pointed out that the relative effectiveness of the elevator is low above a Mach number of 0.8 and it is expected that small changes in stabilizer position may make appreciable difference in the elevator angles for trim. The data in this figure show that, although the variation of elevator angle with Mach number is somewhat different for each condition shown, the same general trends are indicated.

Some difficulties have been experienced in recent tests of other airplanes at transonic speeds with one-dimensional flutter or buzz of the ailerons. There has been no evidence to date of buzz in the XS-1 tests. One probable contributing factor to the absence of this oscillation in addition to the thin wing section is the large amount of friction in the aileron control system. The friction in the ailerons is of the order of 20 foot-pounds. The ailerons are quite small and even though there is no aerodynamic balance, the aerodynamic hinge moment of the ailerons for $q$ corresponding to a Mach number of 0.85 and 30,000 feet, neglecting effects of Mach number on the hinge-moment coefficient, is of the order of 7 foot-pounds per degree. Hydraulic dampers are installed but have not been used. There also has been no evidence of abrupt changes in the floating tendencies of the ailerons.

## CONCLUSIONS

The data obtained in flight with the XS-1 airplane with 8-percent-thick wing up to and beyond the speed of sound at an altitude of 37,000 feet and above show that most of the trim and force changes expected in the transonic range have been experienced. Although

conditions are not normal, the airplane can be flown under control through a Mach number of 1 at altitudes of 37,000 feet and above. In detail, the following has been noted:

1. Buffeting has been experienced in level flight but has been mild. The horizontal-tail loads associated with the buffeting have been small.

2. The airplane has experienced longitudinal trim changes in the speed range from 0.8 up to 1.25. The largest control force associated with these trim changes was 25 pounds. The pilot has been able to control the airplane. The relatively small magnitude of the control force may be attributed to the small size of the elevator and the high altitude of the flight.

3. The elevator effectiveness has decreased more than 50 percent in going from a Mach number of 0.7 to 0.87. There is evidence of further reduction in elevator effectiveness above a Mach number of 0.87. This loss in elevator effectiveness has affected the magnitude of the trim changes as noted by the pilot but the actual trim changes for the most part have been caused by changes in the wing-fuselage moment.

4. No aileron buzz or associated phenomena have been experienced. The airplane becomes right wing heavy with increasing Mach number up to a Mach number of 1.10, but can be trimmed with the ailerons.

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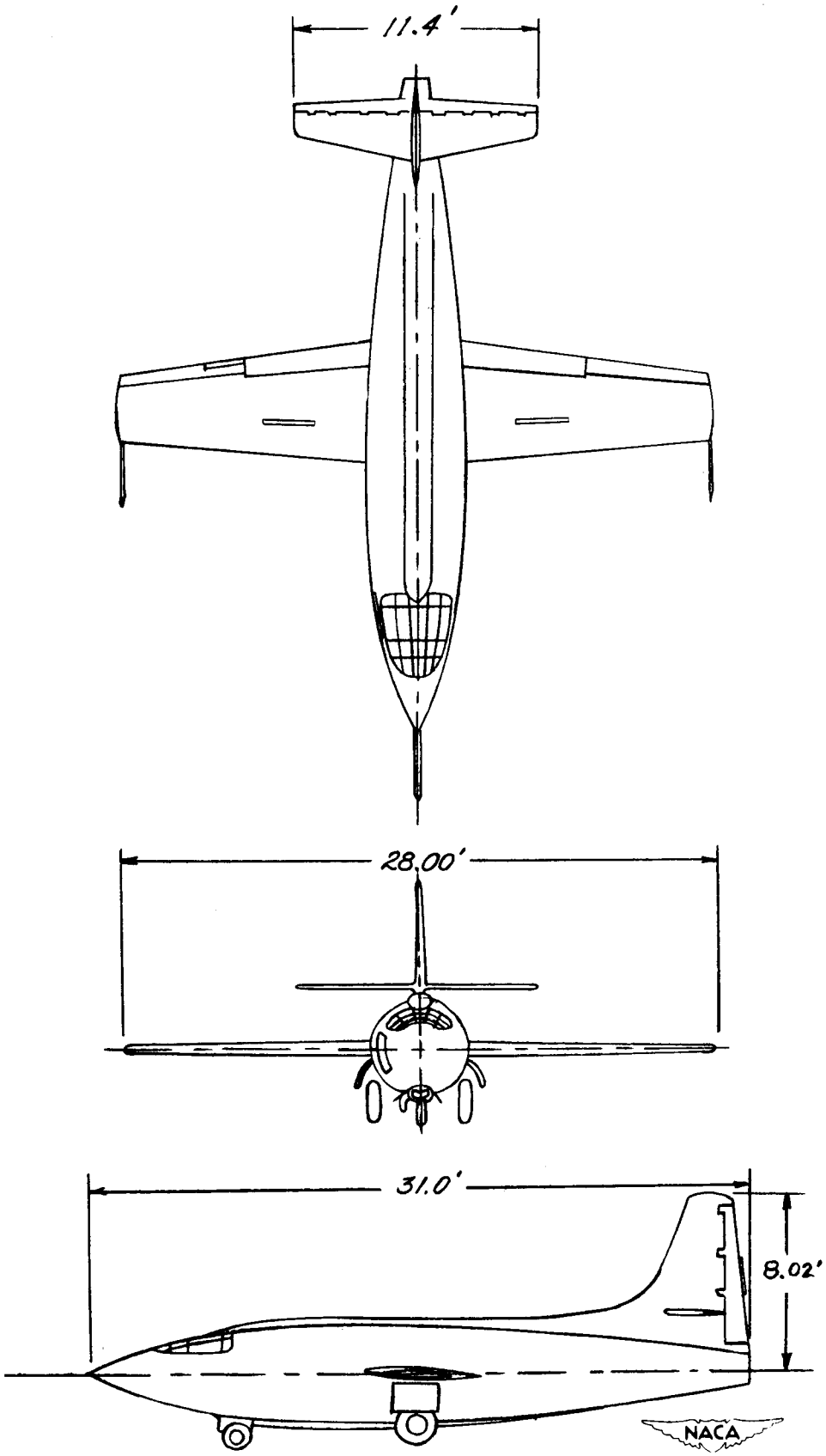


Figure 1.- Three view drawing, XS-1 airplane.

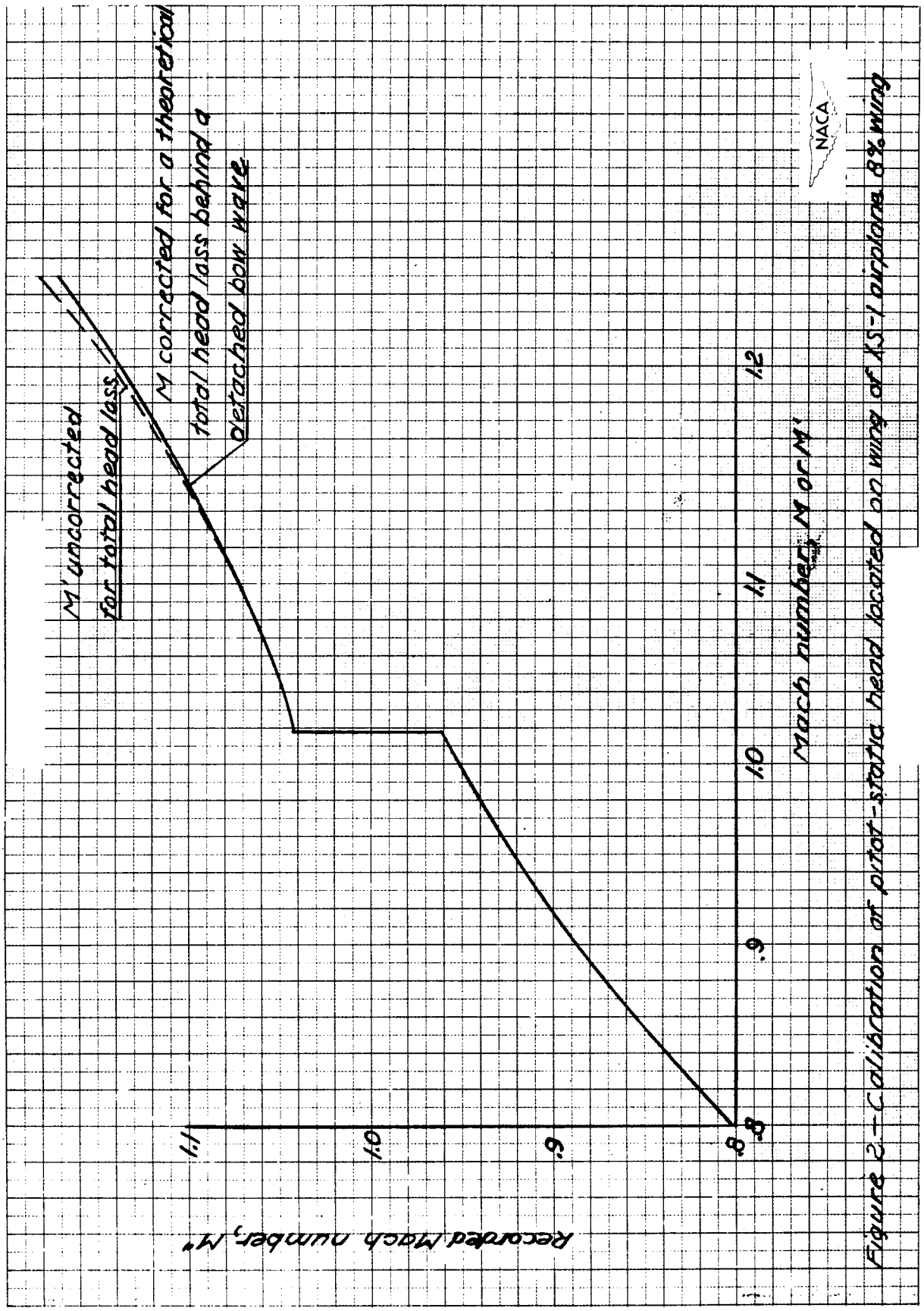


Figure 2.- Calibration of pitot-static head located on wing of XS-1 airplane. 8% wing

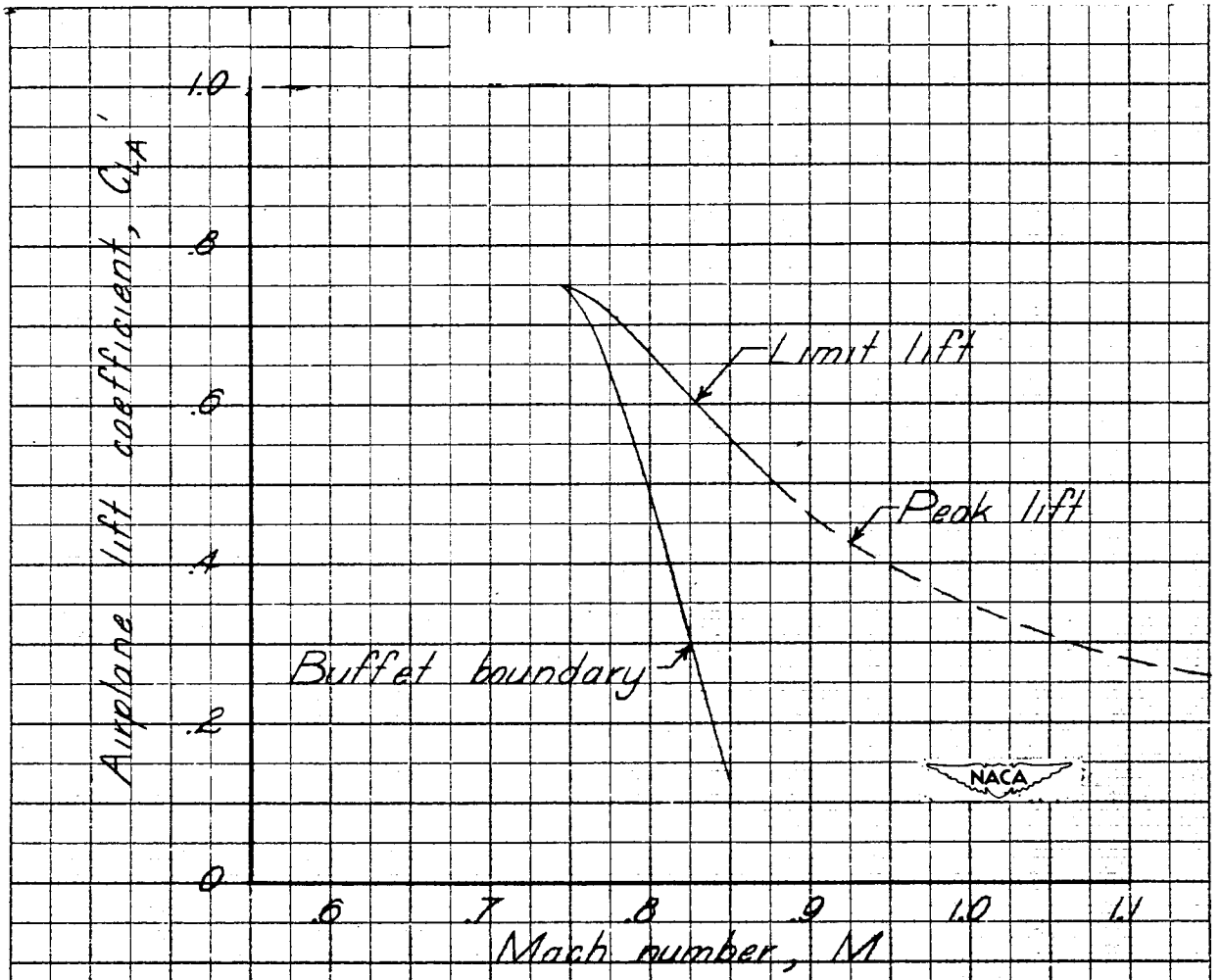


Figure 3.- Envelope of the buffet region. XS-1 airplane. 8% wing. Air Force flights.

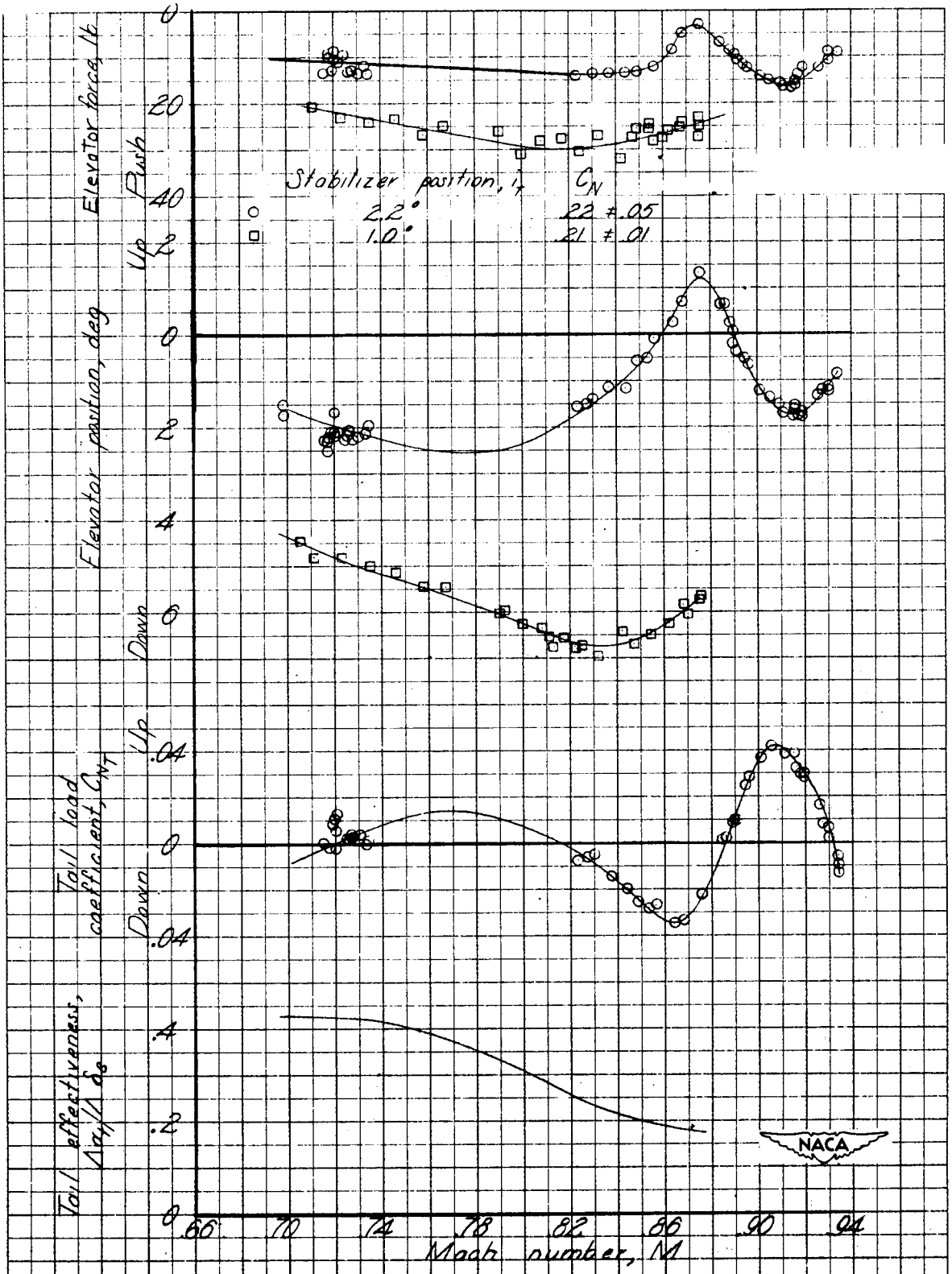


Figure 4 — Variation of measured quantities with Mach number. XS-1 airplane, 8% wing. Altitude 30,000 ft. Air Force flights.

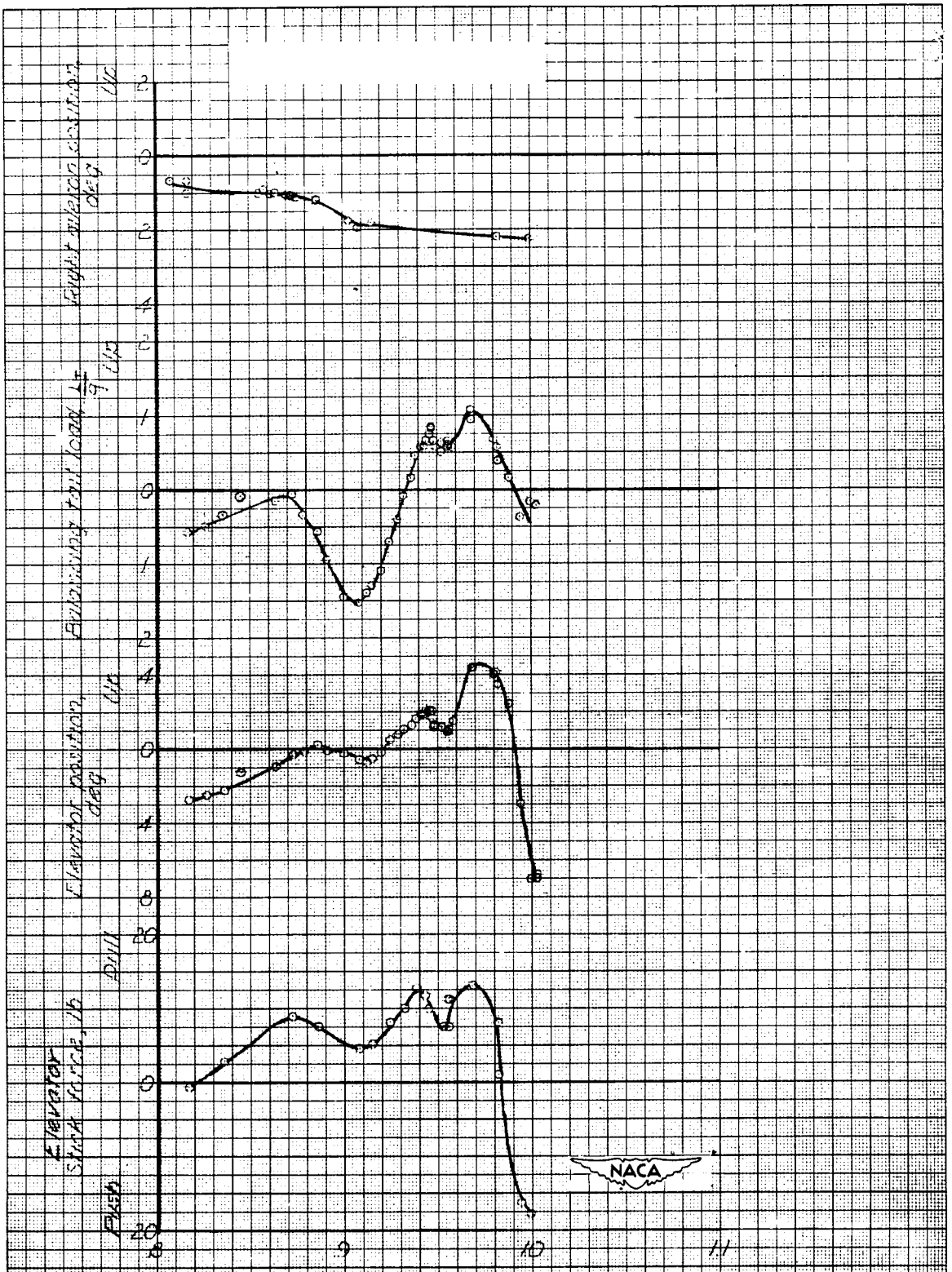


Figure 5.- Variation of measured quantities with Mach number. XS-1 airplane, 8% wing. Altitude 37,000 ft. Air Force flights. $C_{L_h} = .27 \pm .03$, c.g. 24% MAC, $i_t = 2.3°$.

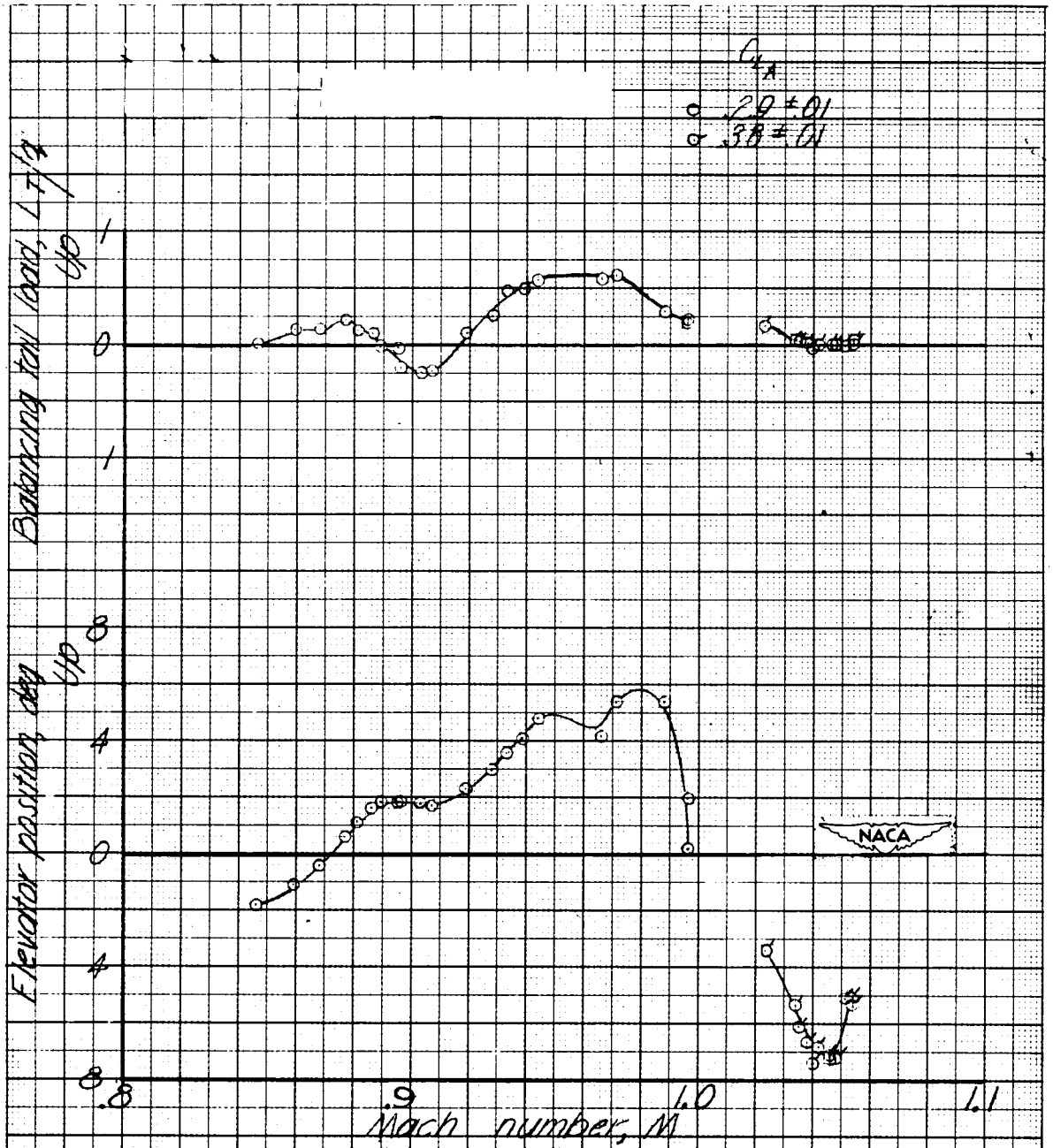


Figure 6 — Variation of measured quantities with Mach number. XS-1 airplane, 8% wing. Air Force flights. Altitude 43000 ft. $C_{L_A}$ = .38 ±.01, .29 ±.01; c.g. 24% MAC. $i_t = 2.4°$

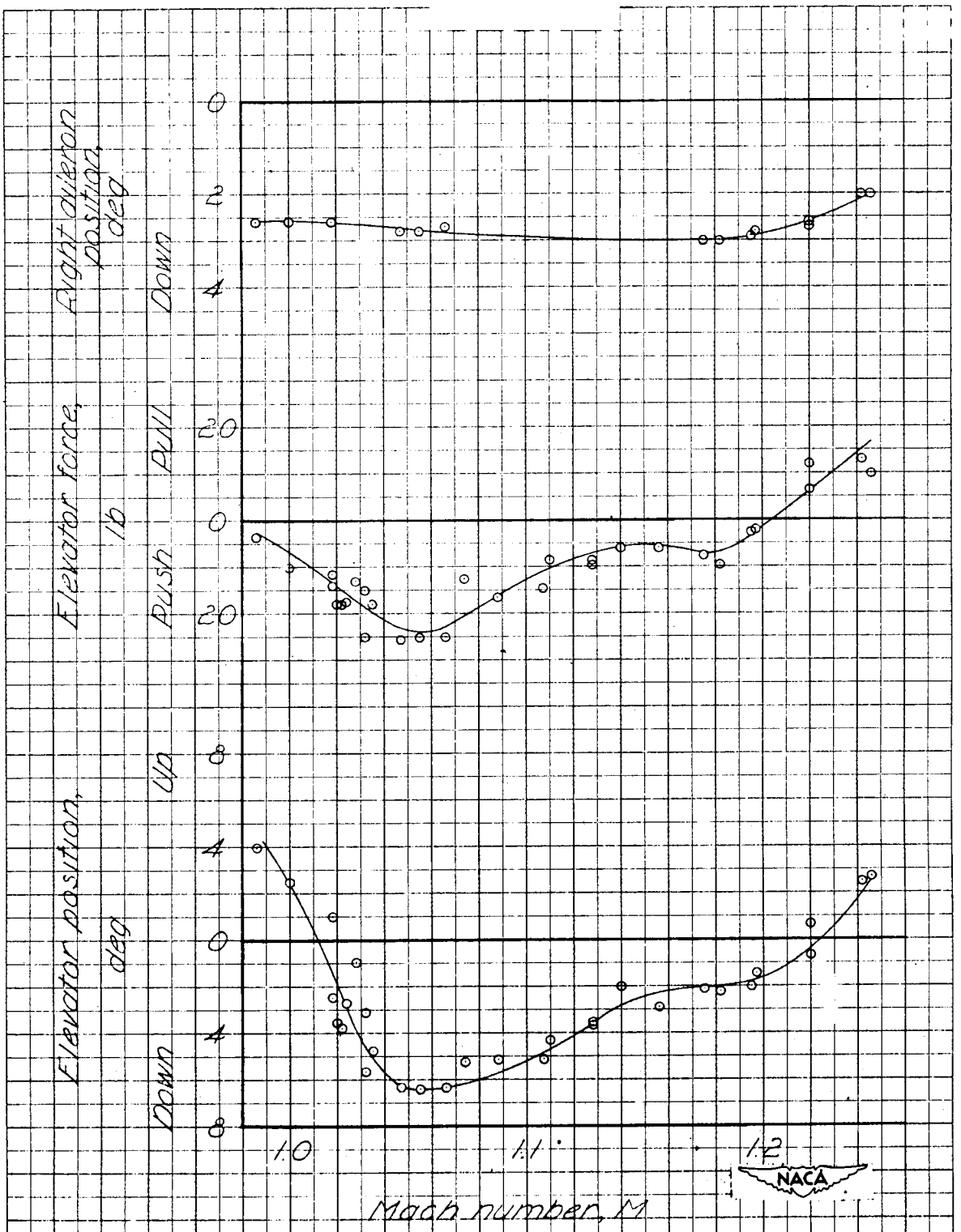


Figure 7.—Variation of measured quantities with Mach number. XS-1 airplane. 8% wing. Altitude 49,000 ft. Air Force flights. cg. 24% MAC, $C_{L_A}$ = .27 ± .07, $i_t$ = 2.2°.

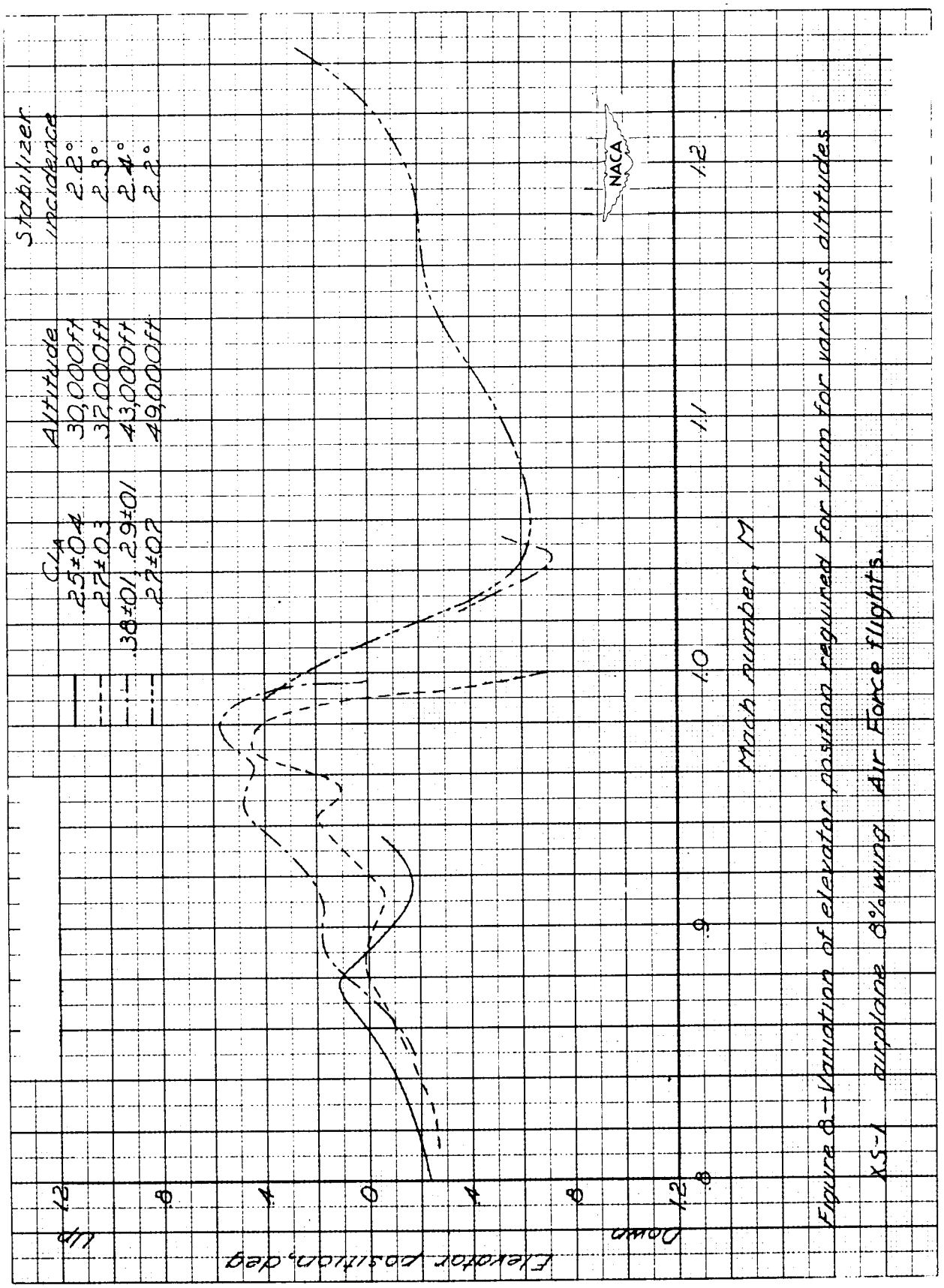


Figure 8.- Variation of elevator position required for trim for various altitudes. X-1 airplane 8% wing. Air Force flights.

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## ABSTRACT


Presents results of the U. S. Air Forces' accelerated transonic flight tests of the XS-1 No. 1 airplane for the Mach number range from 0.70 to 1.25 at altitudes from 30,000 to 49,000 feet.

Data are included on horizontal-tail loads and buffeting, longitudinal trim changes, elevator effectiveness and control forces, and lateral trim characteristics.