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# RESEARCH MEMORANDUM

for the



Air Materiel Command, Army Air Forces

## FLIGHT MEASUREMENTS OF THE FLYING QUALITIES OF A LOCKHEED P-80A AIRPLANE (ARMY No. 44-85099) - LONGITUDINAL-STABILITY AND -CONTROL CHARACTERISTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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# FLIGHT MEASUREMENTS OF THE FLYING QUALITIES OF A LOCKHEED P-80A AIRPLANE (ARMY No. 44-85099).- LONGITUDINAL-STABILITY AND -CONTROL CHARACTERISTICS

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## SUMMARY

This report contains the flight-test results of the longitudinal-stability and -control phase of a general flying-qualities investigation of the Lockheed P-80A airplane (Army No. 44-85099). The tests were conducted at indicated airspeeds up to 530 miles per hour (0.76 Mach number) at low altitude and up to 350 miles per hour (0.82 Mach number) at high altitude.

These tests showed that the flying qualities of the airplane were in accordance with the requirements of the Army Air Forces Stability and Control Specification except for excessive elevator control forces in maneuvering flight and the inadequacy of the longitudinal trimming control at low airspeeds.

## INTRODUCTION

Flight tests on a Lockheed P-80A airplane (Army No. 44-85099) were conducted at the request of the Air Materiel Command, Army Air Forces, to obtain quantitative measurements of the flying qualities. This report presents the data obtained during the longitudinal stability and control tests.

## DESCRIPTION OF THE AIRPLANE

A three-view drawing of the airplane is presented in figure 1 and photographs of the airplane as instrumented for flight tests are given in figures 2 and 3. The basic dimensions of the airplane are given in tables I and II. At the normal gross weight of 12,000 pounds the center-of-gravity range possible in flight is 0.196 to 0.317 M.A.C.

The variation of elevator control position with stick movement (spring tab locked) for the no-load ground condition, is presented in figure 4. The spring tab had a preload of 4 pounds and reached a maximum deflection (22° down) with an elevator control force of approximately 18 pounds. The combination trim and boost tab on the elevator had a boost ratio of $d\delta_t/d\delta_e = -0.33$. Figure 5 shows the variation of elevator control force (bungee effect) with elevator angle for the static no-load condition. The friction in the elevator-control system was found to be approximately 4 pounds as measured while the control was moved slowly through the neutral position.

## INSTRUMENT INSTALLATION

The flight-test data were obtained by the use of standard NACA photographically recording instruments synchronized by an NACA timer. The elevator and elevator-tab position recorders were of the wire-wound resistor type mounted on the inboard edge of the fixed surface.

Indicated airspeed $V_i$ was measured by means of a standard NACA free-swiveling airspeed head mounted approximately two chord lengths ahead of the wing leading edge on the right wing tip (fig. 2). The airspeed values were corrected for position error due to the presence of the wing and also for the inherent static-pressure error of the airspeed head. Values of indicated airspeed were computed from the airspeed formula (corrected for compressibility) commonly used in the calibration of standard airspeed indicators.

## TESTS, RESULTS, AND DISCUSSION

The tests were conducted over the center-of-gravity range at take-off from 0.21 to 0.295 M.A.C., for gross weights (at take-off) of 11,730 and 11,130 pounds, respectively. Records were taken in a low-altitude range of 2,100 to 11,500 feet and a high-altitude range of 27,300 to 36,000 feet. The low-altitude tests were made at indicated airspeeds up to 530 miles per hour (0.76 Mach number M) and the high-altitude tests up to 350 miles per hour (0.82 Mach number). In the presentation of the results, indicated airspeed was considered the primary independent variable for low-altitude tests, and Mach number the primary variable for high-altitude tests.

## Dynamic Longitudinal Stability

Although no quantitative data are presented herein, it was found from flight records that the short-period dynamic oscillations of normal acceleration and elevator angle were damped within one cycle up to the highest test speed of 500 miles per hour at an average pressure altitude $h_{p_{av}}$ of 5000 feet (0.71 Mach number) and 295 miles per hour at 35,000 feet (0.76 Mach number).

## Static Longitudinal Stability

The static longitudinal-stability characteristics are presented in figure 6 for the landing approach (flap and gear down, 50-percent power) and power-on-clean (flap and gear up, 96- to 100-percent power) conditions. Stick-free and stick-fixed characteristics which are in accordance with the requirements of reference 1 are shown by the data in figure 6. Due to the effects of compressibility on the stability of the airplane, the slope of the curves of elevator angle and control force tend to reverse at approximately 0.70 Mach number. (See fig. 6(c).) It can be seen, however, that these changes are of small magnitude up to the highest test Mach number of 0.817.

Figure 7 presents data showing the determination of the stick-fixed and stick-free neutral points for the power-on-clean condition at low altitude. The rate of change of elevator angle $\delta_e$ and trim tab angle $\delta_t$ for zero elevator-control force with lift coefficient $C_L$ were derived from cross plots of data obtained in flight tests in which the trim tab was varied over a suitable range at each of several constant airspeeds. These data (fig. 7), which are for a condition of zero spring-tab deflection, show that the position of the neutral point is approximately 0.34 M.A.C., for both the stick-fixed and stick-free conditions over a $C_L$ range of 0.1 to 0.8 and a Mach number range of 0.19 to 0.74.

## Elevator Control Power

The elevator-control characteristics for the landing condition in the presence of the ground are shown by the data in figure 8. These data were taken from cross plots at three center-of-gravity positions of the variation with airspeed of elevator angle required for ground contact. These data indicate that the elevator power was sufficient to land the airplane at $1.05V_{S_L}$ (120 mph) with the center-of-gravity position as far forward as 0.17 M.A.C. The elevator control forces required to land at $1.05V_{S_L}$ exceeded 35 pounds for the forward center-of-gravity condition, due primarily to the inadequacy of the trimming control.

The elevator-control characteristics in maneuvering flight for the low-altitude tests are shown by the data in figure 9. These results indicate an appreciable increase in stick-force gradient with increasing acceleration for the forward center-of-gravity position, and a slight reduction in stick-force gradient with increasing acceleration for the rear center-of-gravity position. A summary of the foregoing data has been made for the highest test speed, and the results are shown in figure 10 as the variation of the stick-force gradient with center-of-gravity position for various values of $A_Z$. It can be seen that the stick-force gradient is unsatisfactorily large at the higher $A_Z$ values for center-of-gravity positions forward of approximately 0.25 M.A.C., and forward of 0.23 M.A.C., for the lower $A_Z$ values.

Figure 11 presents data showing the variation of elevator angle with indicated airspeed for balance for various values of normal acceleration factor $A_Z$. These data, derived from figure 9 for the forward center-of-gravity position at low altitude, show that the elevator was powerful enough to develop either the maximum lift coefficient or the maximum allowable load factor over the range tested.

The elevator-control characteristics in maneuvering flight at high altitude are shown by the data in figures 12 through 15. The curves showing the variation of elevator angle with Mach number for various $A_Z$ values (figs. 13 and 15) were obtained from cross plots of the data of figures 12 and 14. The curves of elevator angle for trim for $A_Z=1$ are for approximately zero deflection of the spring tab and therefore will not exactly agree with the data presented previously in the static longitudinal-stability characteristics shown in figure 6(c).

A summary of the control-force variation at high altitudes (approximately 29,000 to 36,400 feet) with $A_Z$ is given by the data in figure 16, in which the variation of elevator control-force gradient with Mach number is shown for the forward and rear center-of-gravity positions. These data show a large increase in control-force gradient at the higher Mach numbers for the forward center-of-gravity location. At the rear center-of-gravity location only a small variation of stick-force gradient was noted. This effect is partially attributed to the larger change with Mach number of the elevator deflection per unit $A_Z$ required at the forward center-of-gravity location. (See figs. 12(c) and 14(c).)

## Longitudinal Trim Changes

The longitudinal trim changes encountered at constant speed and trim-tab setting for any variation of power, flap, or gear setting did not exceed 2 pounds.

## Longitudinal Trimming Control

From tests in steady straight flight it was found that the elevator trim tab was not capable of reducing the elevator control force to zero at $1.4V_{S_L}$ (165 mph) and $1.2V_{S_P}$ (150 mph) with the center of gravity in the forward position. The lowest trim speed obtainable with full nose-up tab setting was approximately 200 miles per hour for the forward center-of-gravity position.

## CONCLUSIONS

From the results of the flight tests the following conclusions have been made in regard to the flying qualities of the Lockheed P-80A airplane:

1. The dynamic longitudinal-stability characteristics were satisfactory at indicated airspeeds up to 500 miles per hour at 5,000 feet (0.71 Mach number) and up to 295 miles per hour at 35,000 feet (0.76 Mach number).

2. The static longitudinal-stability characteristics were satisfactory over the test range. The power-on-clean stick-fixed and stick-free neutral points were located at approximately 0.34 M.A.C., for the low-altitude tests.

3. The elevator-control power was sufficient to develop either the maximum lift coefficient or the limit load factor over the test range.

4. The elevator control was sufficiently powerful to hold the airplane off the ground at a speed of $1.05V_{S_L}$ with the center of gravity in the forward position.

5. The elevator control-force gradient in accelerated flight was excessive and varied appreciably with airspeed and acceleration factor for the forward center-of-gravity location. For example, at low altitude for the highest test speed the gradient was 10.8 pounds per g at $A_Z$=2 and 14.2 at $A_Z$=6. At high altitudes, the elevator control-force gradient increased sharply at the higher Mach numbers at the forward center-of-gravity position, where the gradient (taken at $A_Z$=3) varied from 27 pounds per g at 0.75 Mach number to 45 at 0.822 Mach number.

6. The changes in elevator control force required in steady straight flight at constant speed following changes in flap, gear, and power settings were desirably small.

7. The longitudinal trimming control was inadequate in that it was not possible to trim to zero elevator control force at speeds below 200 miles per hour with the forward center-of-gravity location.

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Furthermore a very defined buffeting region is reached at $M$=.74 & $A_Z$=3.3 at 35000' which affects the pilot certainly - if not some of the parameters plotted herein. No mention though!

REFERENCE

1. Anon: Stability and Control Characteristics of Airplanes. Spec. No. R-1815-A, Army Air Forces, April 7, 1945.

TABLE I.— BASIC DIMENSIONAL DATA OF THE TEST AIRPLANE, LOCKHEED P-80A AIRPLANE

| Item | Wing | Horizontal tail | Vertical tail |
|---|---|---|---|
| Area, sq ft | 237 | 34.7 | 22.4 |
| Span, ft | 38.9 | 15.6 | 6.5 |
| Aspect ratio | 6.39 | 7.01 | 1.89 |
| Taper ratio | .364 | .366 | .40 |
| Mean aerodynamic chord, in. | 80.6 | – – – | – – – |
| Dihedral of trailing edge of wing, deg | 3.83 | 0 | – – – |
| Incidence of root chord (with respect to thrust line), deg | 1.0 | 1.30 | – – – |
| Geometric twist, deg | 1.5 washout from root to tip | 0 | 0 |
| Root section | NACA $65_1$-213 (a=0.5) | NACA 65-010 | NACA 65-010 |
| Tip section | NACA $65_1$-213 (a=0.5) | NACA 65-010 | NACA 65-010 |

[redacted]

TABLE II.– DIMENSIONAL CHARACTERISTICS OF THE SURFACES OF THE TEST AIRPLANE, LOCKHEED P-80A AIRPLANE

| Item | Elevators | Rudder | Flaps | Ailerons |
|---|---|---|---|---|
| Area aft of hinge line (both sides), sq ft | 8.5 | 5.6 | 30.7 | 17.5 |
| Hinge-line location, percent chord of fixed surface | 75 | 75 | 75 | 75 |
| Type of flap and balance | Boost tab plus spring tab; radius nose on elevator. Static and dynamic mass balance | No balance; radius nose on rudder. Rudder has centering spring. Static and dynamic mass balance. | Split, no balance | None; piano hinge on upper wing surface. Aileron control system has power boost. Static and dynamic mass balance. |
| Travel | $37^{\circ}$ up, $16^{\circ}$ down | $15.5^{\circ}$ left and $15.5^{\circ}$ right | Down $45^{\circ}$ | $41.5^{\circ}$ total |
| Tabs | Trim and boost-tab area, 0.55 sq ft (total). Boost-tab ratio, 0.33. Spring tab (on inboard and of elevator) area, 0.51 sq ft. (total) | Bent tab on trailing edge of rudder. | – – – – | Trim tab on left aileron |

Note: All movable surfaces are metal covered.

# FIGURE LEGENDS

Figure 12.– Concluded. (c) M, .812, .822.

Figure 13.– Variation of elevator angle with Mach number for various $A_Z$ values. Forward c.g. position. Power-on, clean. High altitude.

Figure 14.– Elevator control characteristics at high altitude. Rear c.g. position. Power-on, clean. (a) M, .415, .528, .670, .739.

Figure 14.– Continued. (b) M, .762, .774, .787.

Figure 14.– Concluded. (c) M, .798, .817.

Figure 15.– Variation of elevator angle with Mach number for various $A_Z$ values. Rear c.g. position. Power-on, clean. High altitude.

Figure 16.– Variation of control-force gradient with Mach number for the forward and rear c.g. positions. Power-on, clean. High altitude.

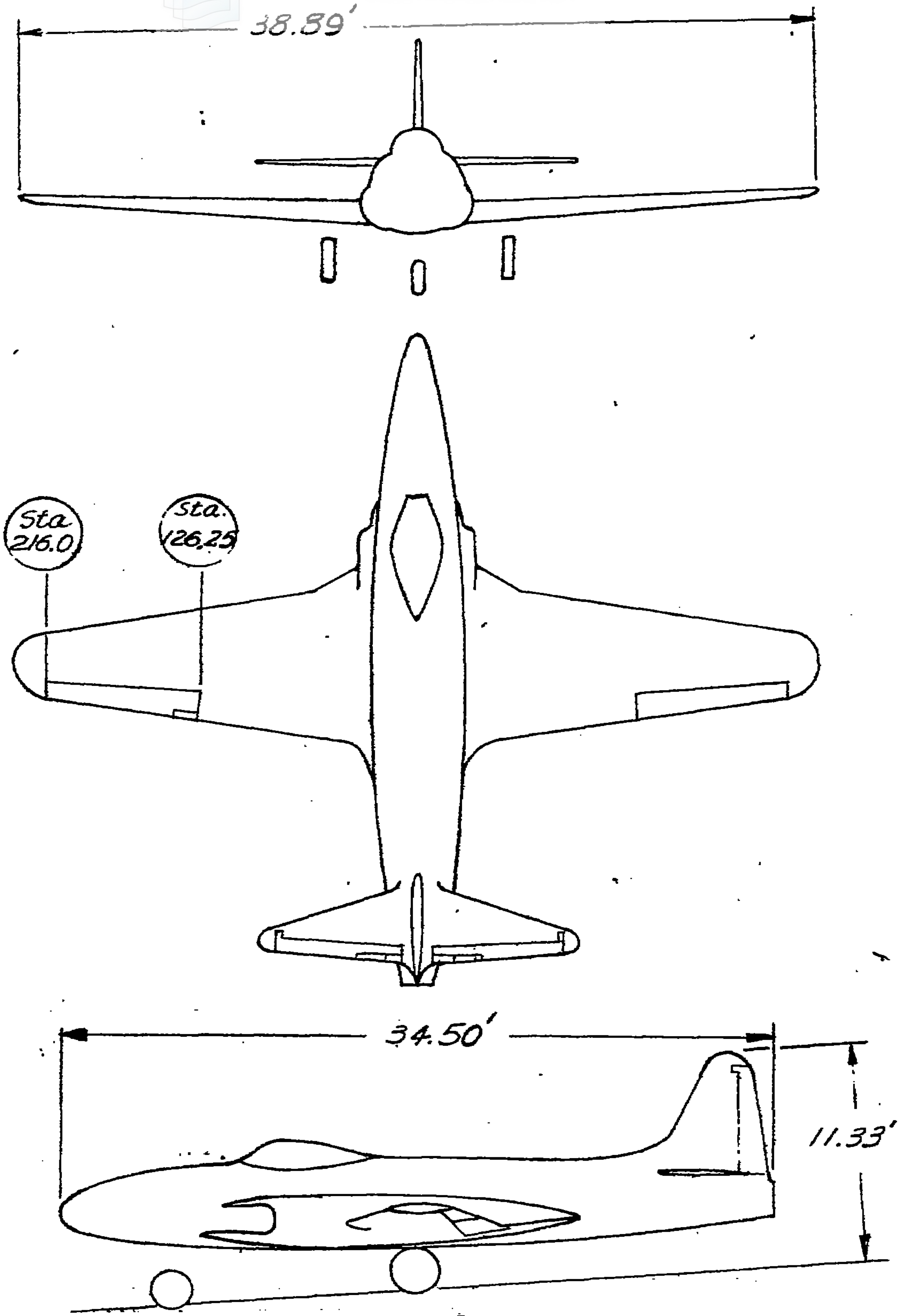




Figure 1.- Three-view drawing of test airplane.

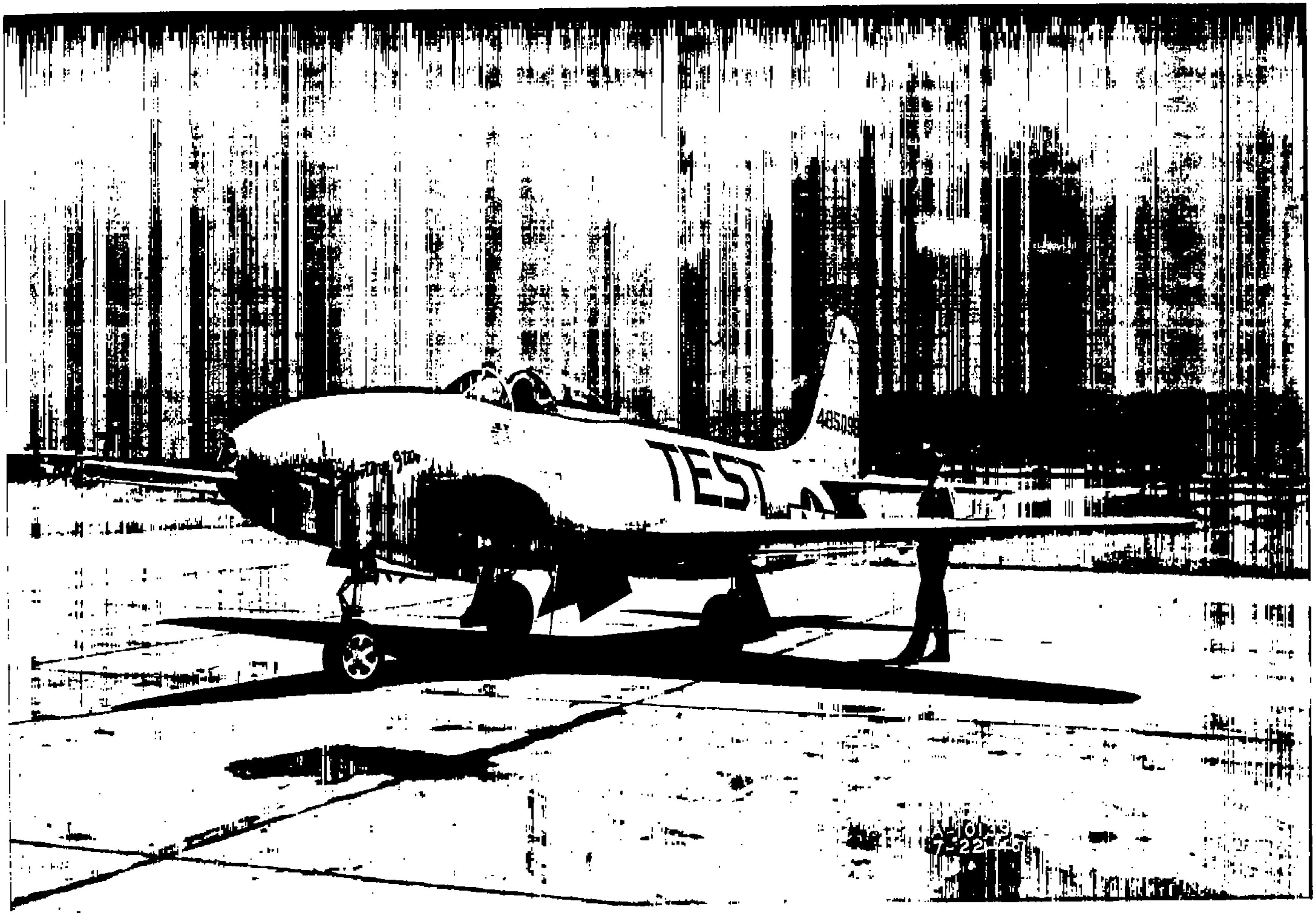

Figure 2.- Three-quarter front view of the test airplane as instrumented for flight tests.

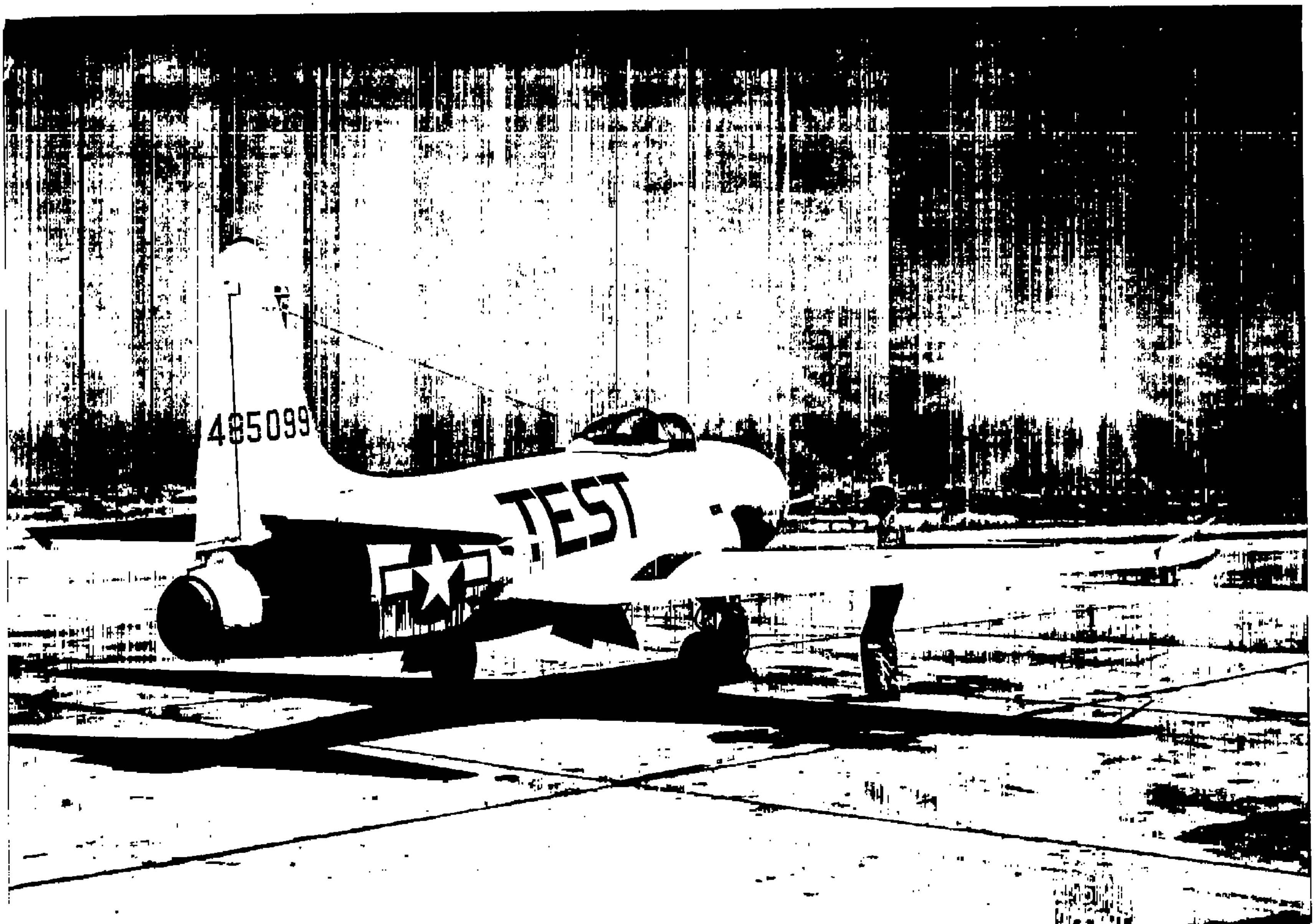


Figure 3.- Three-quarter rear view of the test airplane.

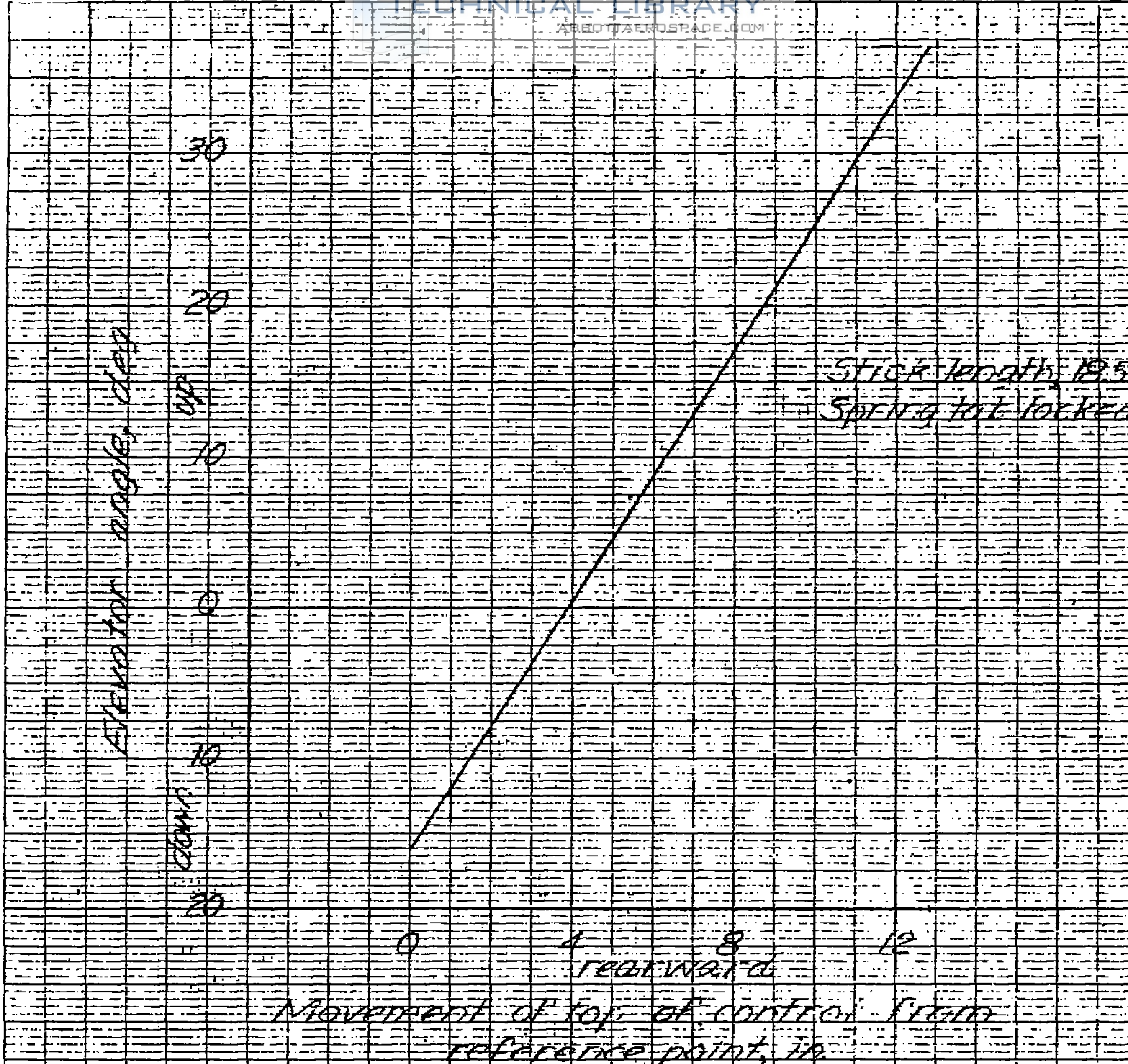


Figure 4.- Variation of elevator angle with stick movement for static no-load condition.

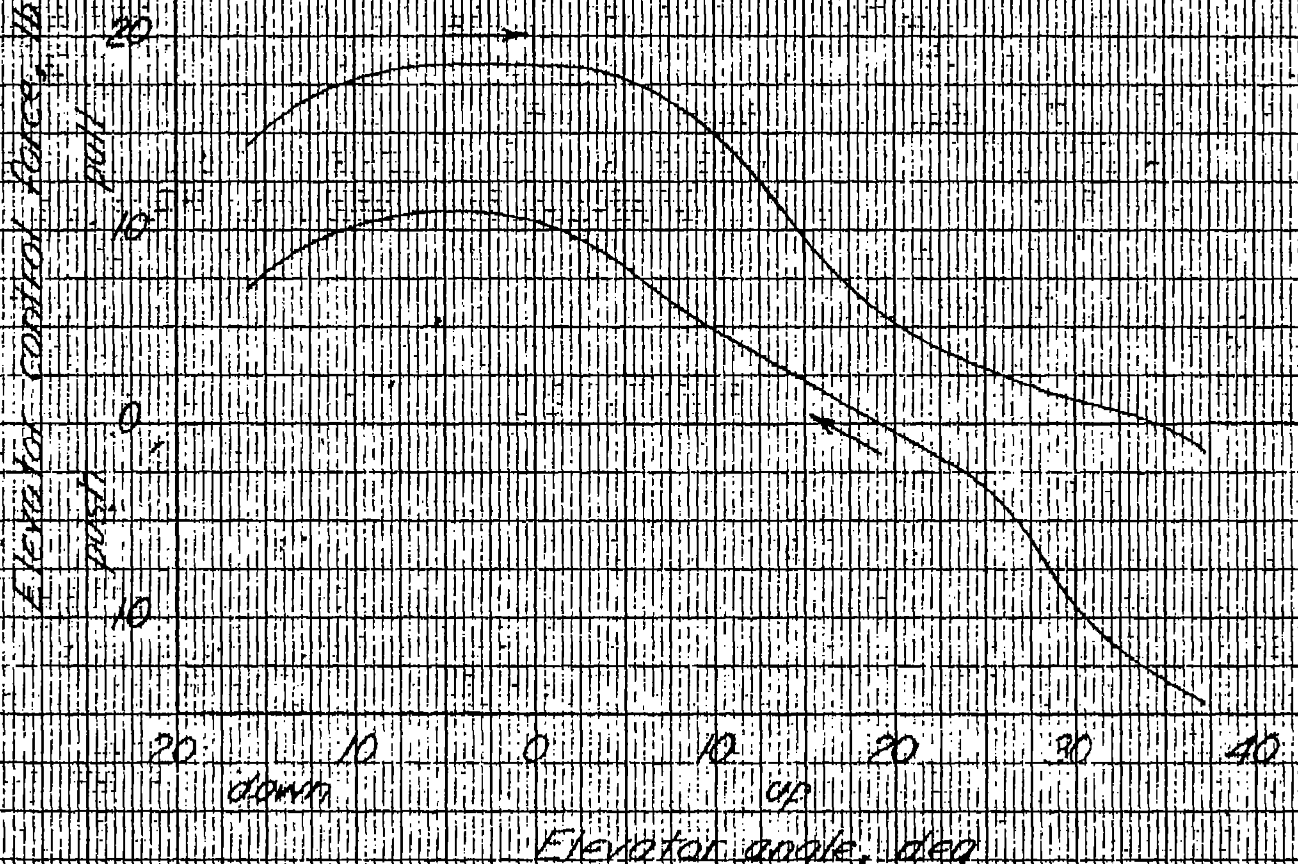


Figure 5.- Variation of elevator control force with elevator angle for static no-load condition.

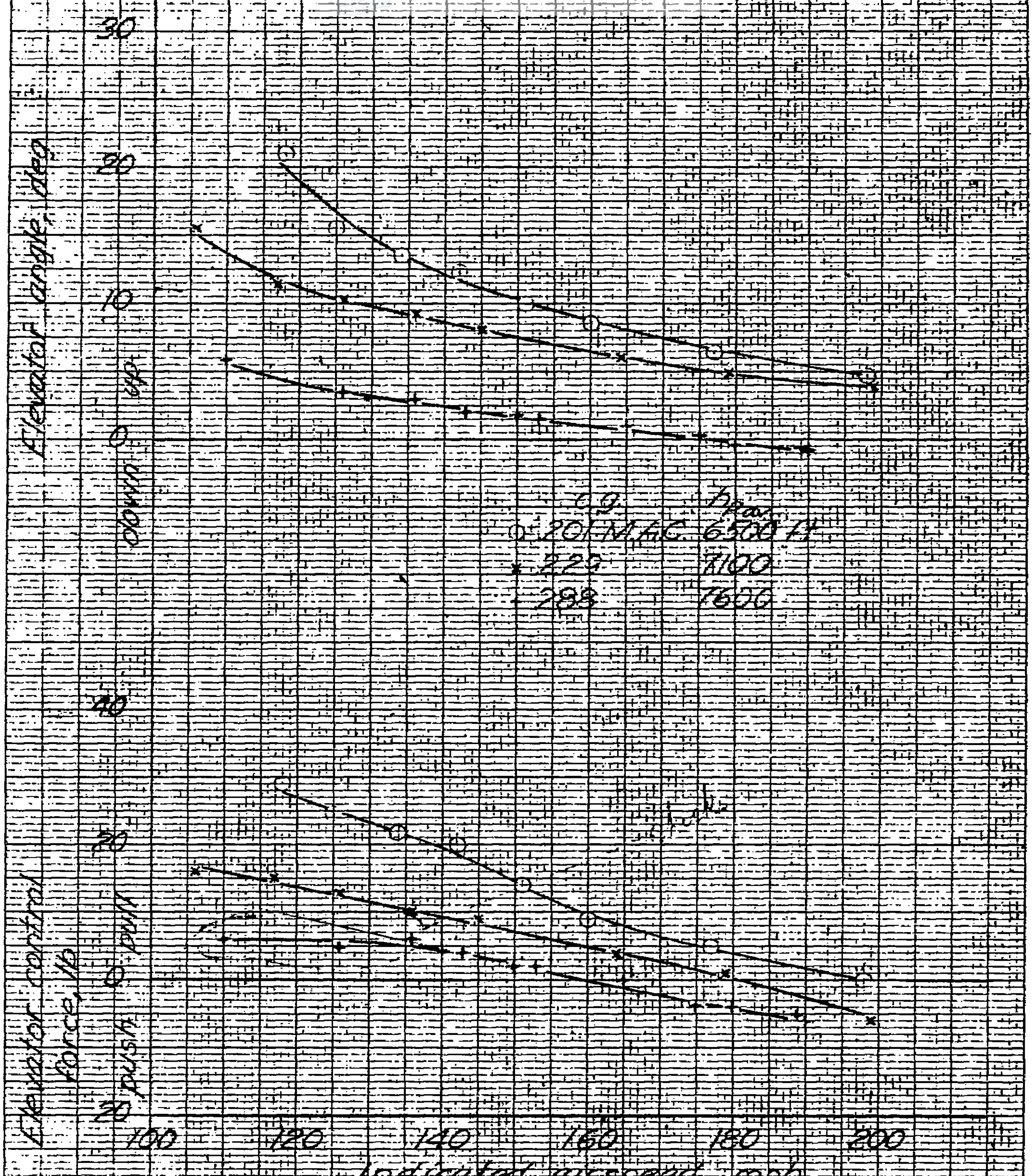


Figure 6. - Static longitudinal stability characteristics
(a) Landing approach condition. Low altitude

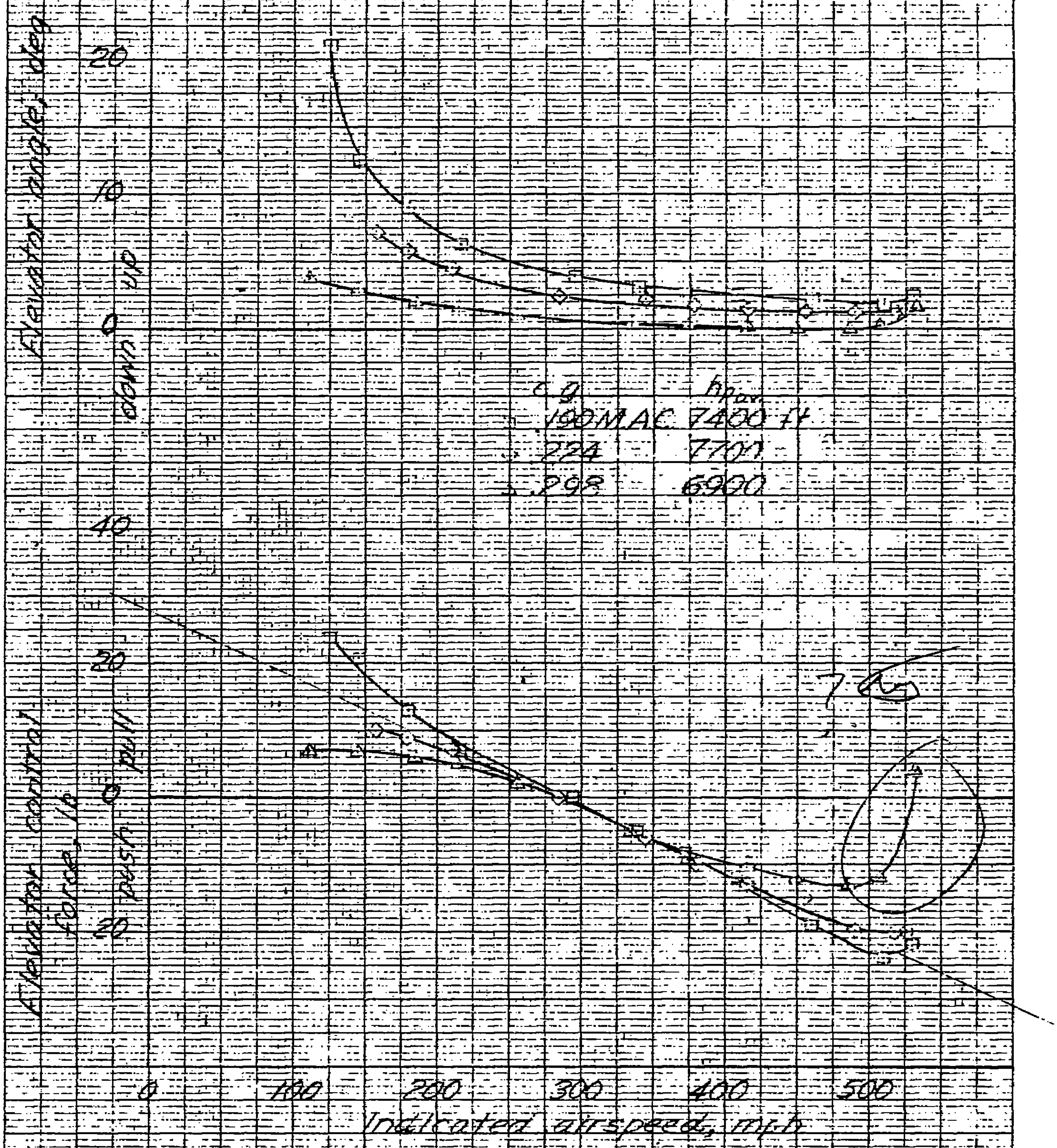


Figure 6.– Continued
(b) Power-on, clean, low altitude

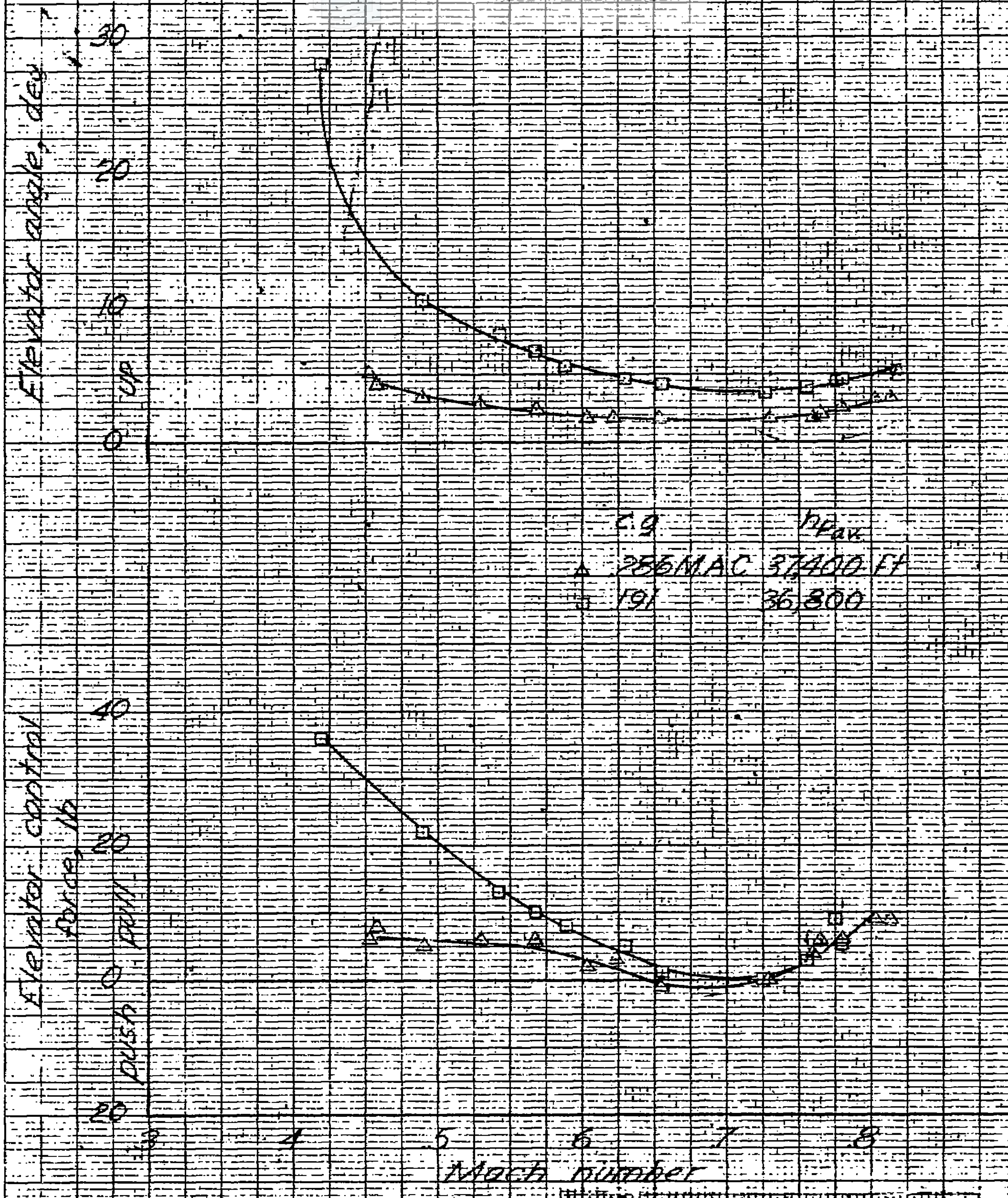


Figure 6.- Concluded.
(c) Power-on, clean. High altitude.

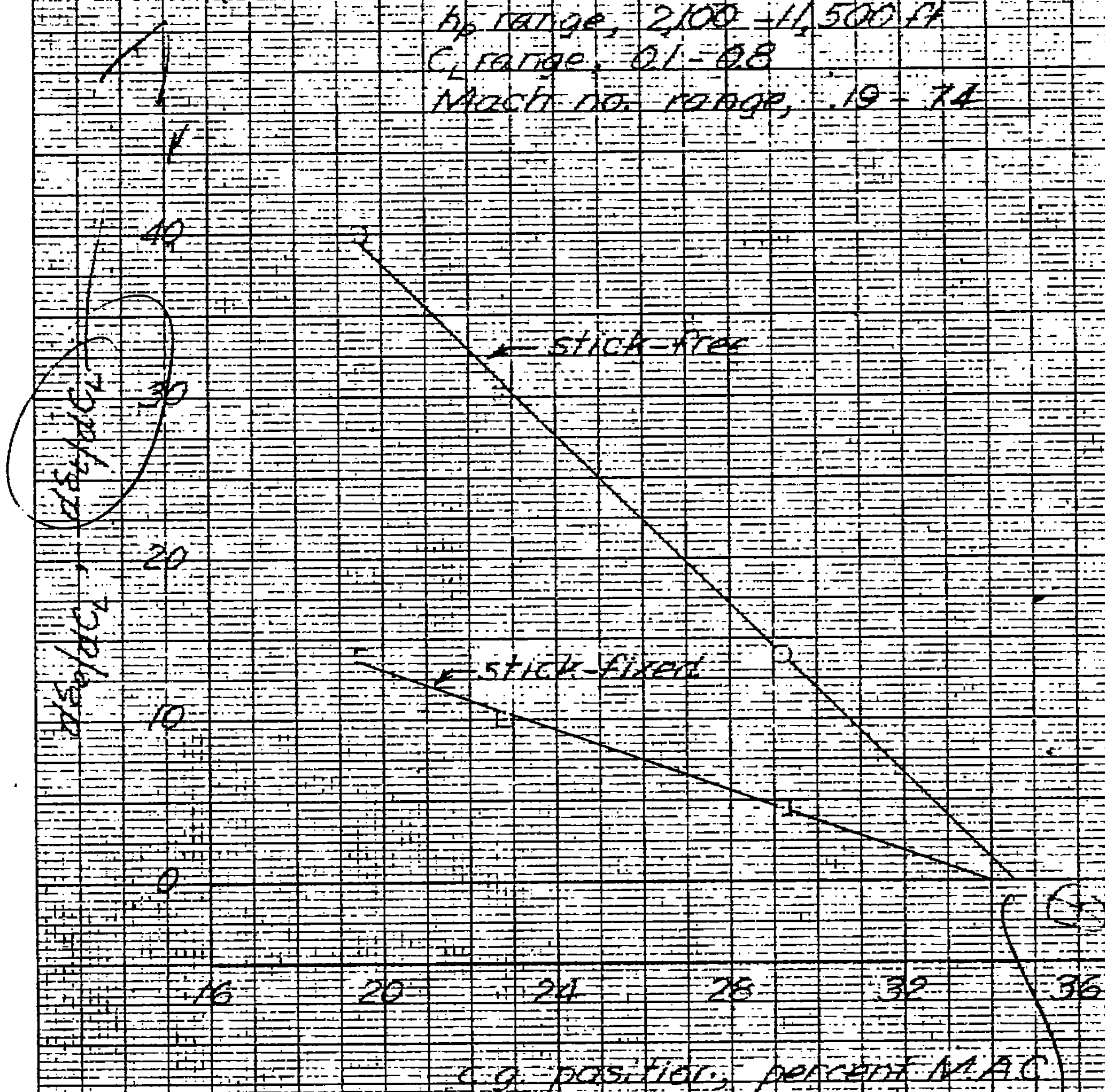


Figure 7.- Determination of the stick-fixed and stick-free neutral points. Power-on, clean, low altitude.

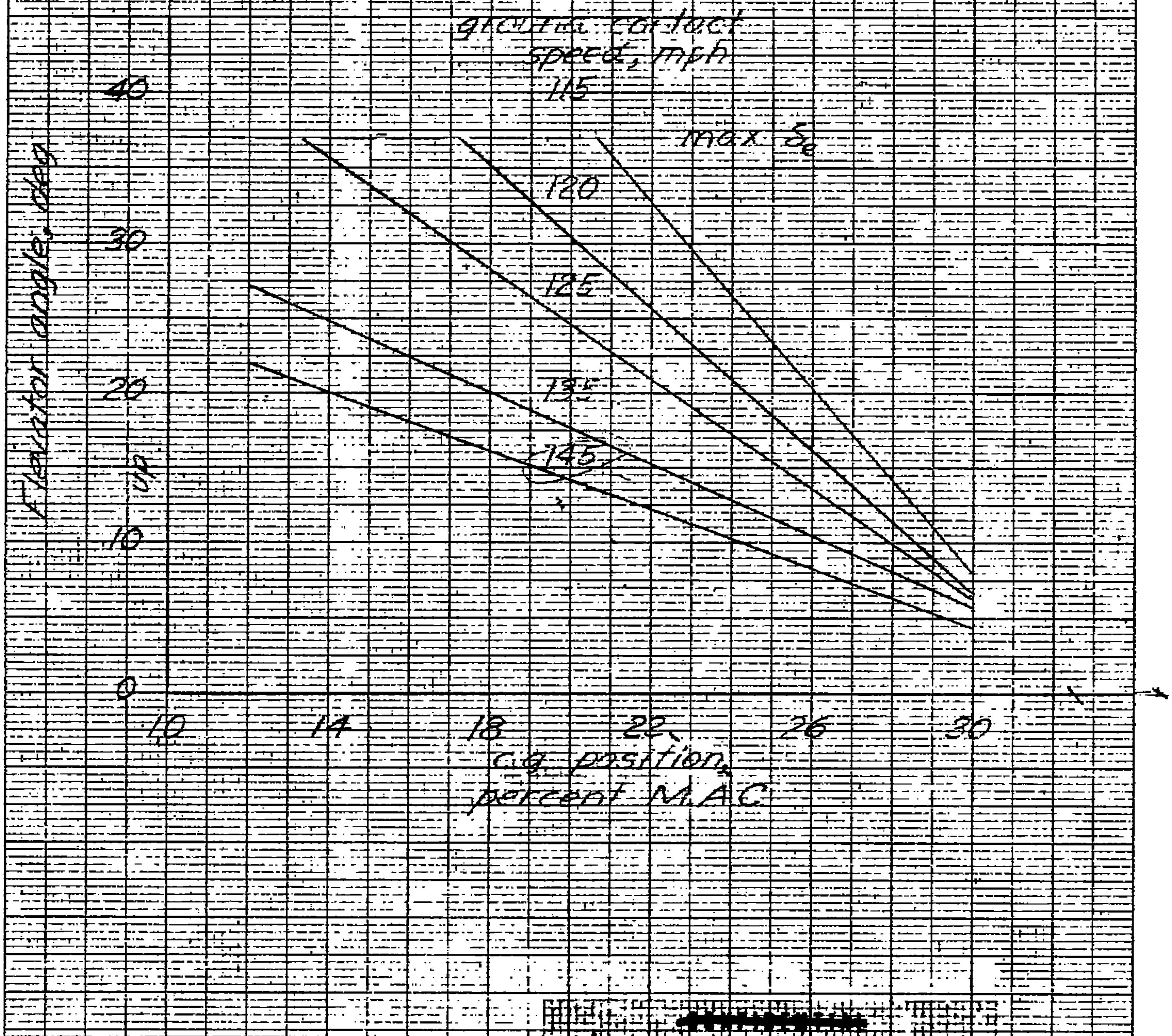




Figure 8. Variation of elevator angle with c.g position for various touchdown speeds Flap and gear down, engine throttled.

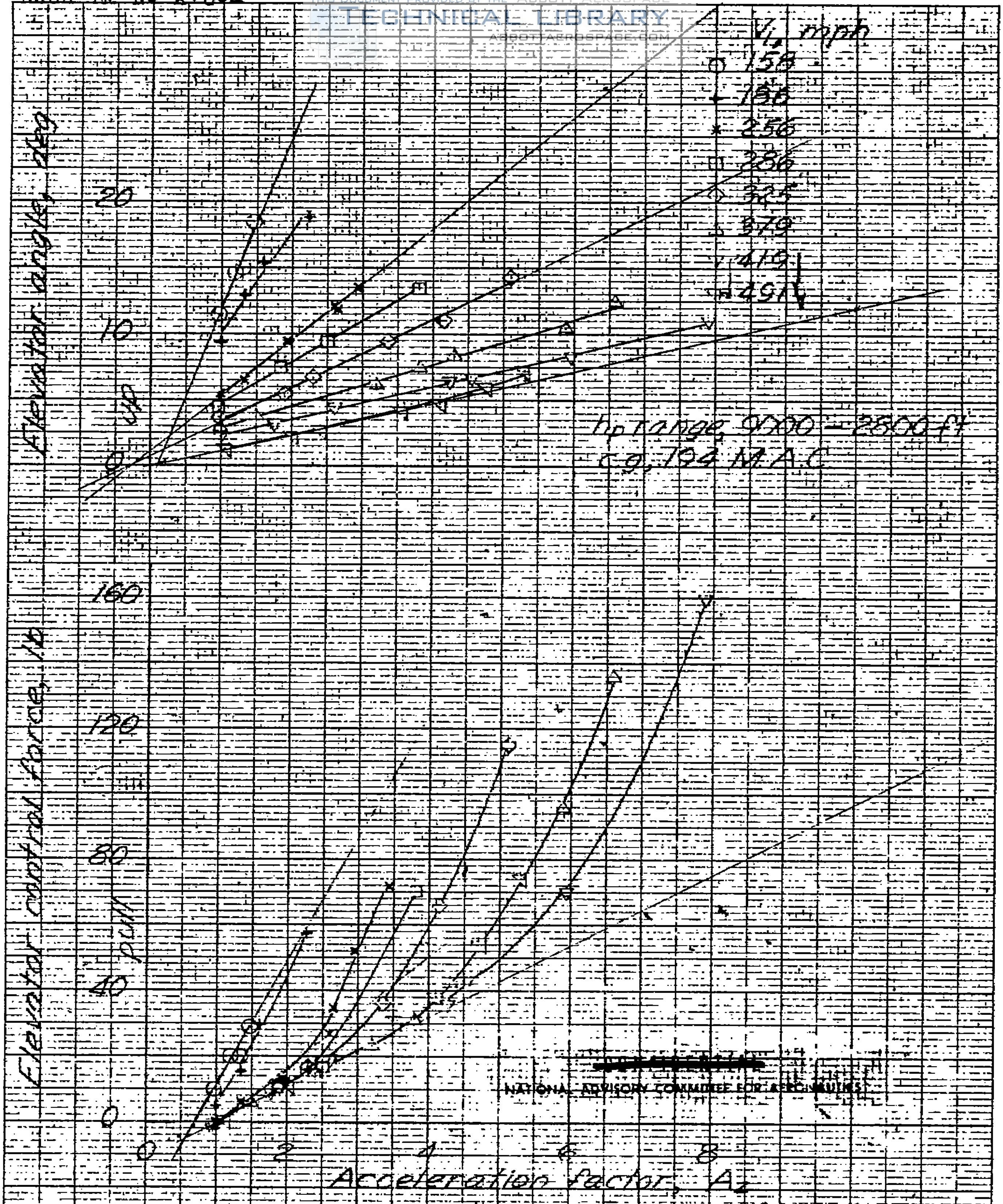




Figure 9. - Elevator control characteristics at low altitude. Power-on, clean.
(a) Forward c.g.

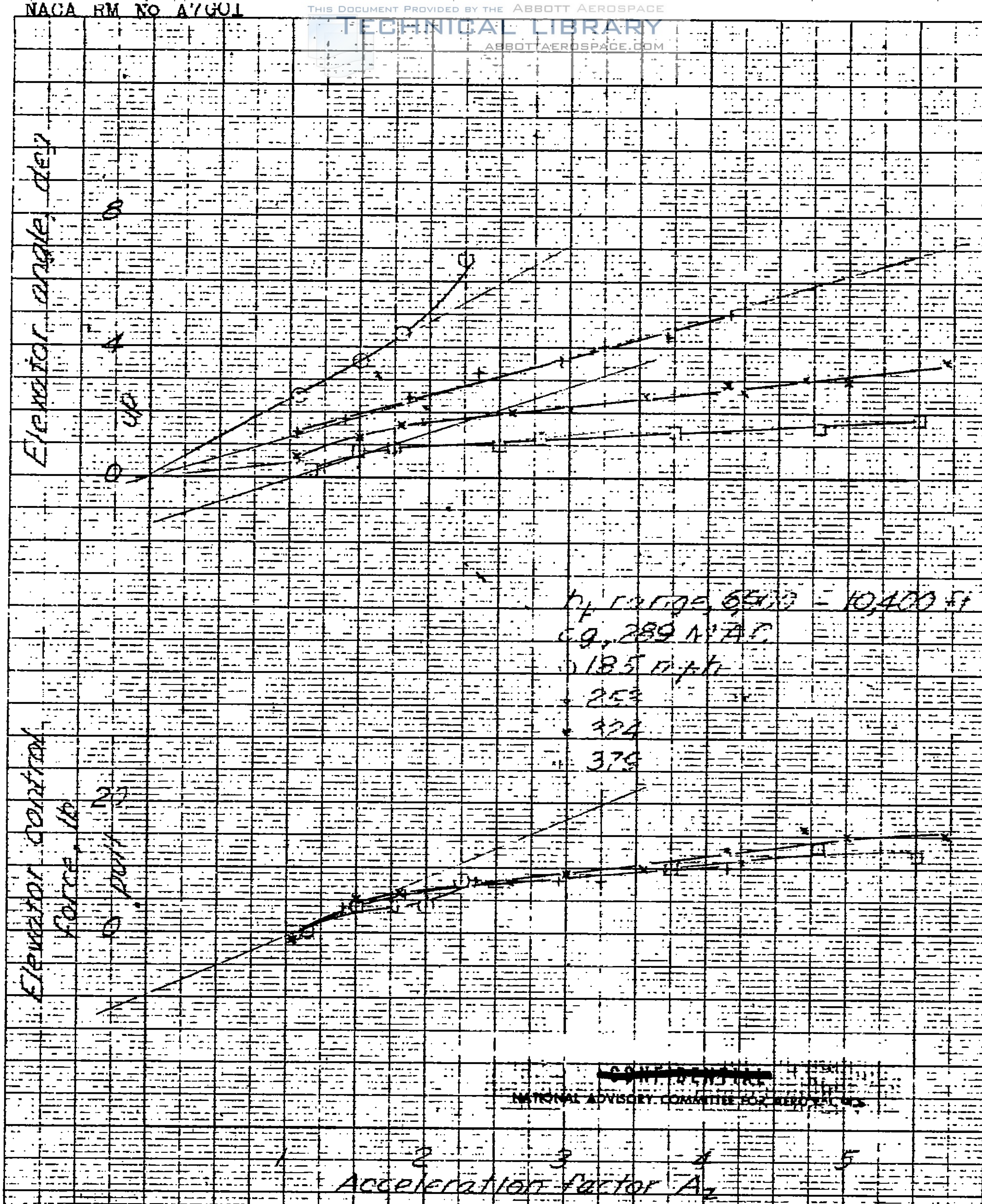


Figure 9 – Continued

(b) Rear c.g., 185, 253, 324, 379 mph

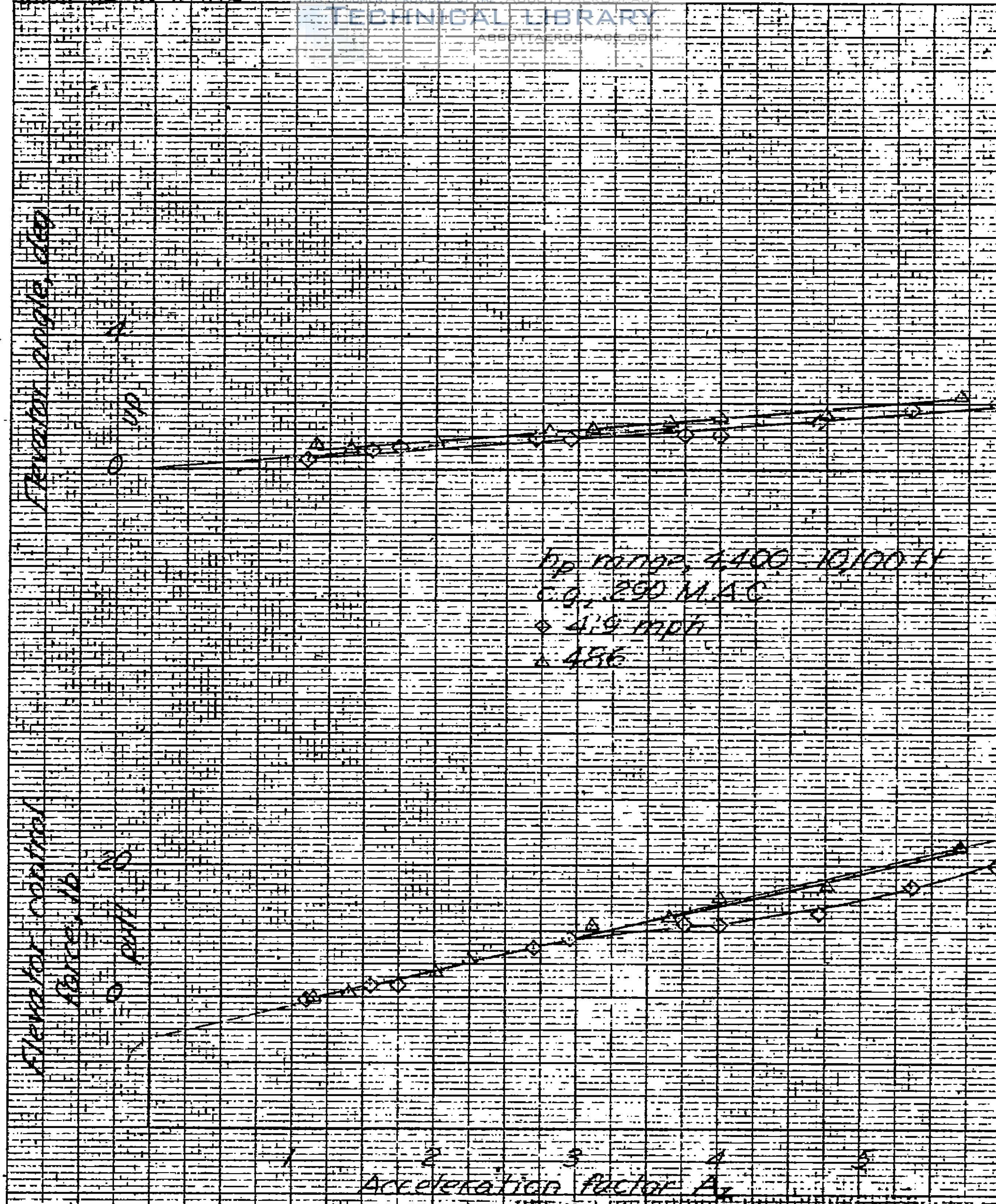


Figure 9.- Concluded.

(c) Rear c.g., 419, 486 mph

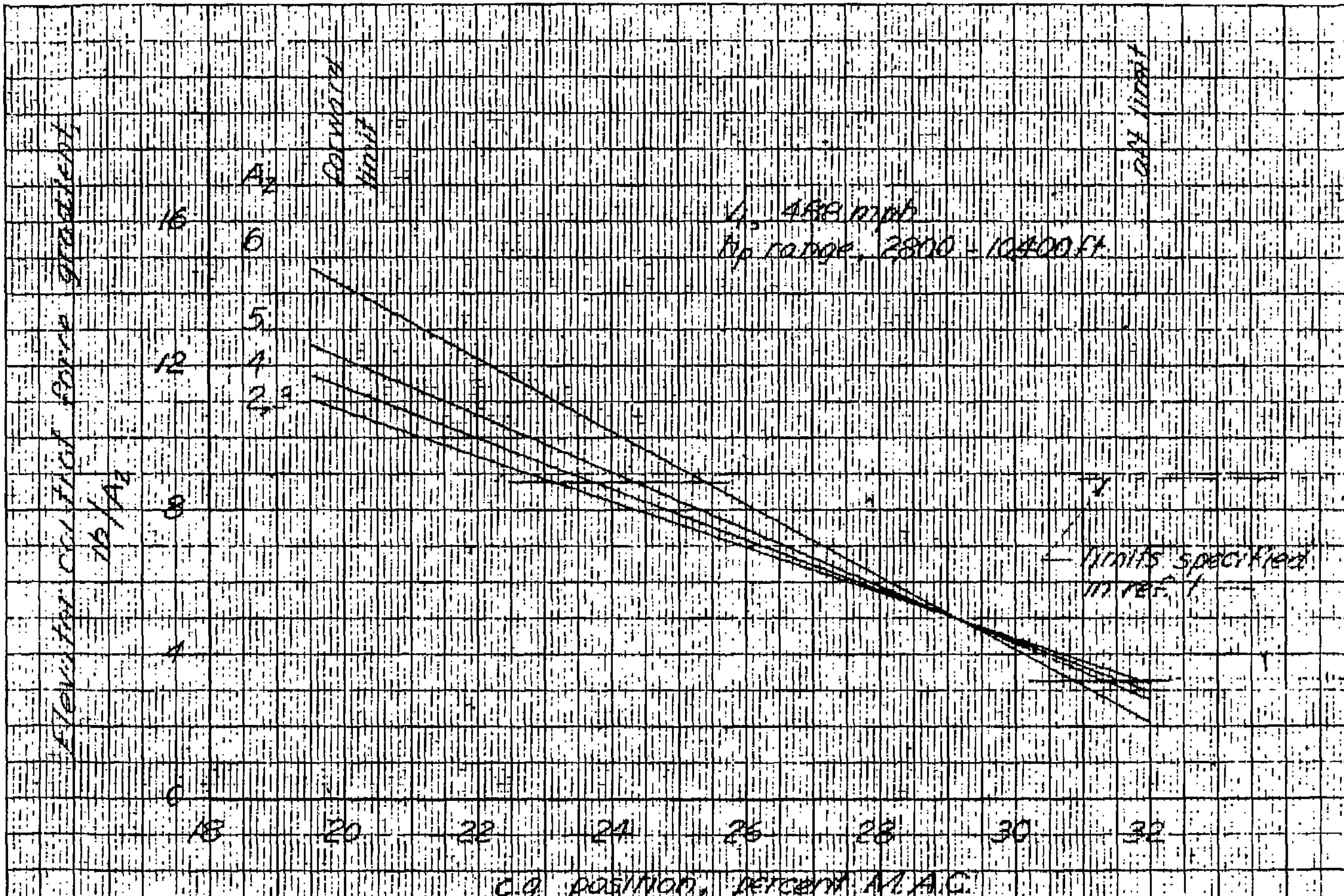


Figure 10.- Variation of control force gradient with c.g. position for various $A_z$ values. Power-on, clean. Low altitude.

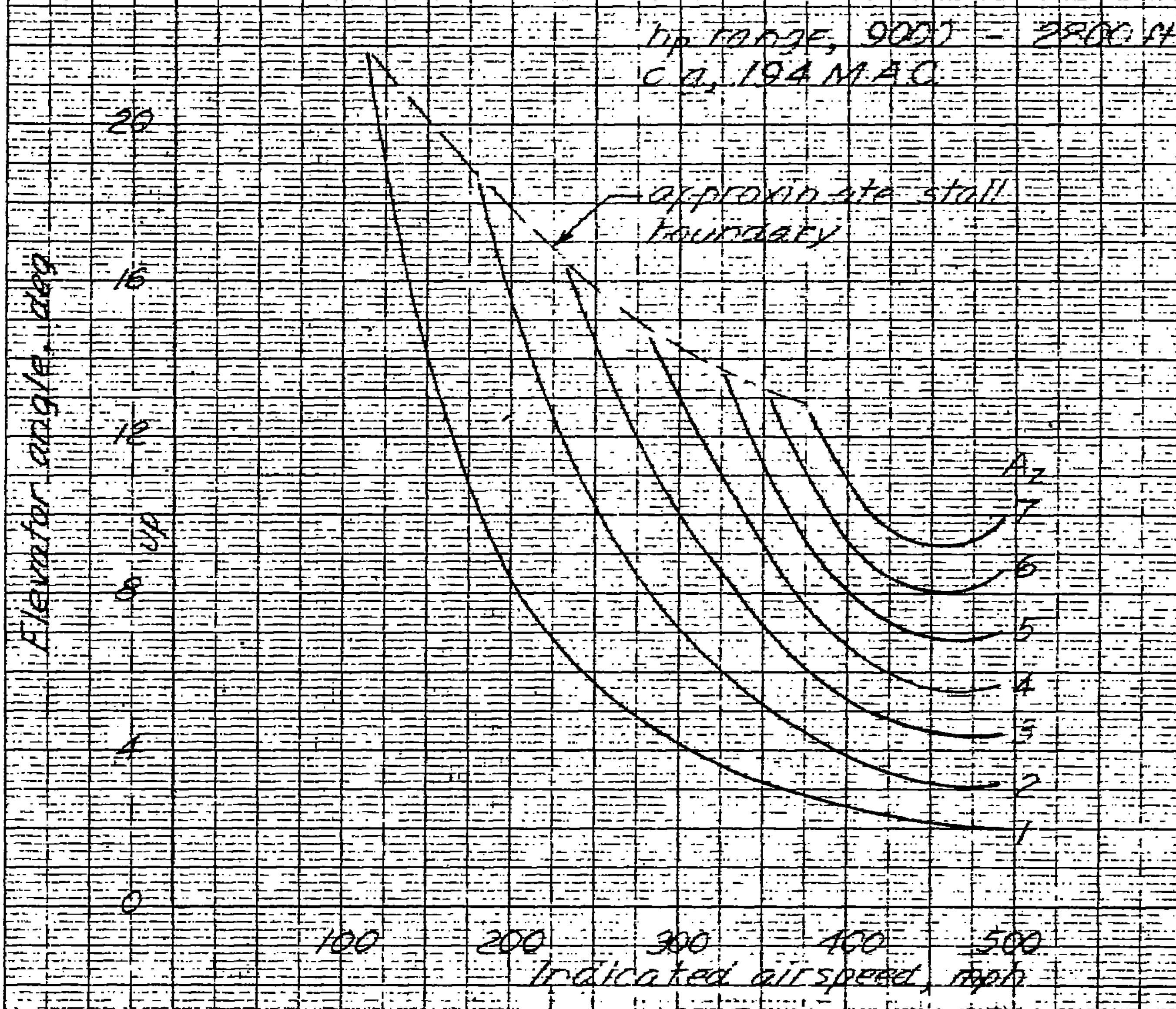




Figure 11.- Variation of elevator angle with airspeed for various values of $A_z$. Power on, clean, low altitude, c.g. forward.

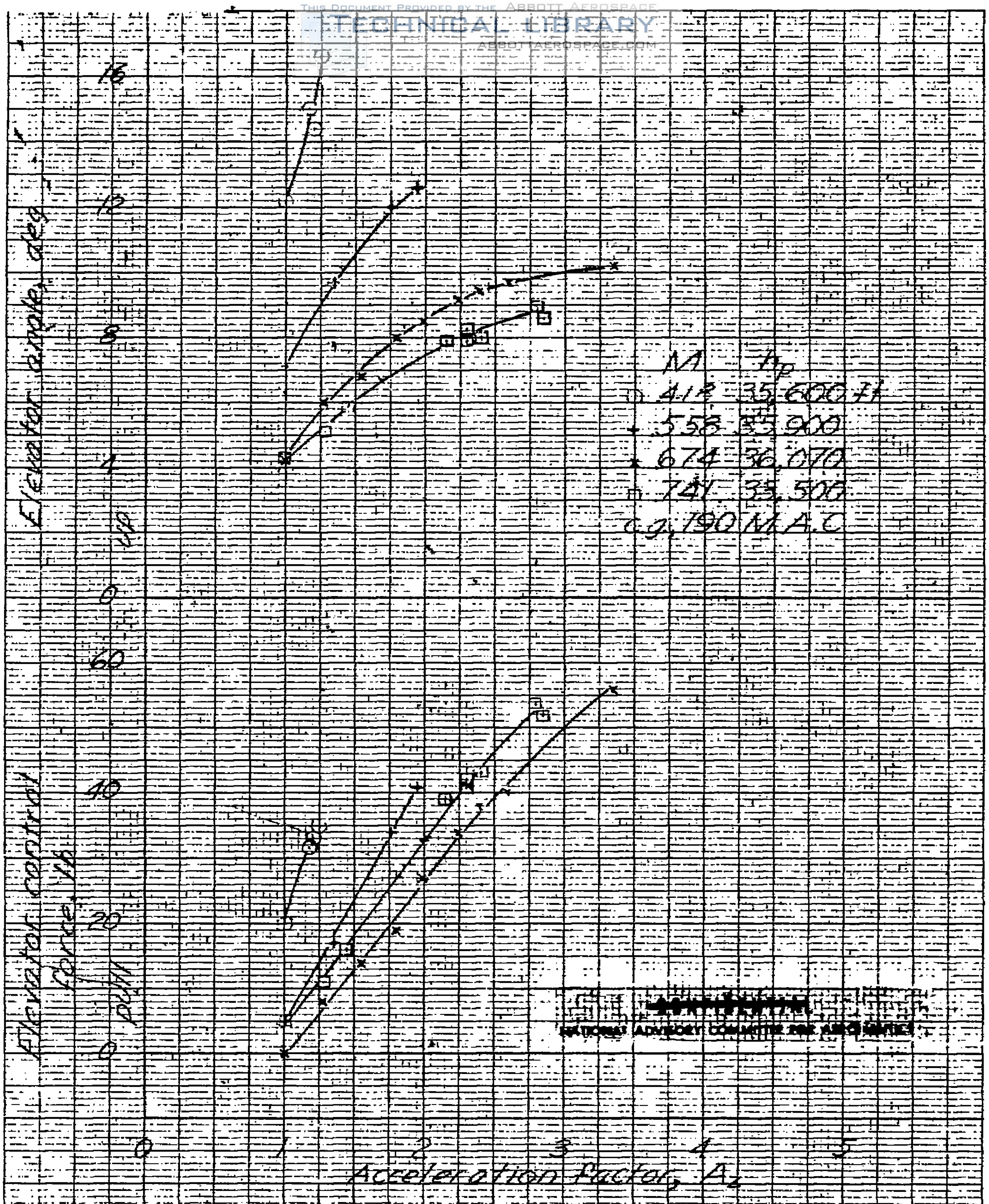


Figure 12.- Elevator control characteristics at high altitude. Forward c.g. position. Power-on clean. (a) M, .418, .558, .674, .741.

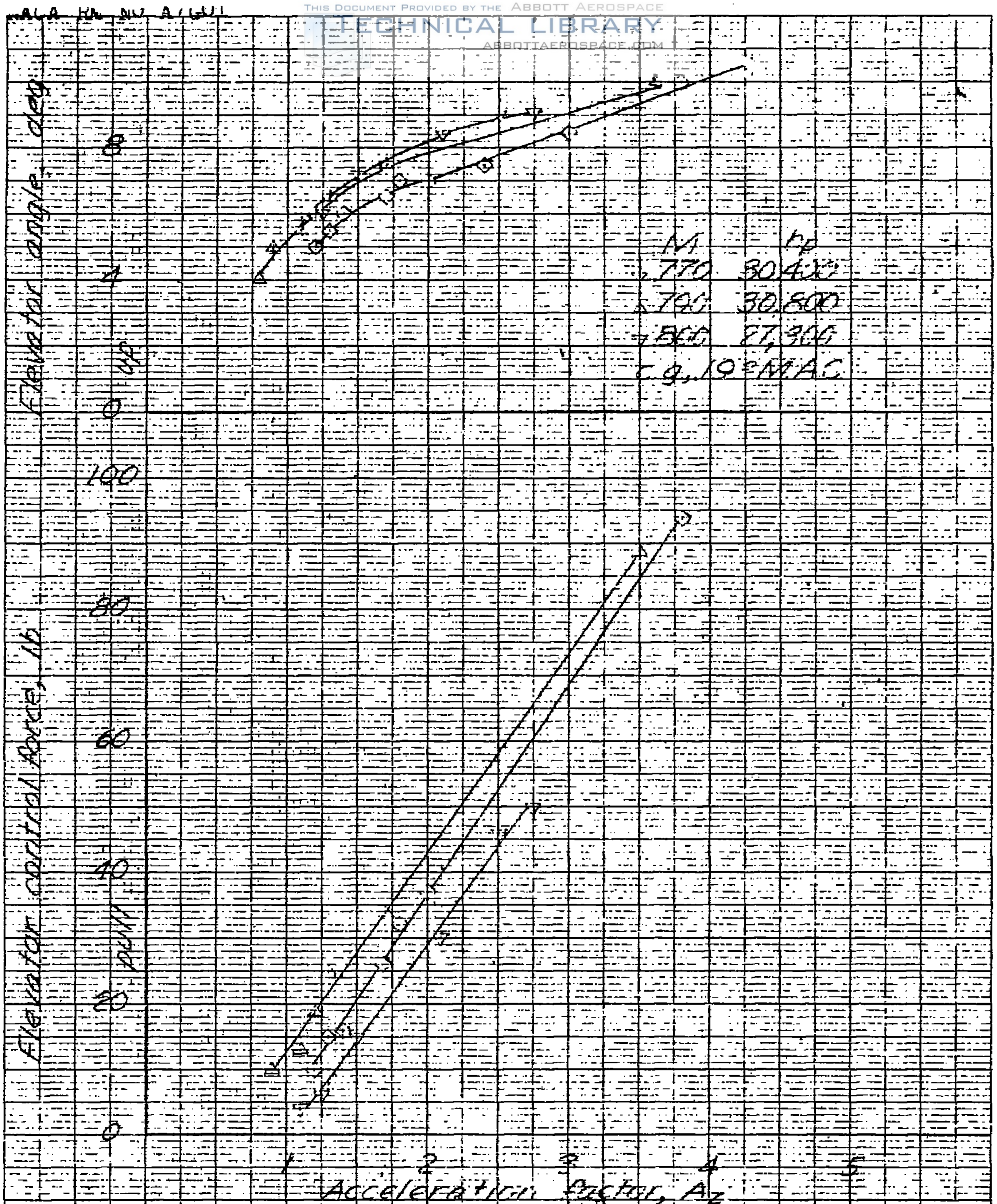


Figure 12.- Continued.
(t) M, .770, .790, .800

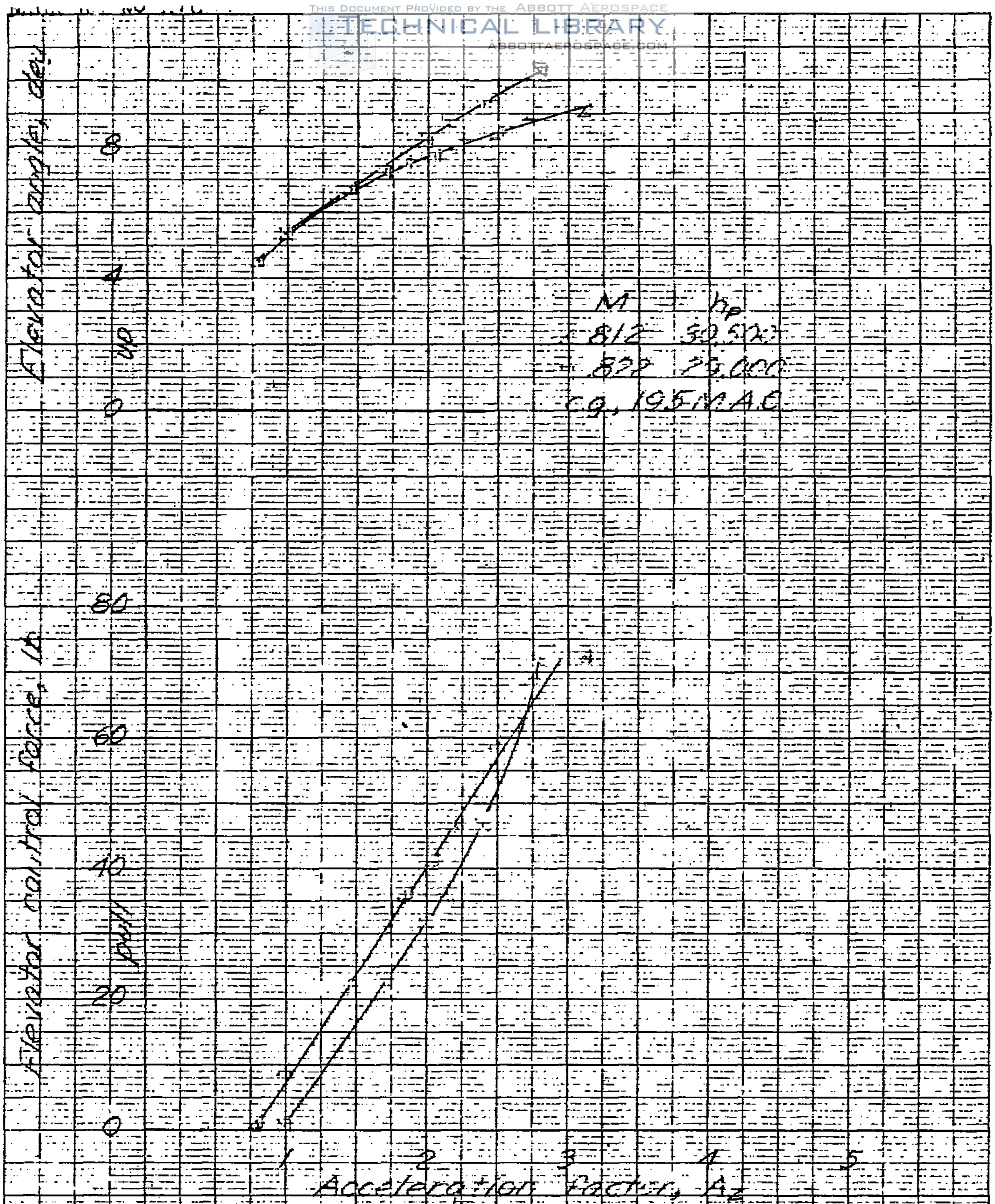


Figure 12.- Concluded.
(c) M, .82 .823

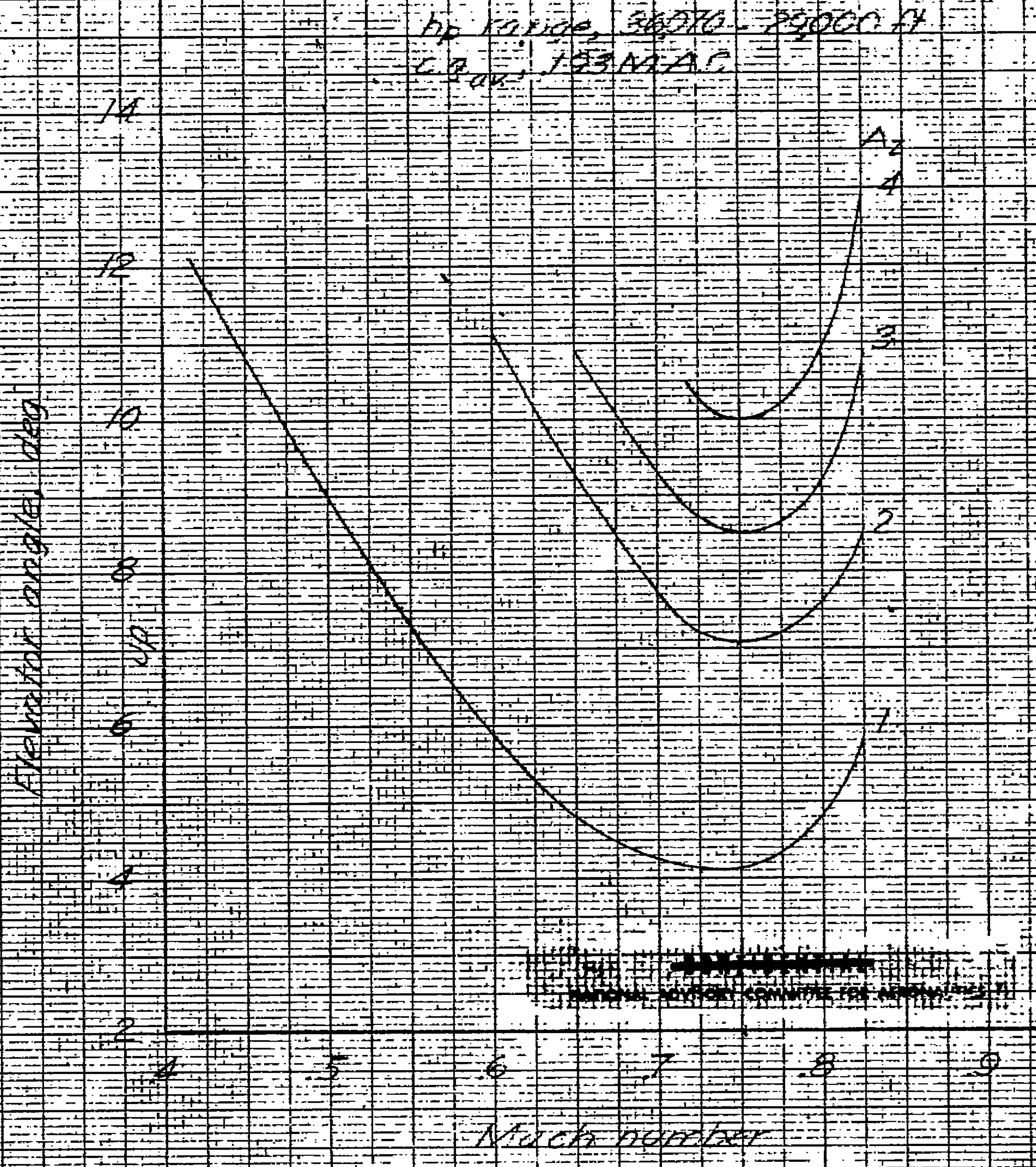


Figure 13. Variation of elevator angle with Mach no. for various $A_z$ values. Forward c.g. position. Power on, clean. High altitude.

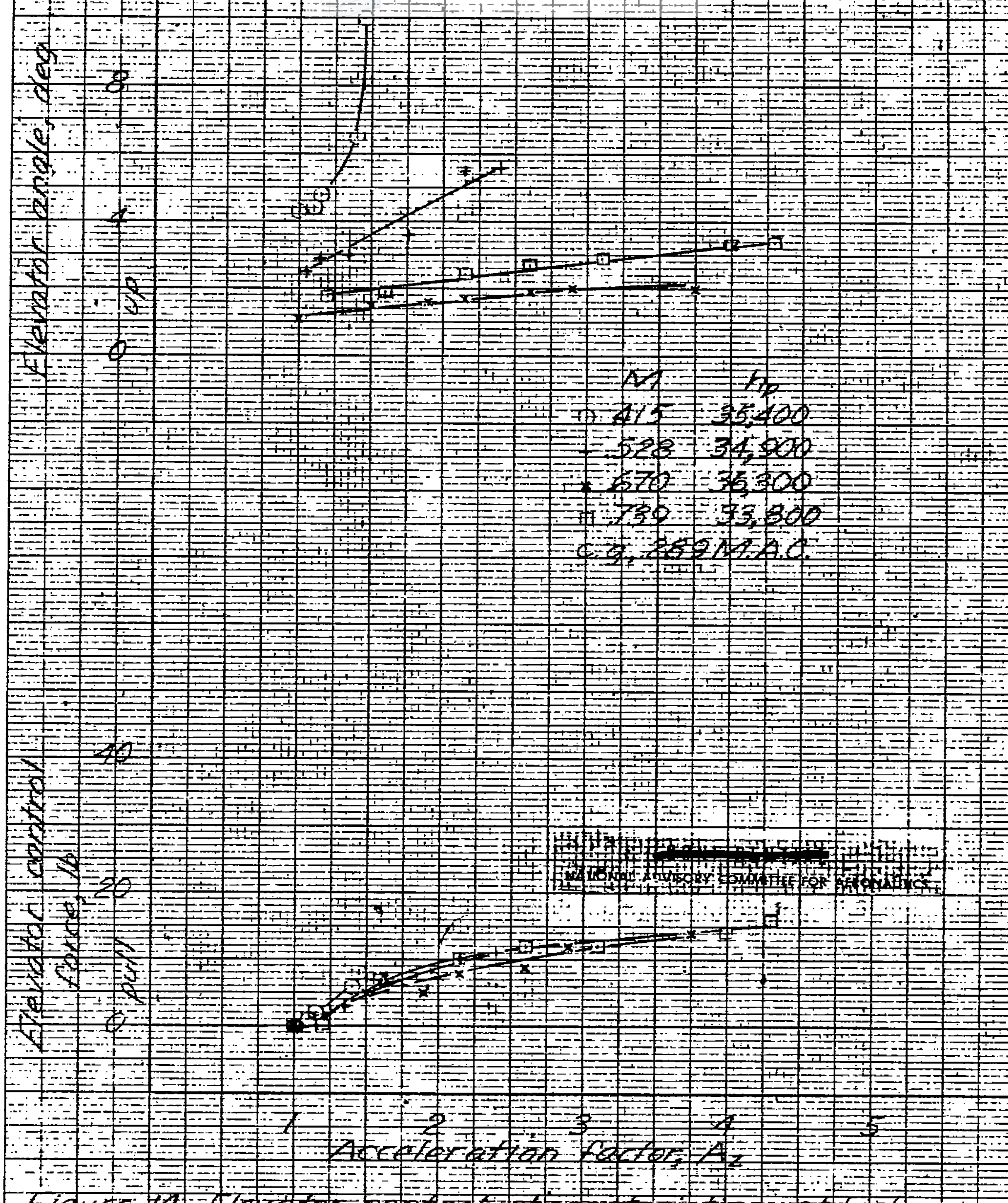


Figure 14.- Elevator control characteristics at high altitude. Rear c.g. position. Power on, clean.
(a) M, .415, .528, .670, .739

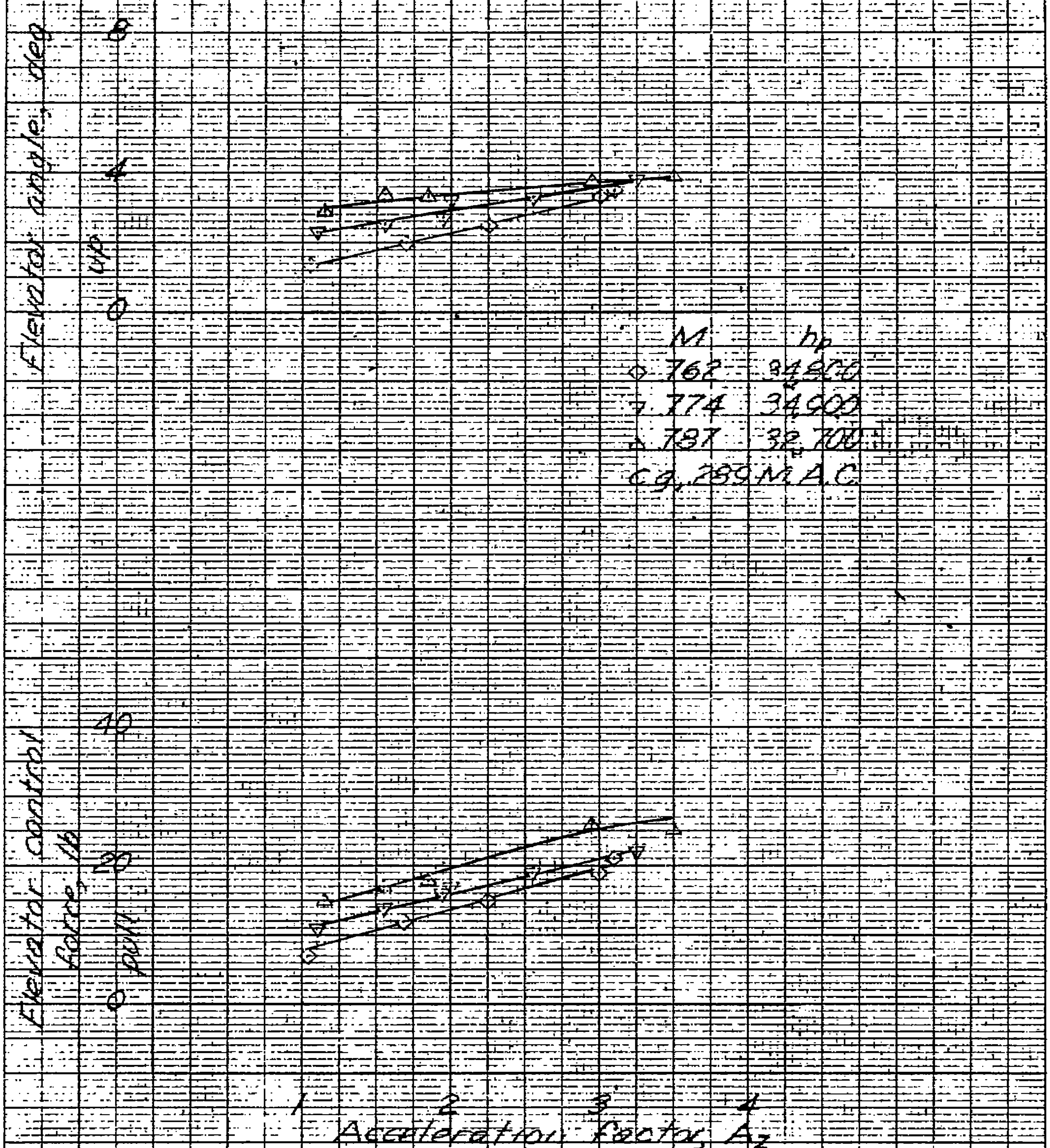


Figure 14.- Continued.
(b) M, .762, .774, .787

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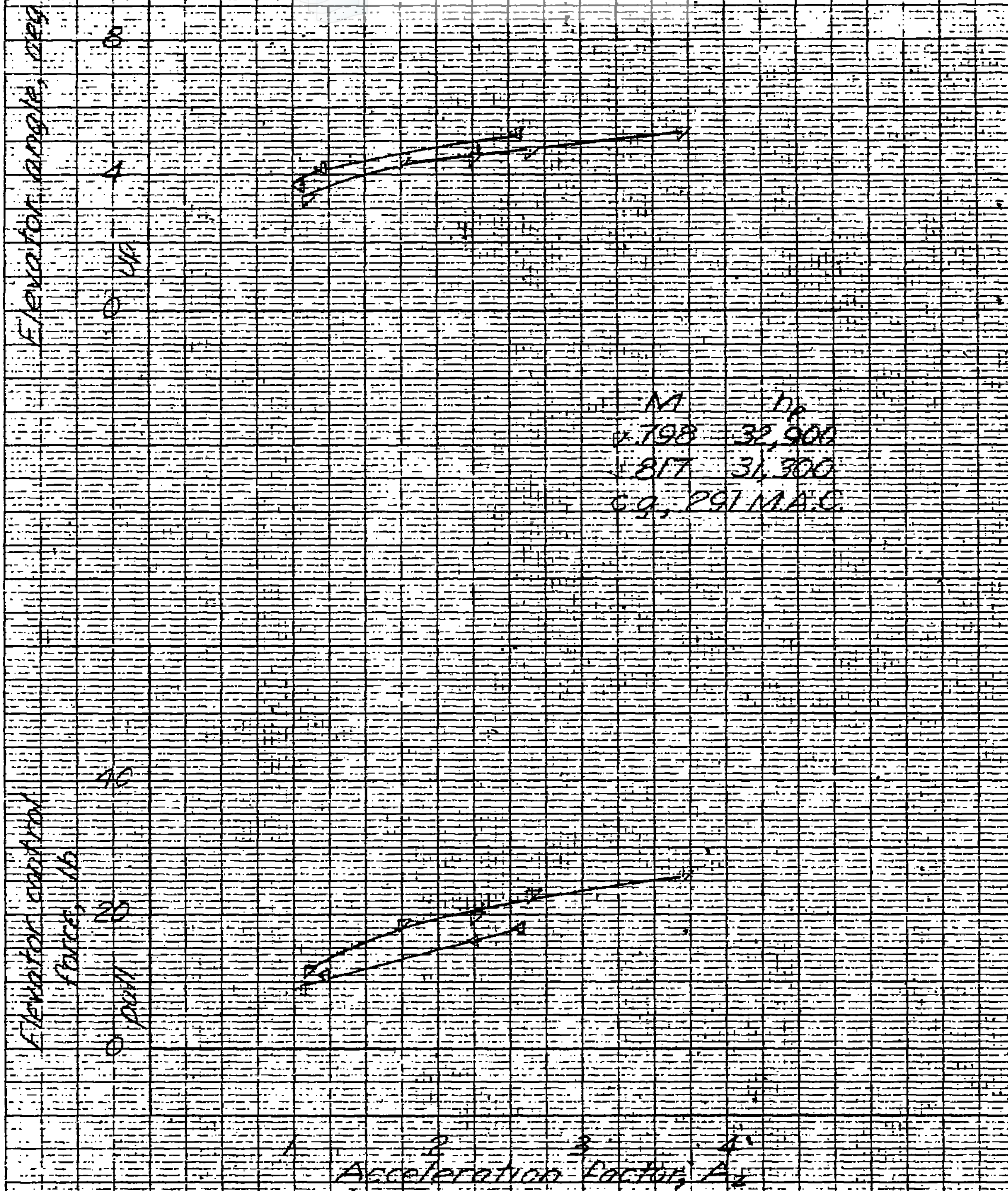


Figure 14. Continued.
(c) M. .798, .817

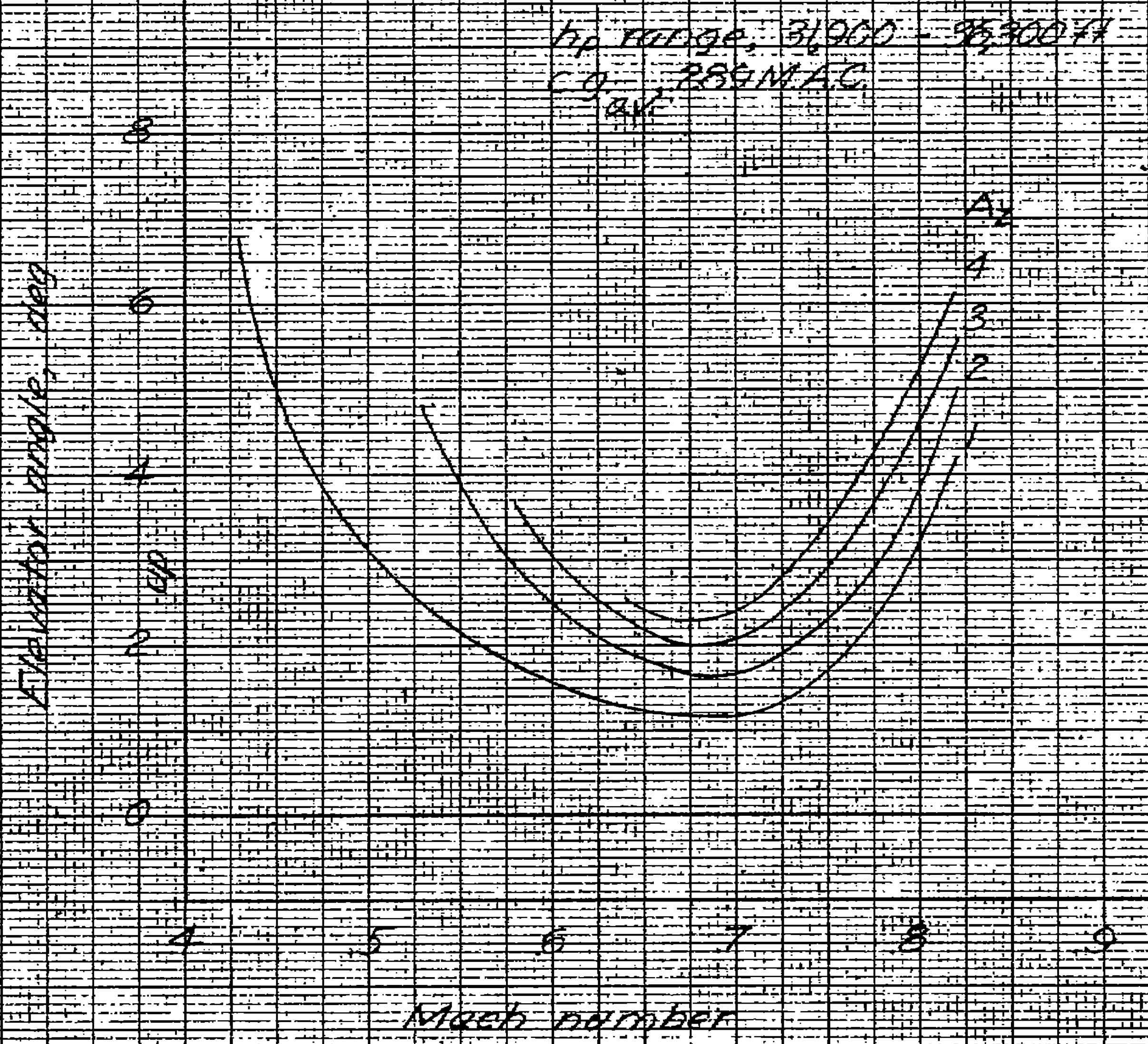




Figure 15.- Variation of elevator angle with Mach number for various $A_z$ values. Rear c.g. position. Power-on, clean. High altitude

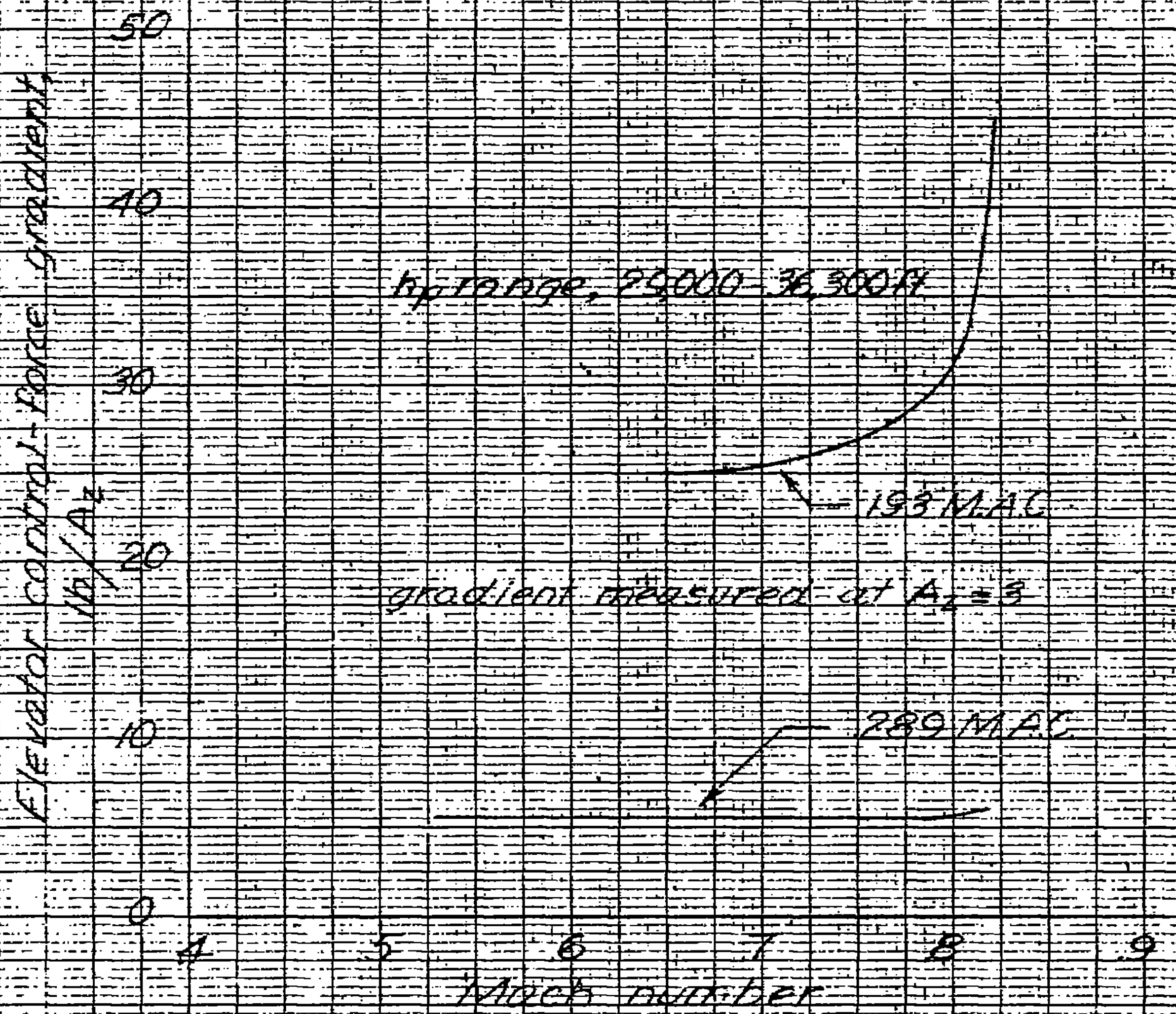




Figure 16.- Variation of control-force gradient with Mach number for the forward and rear cg positions. Power-on, clean. High altitude.