NACA

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).- LATERAL- AND DIRECTIONAL-STABILITY AND CONTROL CHARACTERISTICS

By Seth B. Anderson and George E. Cooper

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
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FLIGHT MEASUREMENTS OF THE FLYING QUALITIES OF A LOCKHEED P-80A AIRPLANE (ARMY No. 44-85099).— LATERAL- AND DIRECTIONAL-STABILITY AND CONTROL CHARACTERISTICS

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SUMMARY

This report contains the flight-test results of the lateral- and directional-stability and control phase (including tests with wing-tip tanks) of a general flying-qualities investigation of the Lockheed P-80A airplane (Army No. 44-85099). These tests were conducted at indicated airspeeds up to 494 miles per hour (0.691 Mach number) at low altitude and up to 378 miles per hour (0.816 Mach number) at high altitude.

These tests showed that the flying qualities of the airplane were for the most part in accordance with the requirements of the Army Air Forces Stability and Control Specifications. The only major deficiency noted was the negative lateral stability with the wing-tip tanks installed.

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 lateral- and directional-stability and control tests. The longitudinal-stability and control characteristics have been reported in reference 1.

DESCRIPTION OF THE AIRPLANE

A three-view drawing of the airplane is presented in figure 1

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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. The normal gross weight of the airplane is 12,000 pounds and the center-of-gravity range possible in flight for various loading conditions is 0.196 to 0.317 M.A.C.

The ailerons are piano hinged on the upper wing surface and have no aerodynamic balance. The aileron control forces are lessened by the use of a hydraulic boost system employing a boost ratio of 15 to 1. The friction of the aileron control as measured on the ground during a slow lateral movement of the stick (no load on the surfaces, aileron boost operating) was 4.5 pounds through the neutral position. This value is greater than the 2-pound allowable friction value specified in reference 2. Figure 4 presents the variation of total aileron angle with stick position as measured on the ground with no load applied to the aileron surfaces. The rudder-control friction was ±8 pounds when measured at the point where the pilot normally applies pressure. The maximum allowable friction force specified in reference 2 is 7 pounds. The rudder is equipped with a centering spring to aid in returning the control to 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.

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 itself as determined from wind-tunnel tests. 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 at an average center-of-gravity position of 0.240 M.A.C. at a gross weight of 11,400 pounds. The wing-tip tanks (165 gallons each) were empty except for various tests of the dynamic directional characteristics.) Records were taken in a low-altitude range of 3,300 to 8,800 feet and a high-altitude range of 23,800 to 35,900 feet. Tests with the wing-tip tanks were made at indicated airspeeds up to 420 miles per hour (0.589 Mach number) at low altitude and up to 358 miles per hour (0.767 Mach number) at high altitude. Tests with the wing-tip tanks off extended up to indicated airspeeds of 494 miles per hour (0.691 Mach number) at low altitude and to 378 miles per hour (0.816 Mach number) at high altitude.

Directional Stability and Control

Dynamic directional stability.- It was found from flight records that the airplane possessed both rudder-fixed and rudder-free positive dynamic directional stability in all configurations and for all airspeeds tested. When the rudder was deflected and released quickly, it returned to its trim position; however, there was an oscillation of less than 1° which required two cycles to disappear.

Directional oscillatory characteristics of the airplane were measured at two altitudes in the power-on, clean condition (flap and gear up) by placing the airplane in small-amplitude sideslips and then abruptly releasing all controls. The data are presented in figures 5 and 6 for wing-tip tanks filled, empty, and tanks off. As would be expected due to the increased moment of inertia, the major effect on the period occurred in going from the wing-tip-tanks-empty condition to the full condition; where, for example, the period of the oscillations increased from 2.6 seconds to 3.7 seconds at 250 miles per hour. No appreciable effect on the period was noted in changing altitude or adding the empty wing-tip tanks. It can be seen from figure 6 that the control-free oscillations of the airplane damped to one-half amplitude in less than two cycles for all conditions and speeds tested. The most outstanding effect on the damping occurred in increasing altitude which increased the number of cycles to damp to one-half amplitude. Removing the centering spring from the rudder control system had no appreciable effect on the oscillatory characteristics of the airplane.

Static directional stability.- Directional characteristics were measured by performing steady sideslips in the power-approach (flap and gear down, 50-percent power) and power-on, clean conditions. These data are presented in figure 7 for tests both with and without wing-tip tanks.

For all cases tested the rudder-fixed static stability was satisfactory in that rudder deflection from trim produced sideslip in the correct direction and the angle of sideslip was substantially proportional to rudder deflection over the range tested.

For tests both with and without tip tanks the rudder-free static directional stability was such that with the rudder free, the airplane tended to return to the trim sideslip angle and for angles of sideslip between ±15° the angle of sideslip was substantially proportional to the rudder force. No overbalancing tendency of the rudder force was observed.

The amount of rudder-fixed static directional stability is indicated in figure 8. These data were obtained by rolling out of a steady 45° banked turn with various amounts of aileron deflection, rudder held fixed. These data show that the directional stability was marginal at small aileron deflections in restricting the angle of sideslip to the required value (reference 1) of 1° per 5 percent of full aileron deflection. Additional information on the rudder-fixed static directional stability is given in figure 9. These data show the maximum sideslip angle obtained in rudder-fixed aileron rolls for full stick throw over the speed range.

Rudder control power.- Since there are no slip-stream effects with this airplane, only small changes in directional trim are encountered over the speed range.

In all cases tested the rudder gave sufficient directional control to maintain straight ground paths during normal take-offs and landings.

The rudder was capable of overcoming the adverse aileron yaw using approximately 100 (allowable limit of 180 lb) pounds of rudder control force. These tests were made by rolling out of a 45°-banked turn with full aileron deflection in the approach condition at 140 miles per hour.

Lateral Stability and Control

Dynamic lateral stability.- Although no quantitative data are presented herein, it was found from flight records that the ailerons returned to their trim position when deflected and released, and the oscillations had disappeared in less than one cycle. The lateral oscillatory characteristics of the airplane have been discussed previously under dynamic directional-stability characteristics.

Static lateral stability.- The variations of aileron deflection with sideslip angle plotted in figure 7 show positive stick-fixed static lateral stability for all test conditions without the wing-tip tanks installed. For the same test conditions the stick-free stability was slightly positive to neutral. The magnitude of the aileron forces was within the friction range. With the wing-tip tanks installed both the stick-fixed and stick-free stability was neutral to negative for the various conditions tested.

It is difficult to maintain steady flight laterally, particularly at low speeds at very high altitudes. The control difficulty is increased with the addition of the wing-tip tanks. This effect is partially attributed to the neutral to negative dihedral effect of the airplane and also to the poor centering and trimming characteristics of the aileron control system.

Rudder kicks (ailerons fixed) were performed in the approach and power-on clean conditions. These data are presented in figure 10(a). Data from rudder kicks for the wing-tip-tanks-on condition are presented in figure 10(b). These data show that adding wing-tip tanks results in an abnormal rolling tendency (i.e., right rudder deflection produces left rolling velocity). This negative dihedral effect was not considered particularly objectionable to the pilot in normal flying of the airplane because large angles of sideslip are not obtained under normal flight conditions and the ailerons are used exclusively for raising a wing.

Aileron control power.— The aileron control was investigated by performing aileron rolls to the right and left with the rudder held fixed in its trim position. A time history of a typical aileron roll is presented in figure 11. The variation of $pb/2V$ and aileron control force with total aileron angle is presented in figure 12 for the power-on, clean condition including tests made with the empty wing-tip tanks installed. No pronounced reduction in aileron control power with increasing Mach number was evident in tests up to 0.816 Mach number.

The data of figure 12 have been summarized in figure 13 by plotting maximum $pb/2V$ limited by maximum stick throw or a 30-pound stick force as a function of indicated airspeed. These foregoing values have been plotted for average altitudes h_p of 5,000 and 35,000 feet. It can be seen that the values of $pb/2V$ obtained are in excess of the requirement of reference 2 for the low-altitude tests, but are less than the requirement over most of the test range for the high-altitude tests. Although the data in figure 13 show the $pb/2V$ values for the high-altitude tests are approximately 0.025 to 0.030 lower than the low altitude tests, it should be noted that the total aileron deflection obtainable was correspondingly lower for the high-altitude tests. Adding the empty wing-tip tanks produced only a

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small decrease in pb/2V obtainable.

The variation of rolling velocity with indicated airspeed as limited by full stick throw or a 30-pound control force is shown in figure 14. The maximum rolling velocity obtained in these tests was 165° per second at 35,000 feet altitude. This maximum rolling velocity was approximately 30° per second greater than the maximum low-altitude value where pb/2V was adequate; however, the airplane did not meet the pb/2V requirements at high altitude. Although this might indicate that the pb/2V requirements should be less at altitude, it is felt that, since no upper limit on rolling velocity has been obtained in the opinion of the pilots, the greater rolling velocity at altitude occurring for a given value of pb/2V can be used at the discretion of the pilot.

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 directional-stability characteristics were satisfactory in all configurations over the speed range tested. When the filled wing-tip tanks were added, the period of the oscillations was increased by approximately 50 percent at low airspeeds.

2. The static directional-stability characteristics were satisfactory in sideslips. The rudder-fixed directional stability was marginal at small aileron deflections in restricting the angle of sideslip to 1° per 5 percent of full aileron deflection.

3. The rudder-control power was satisfactory in all conditions tested.

4. The dynamic lateral stability characteristics were satisfactory for all conditions tested.

5. The stick-fixed static lateral stability was positive for all test conditions without the wing-tip tanks installed. For the same configuration the stick-free stability was slightly positive to neutral. With the wing-tip tanks installed the stick-fixed and stick-free lateral stability was neutral to negative in steady sideslip maneuvers. A negative dihedral effect was also shown in rudder-kick maneuvers. These lateral-stability characteristics combined with the poor trimming and centering characteristics of

the ailerons made it difficult to maintain steady flight laterally, particularly at low speeds and high altitudes.

5. The aileron control power was satisfactory over the low-altitude test range for the tip tanks on and off conditions. At high altitude the values of $pb/2V$ were less than the requirement over most of the test range; however, the total aileron deflection was correspondingly reduced at high altitude. The maximum rolling velocity was 165° per second at an altitude of 35,000 feet.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

REFERENCES

1. Anderson, Seth B., Christofferson, Frank E., and Clousing, Lawrence A.: Flight Measurements of the Flying Qualities of a Lockheed P-80A Airplane (Army No. 44-85099).– Longitudinal-Stability and -Control Characteristics. NACA CRM No. A7G01, 1947.

2. 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

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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° up, 16° down	15.5° left and 15.5° right	Down 45°	41.5° 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 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 aileron position with lateral stick position as measured on the ground.

Figure 5.– Variation of period with indicated airspeed for various test conditions. Power-on, clean.

Figure 6.– Variation of cycles to damp to half amplitude with indicated airspeed for various test conditions. Power-on, clean.

Figure 7.– Characteristics in steady sideslips. (a) Approach condition, V_i, 139. h_p, 8,000. Tanks off.

Figure 7.– Continued. (b) Approach condition V_i, 156. h_p, 7,900. tanks on.

Figure 7. Continued. (c) Powor-on clean. V_i, 154 and 254. h_p, 8,000. Tanks off.

Figure 7. Continued. (d) Power-on clean. V_i, 154. h_p,8,800. Tanks on.

Figure 7.– Continued. (e) Power-on clean. V_i, 351. h_p, 8,000. Tanks off.

Figure 7.– Continued. (f) Power-on clean. V_i, 343. h_p, 8,500. Tanks on.

Figure 7.– Continued. (g) Power-on clean. V_i, 436. h_p, 5,000. Tanks off.

Figure 7.– Continued. (h) Power-on clean, V_i, 247. h_p, 35,000. Tanks off.

Figure 7.– Continued. (i) Power-on, clean, V_i, 249. h_p, 35,200. Tanks on.

Figure 7.– Continued. (j) Power-on clean. V_i, 300. h_p, 34,600. Tanks off.

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Figure 12.– Aileron control characteristics. Power-on, clean. (a) V_i, 153, 197, 248. High altitude. Tanks off.

Figure 12.-Continued. (b) V_i, 250, 286. High altitude. Tanks on.

Figure 12.– Continued. (c) V_i, 293, 366, 387. High altitude. Tanks off.

Figure 12.– Continued. (d) V_i, 150, 196, 273. Low altitude. Tanks off.

Figure 12.– Continued. (e) V_i, 198, 271, 344. Low altitude. Tanks on.

Figure 12.– Continued. (f) V_i, 348, 392, 441. Low altitude. Tanks off.

Figure 12.– Concluded. (g) V_i, 463, 494. Low altitude. Tanks off.

Figure 13.– Variation of pb/2V and aileron angle with indicated airspeed as limited by control stick position or 30-lb control force. Power-on, clean.

Figure 14.– Variation of maximum rolling velocity with airspeed as limited by full stick throw or 30-lb control force. Clean condition.

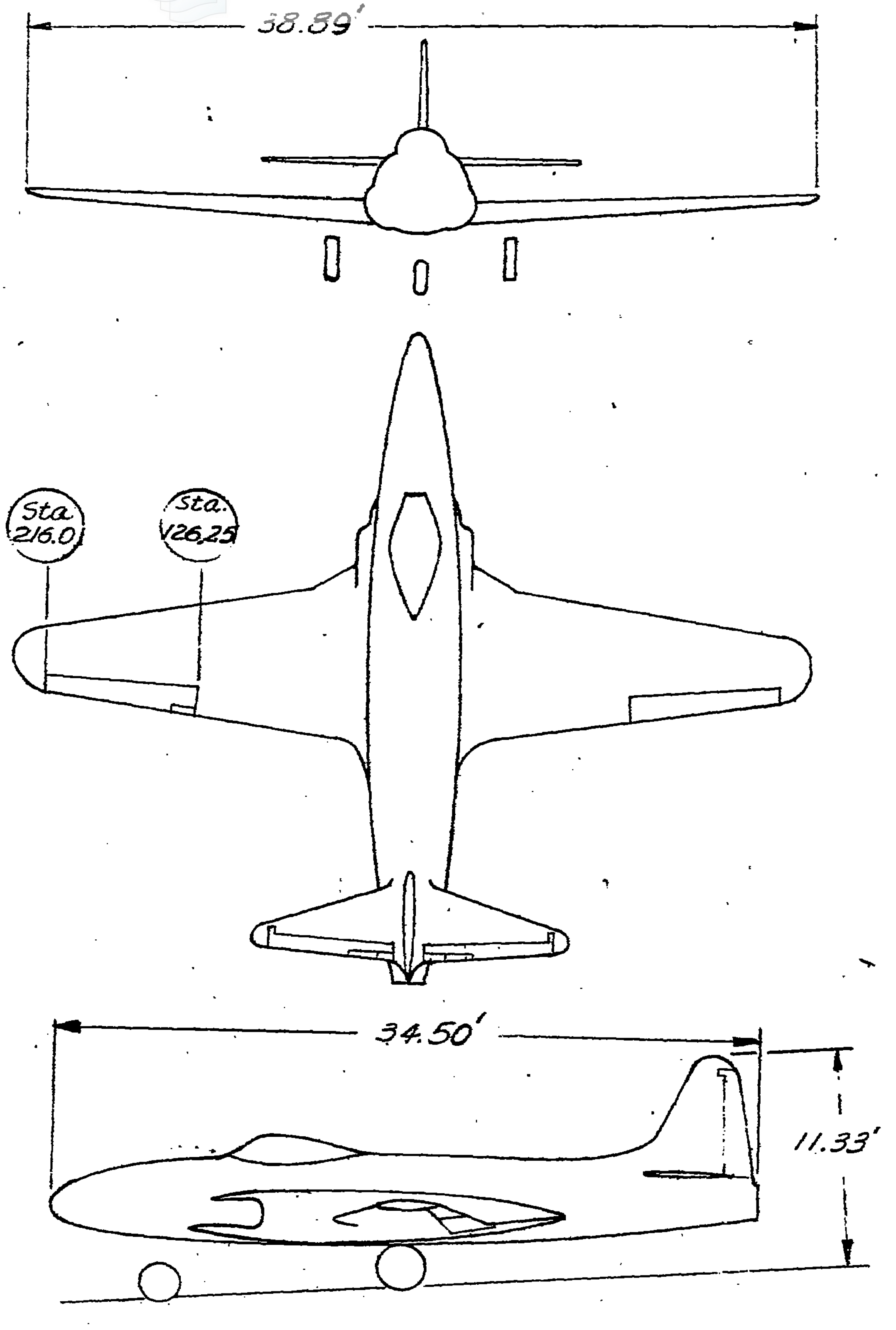

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Figure 1.- Three-view drawing of test airplane.

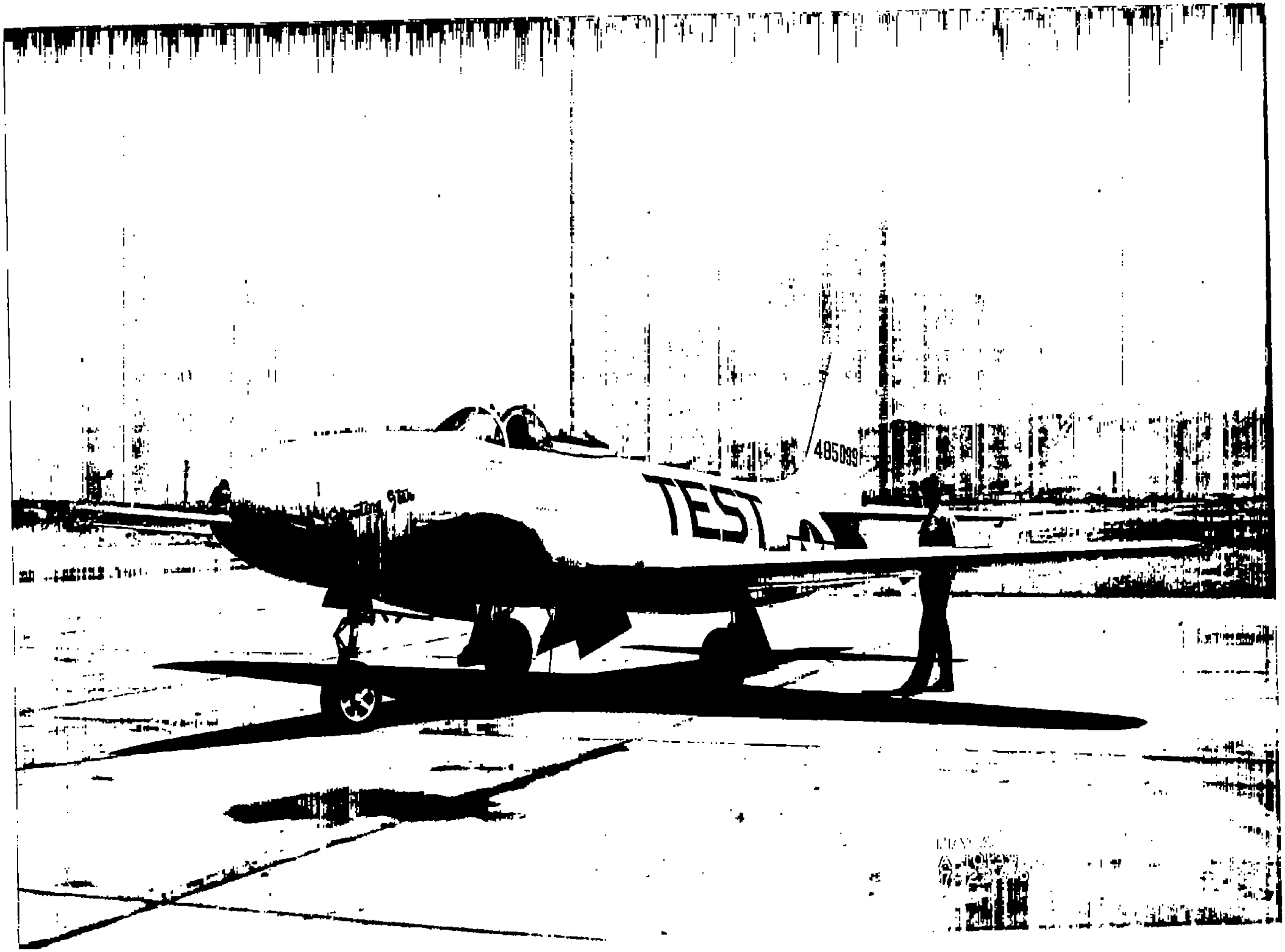

Figure 2.– Three-quarter front view of the test airplane as instrumented for flight tests.

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AMES AERONAUTICAL LABORATORY — MOFFETT FIELD, CALIF.

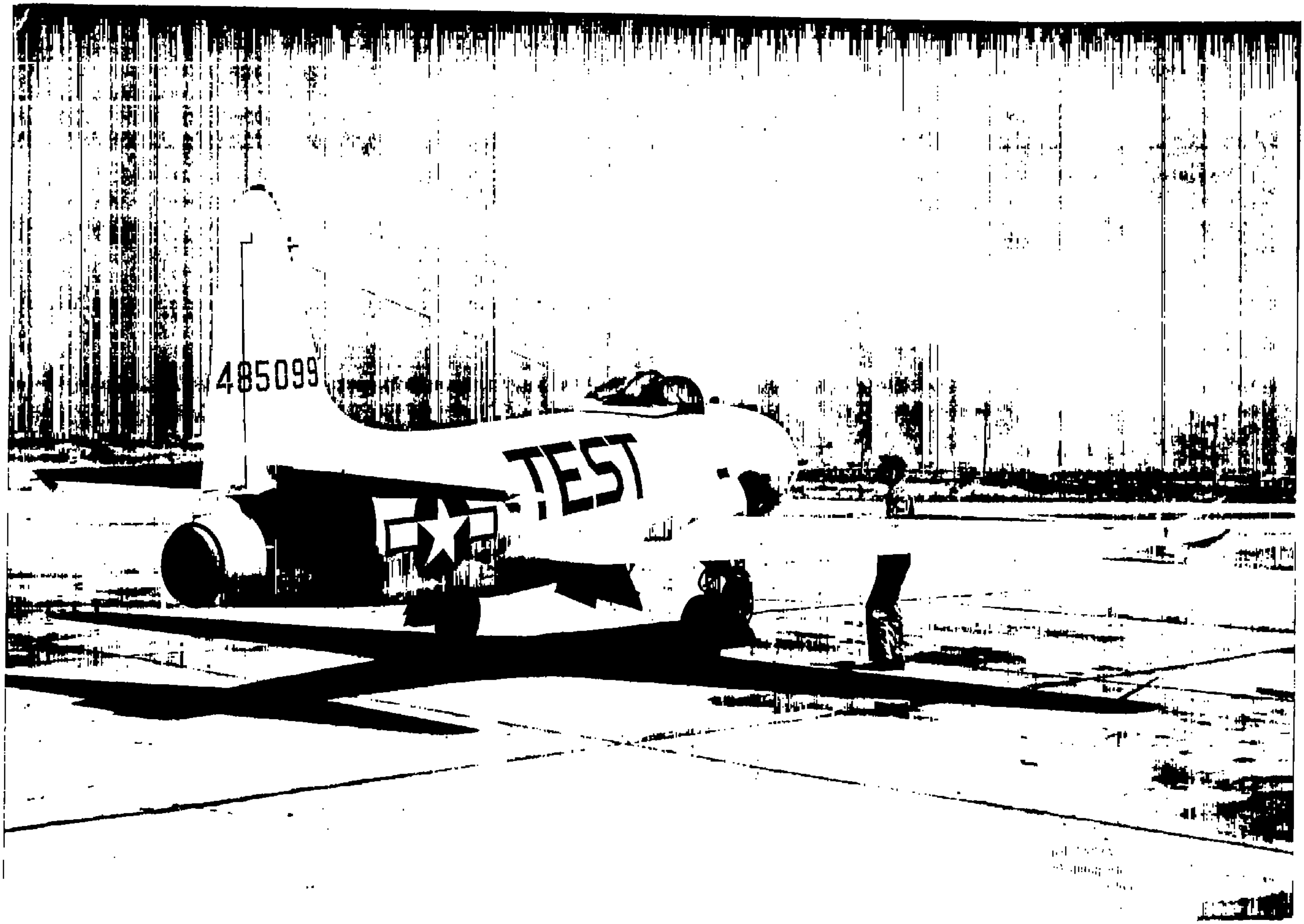

Figure 3.- Three-quarter rear view of the test airplane.

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AMES AERONAUTICAL LABORATORY - MOFFETT FIELD, CALIF.

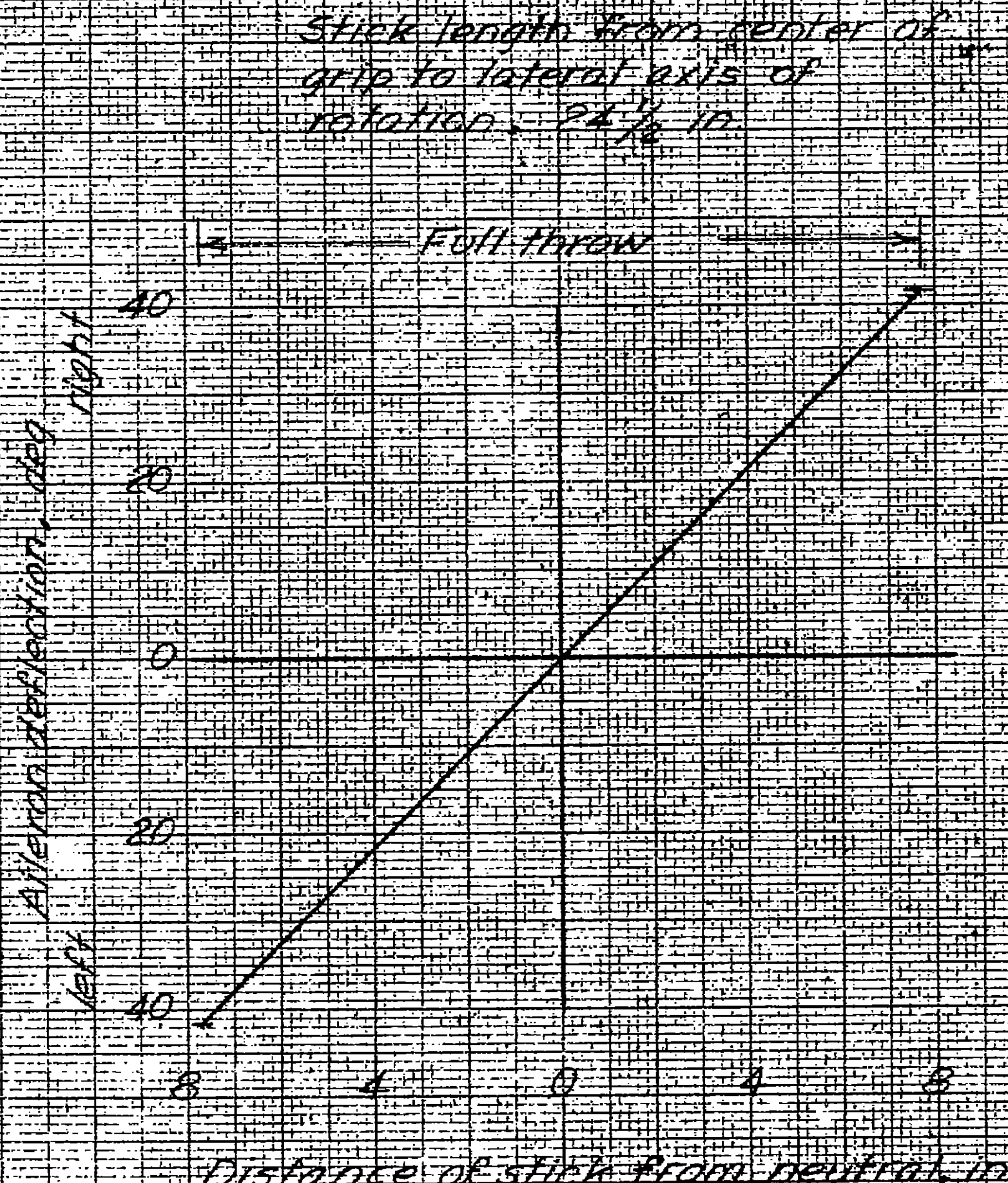

Figure 4.- Variation of aileron position with lateral stick position as measured on the ground.

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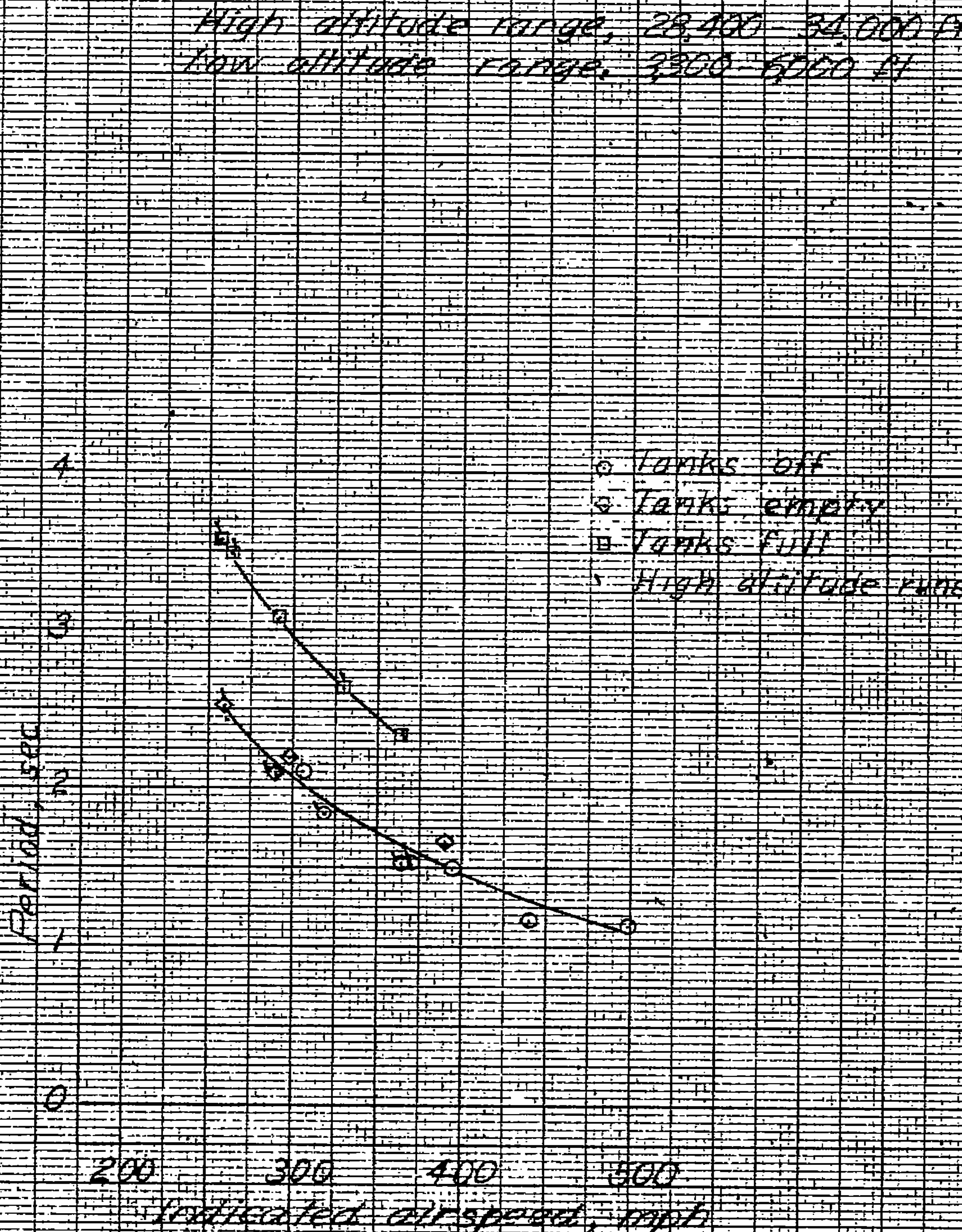

Figure 5. Variation of period with indicated airspeed for various test conditions. Power-on, clean.

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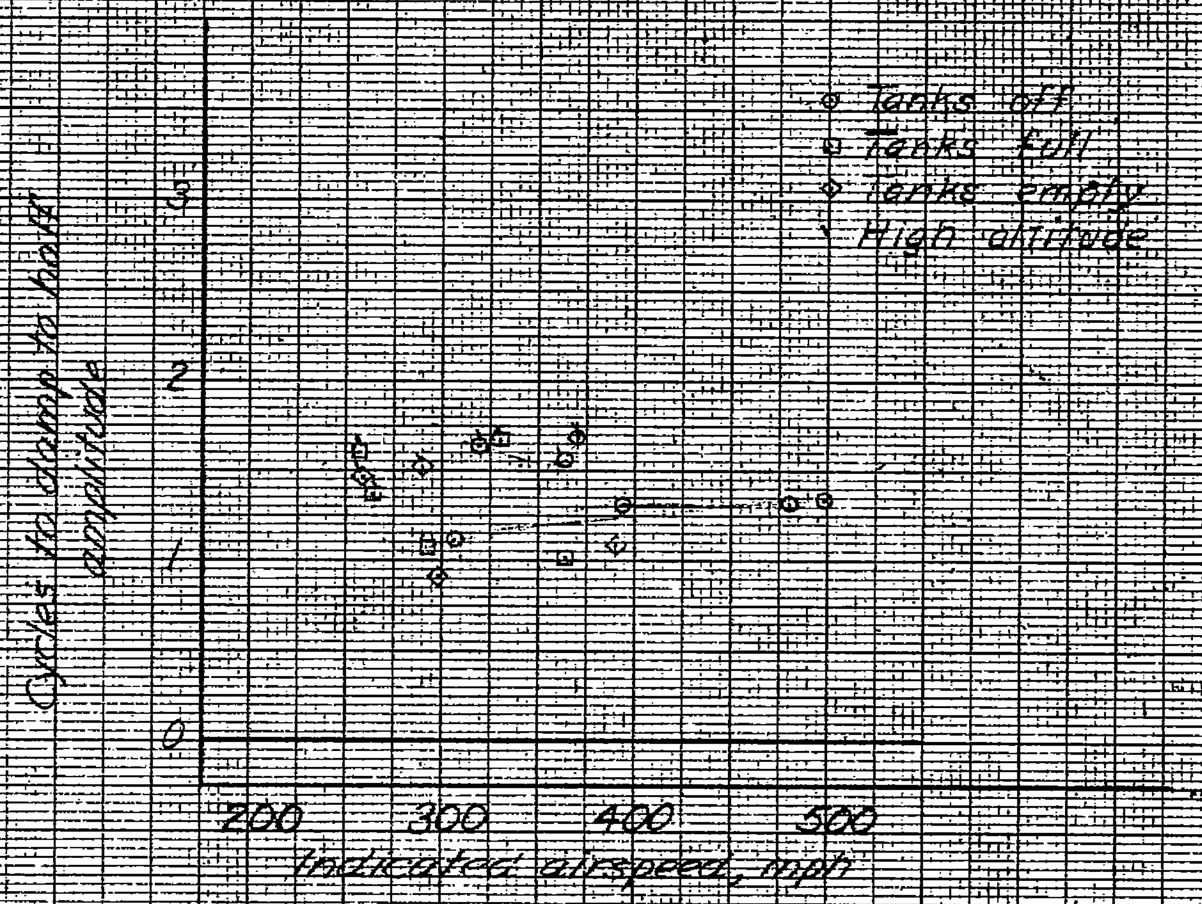

Figure 6 - Variation of cycles to damp to half amplitude with indicated airspeed for various test conditions. Power on, clean.

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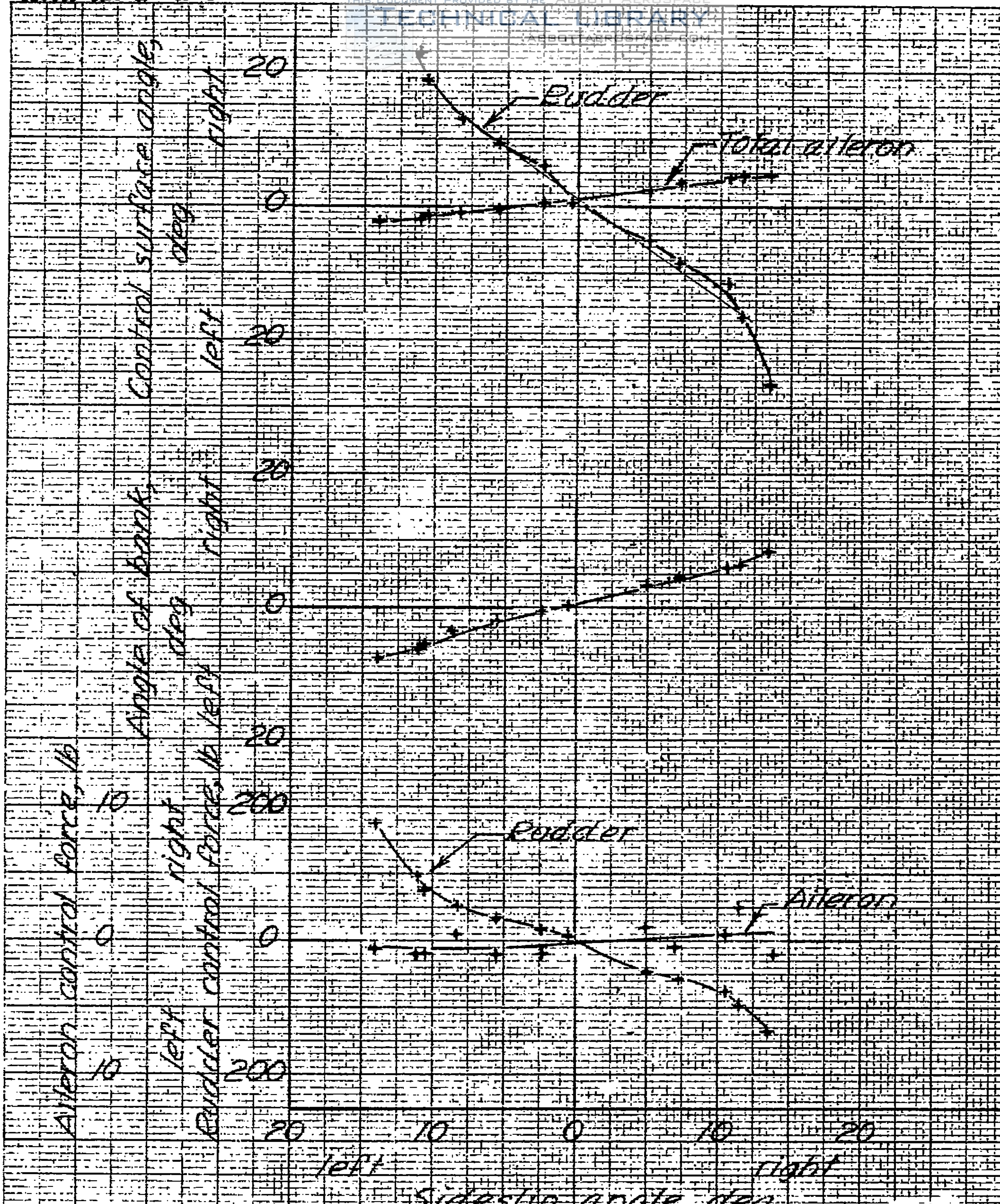

(a) Approach condition. V_i, 139
h_p, 8,000. Tanks off

Figure 7 - Characteristics in steady sideslips

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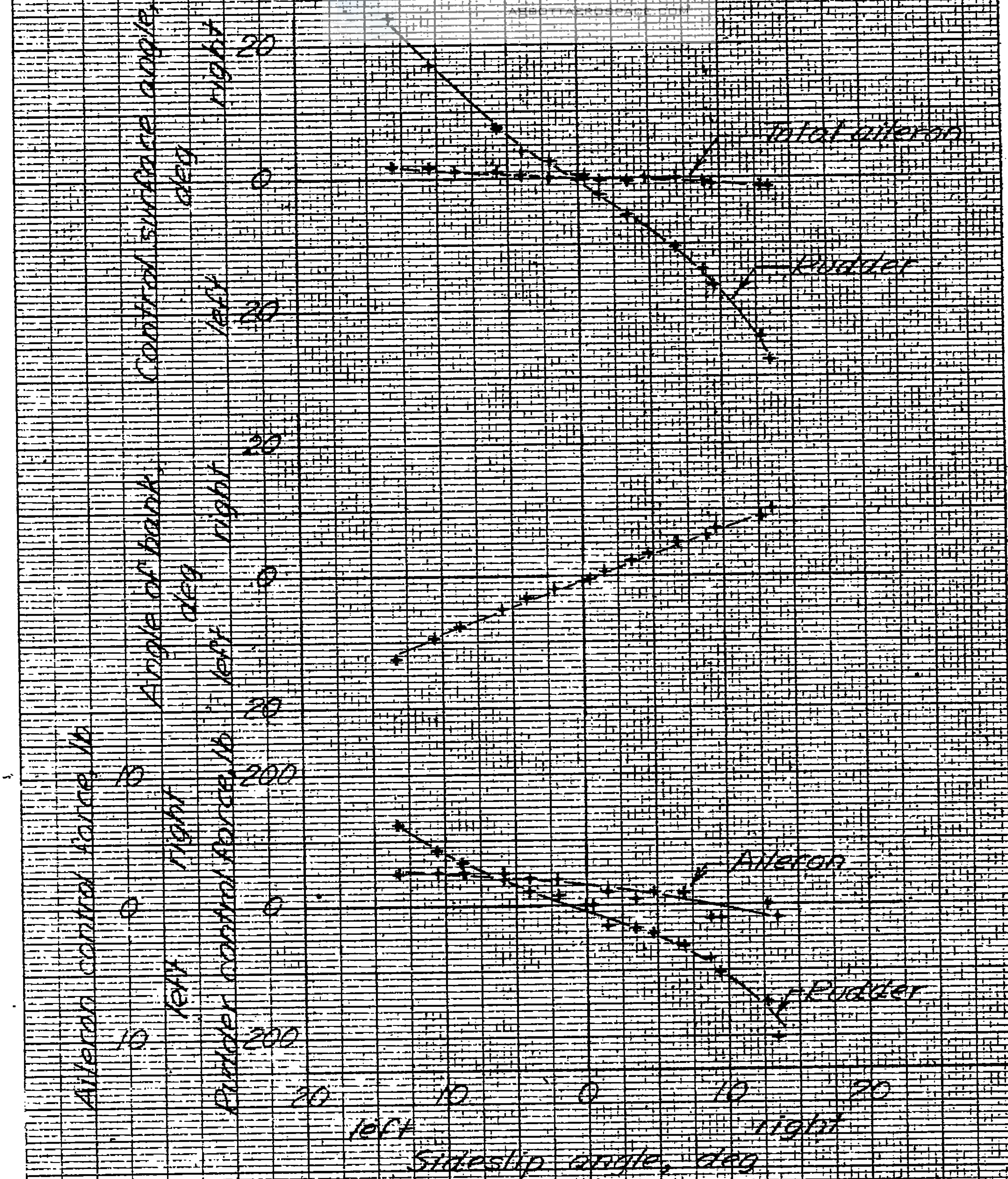

(b) Approach condition V_i, 156 hp, 7900. Tanks on.

Figure 7.- Continued.

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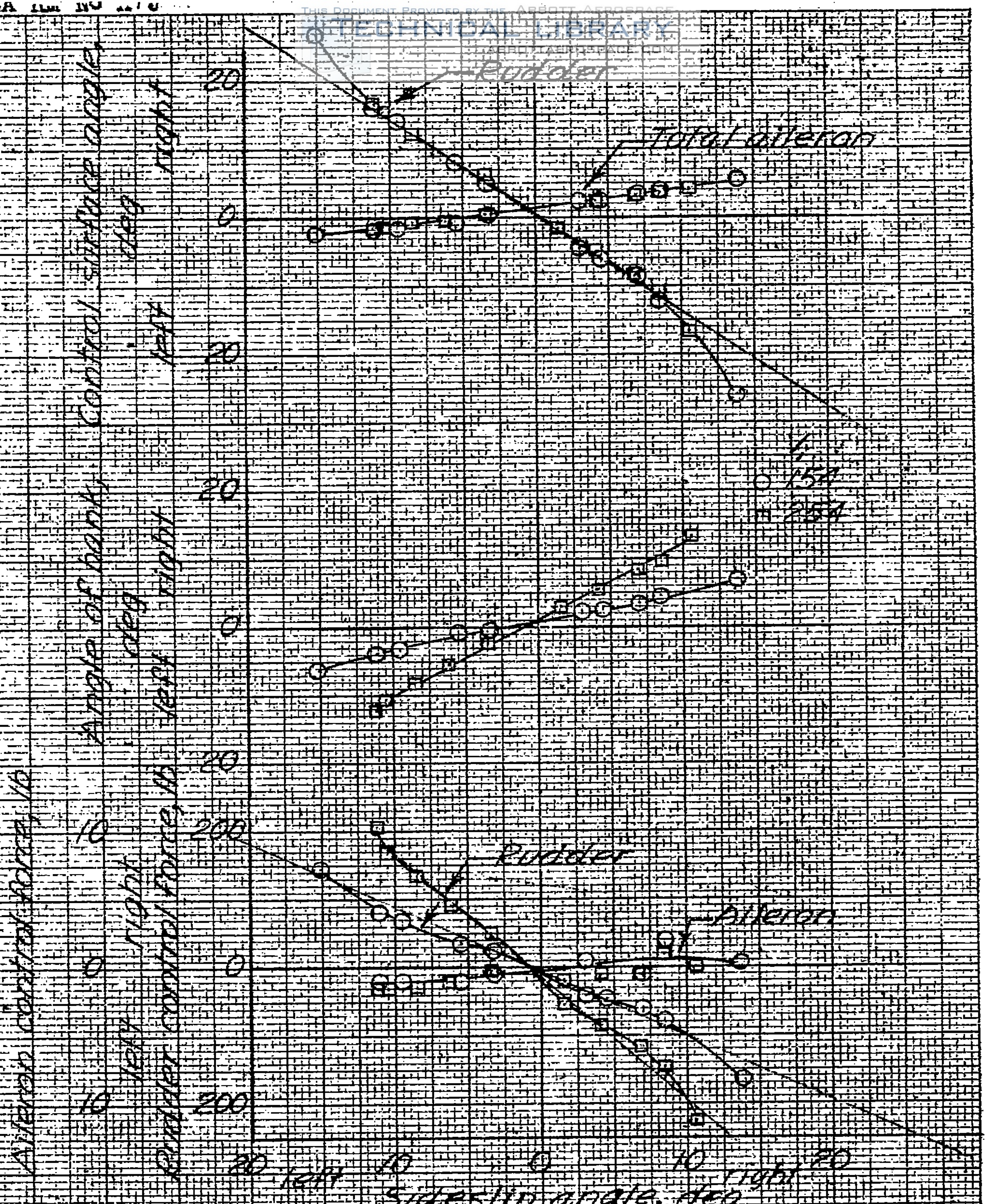
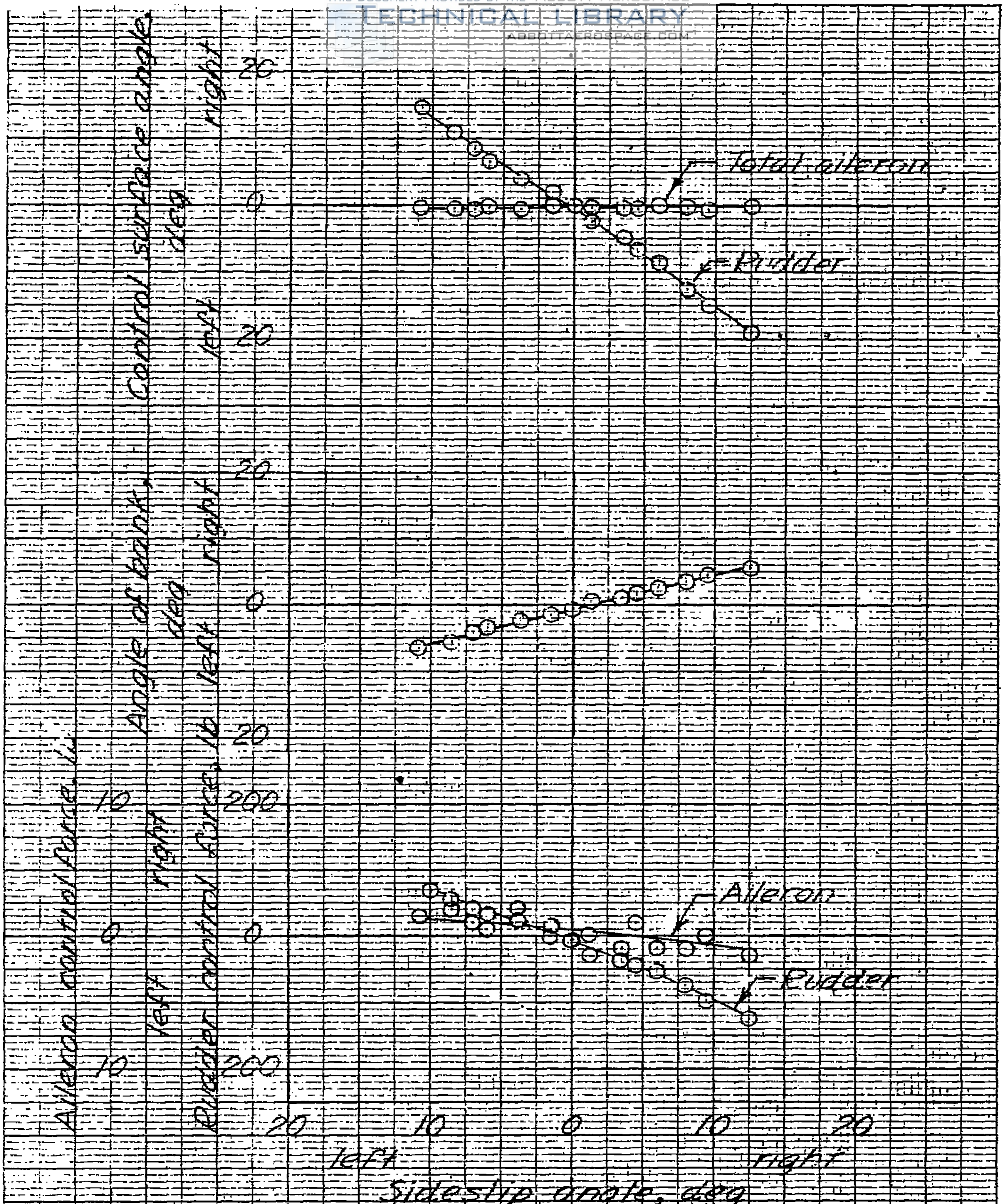


(c) Power-on clean V, 154 and 254
hp 5,000 tanks off

Figure 7.- Continued.



(d) Power on clean V_i, 154 hp, 8,800 tanks on

Figure 7 Continued

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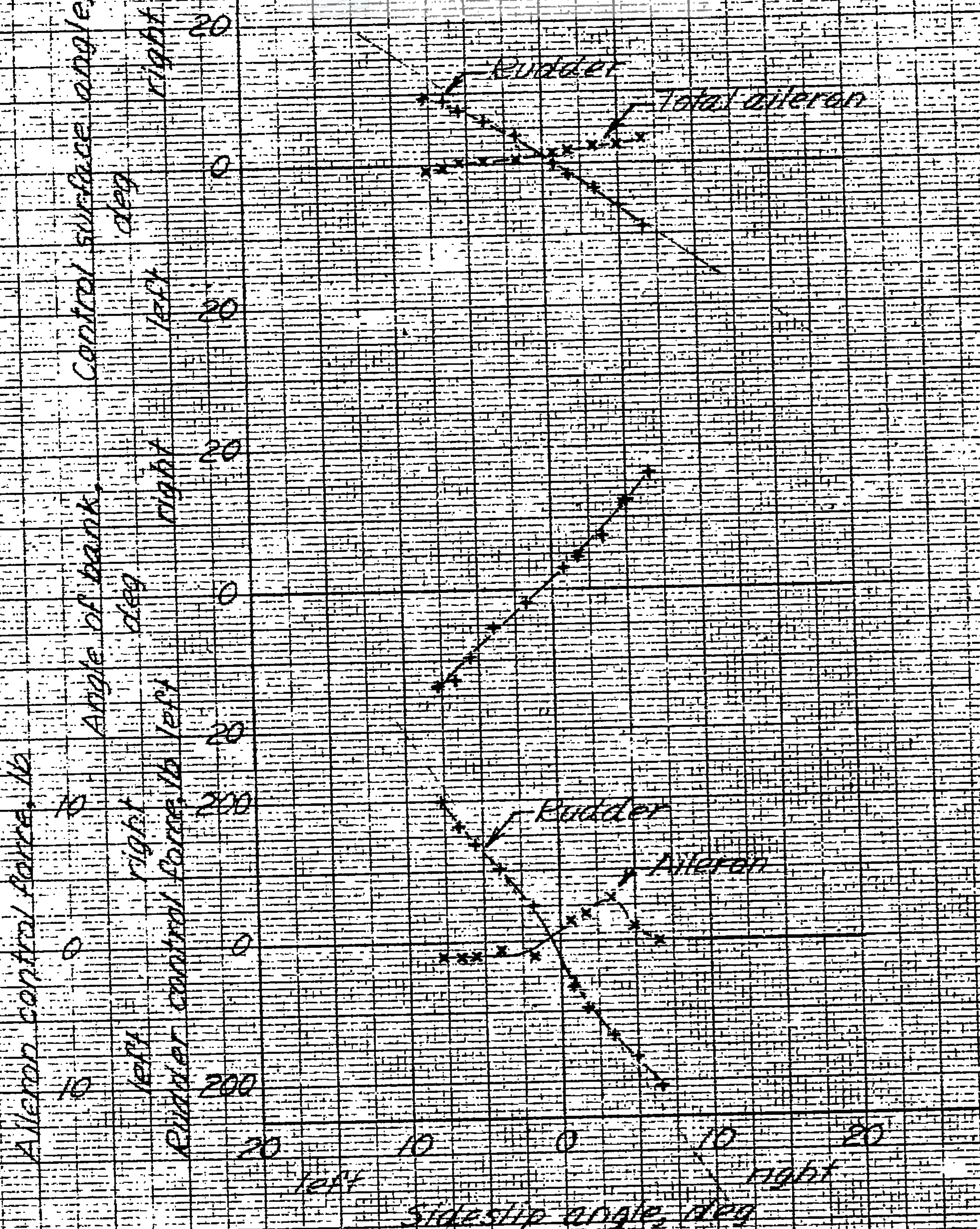

(e) Power-on clean V_s 351 hp, 8000. Tanks off

Figure 7.- Continued.

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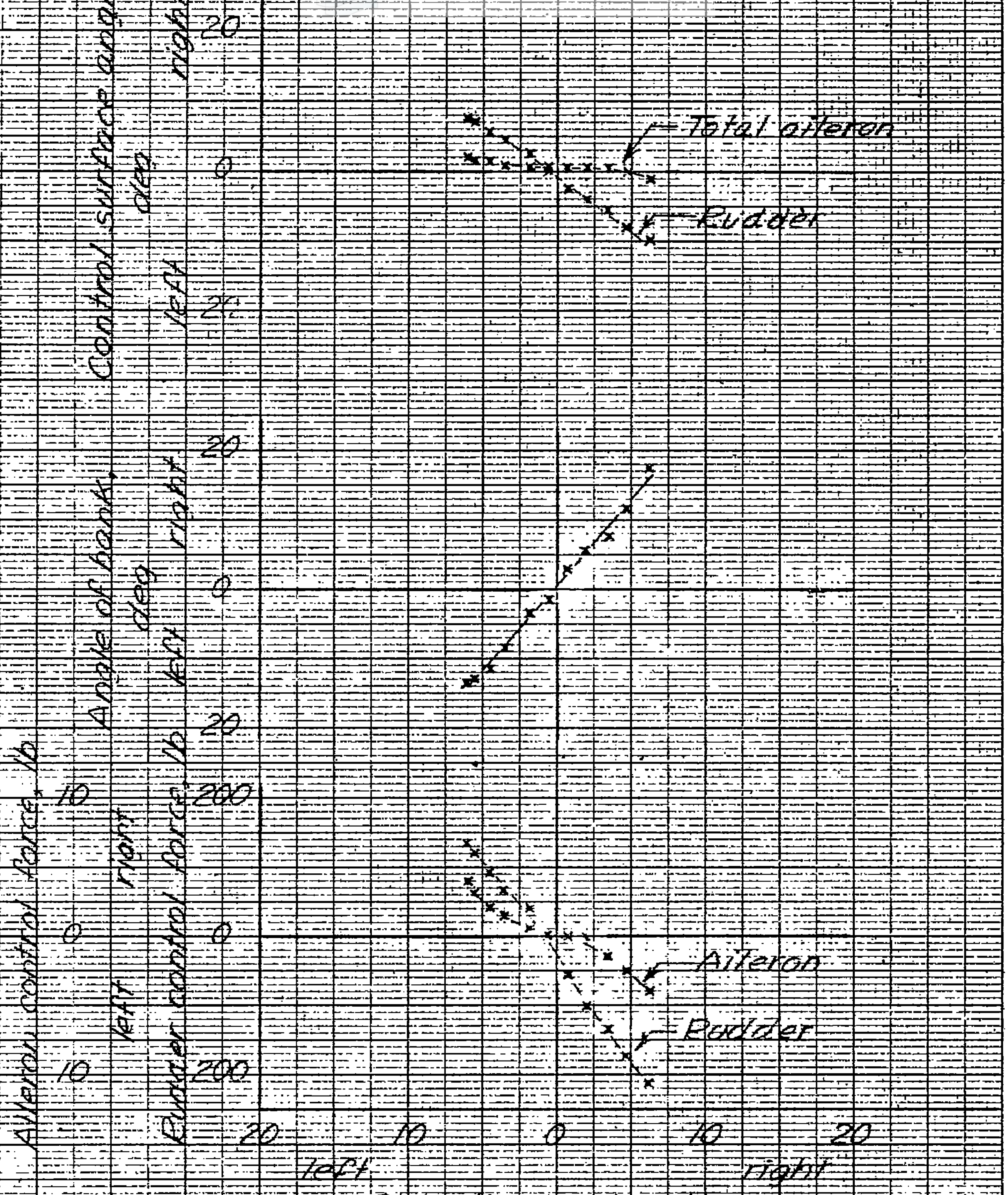

(f) Power-on clean. V_i, 343, hp, 8,500
Tanks on

Figure 7.- Continued.

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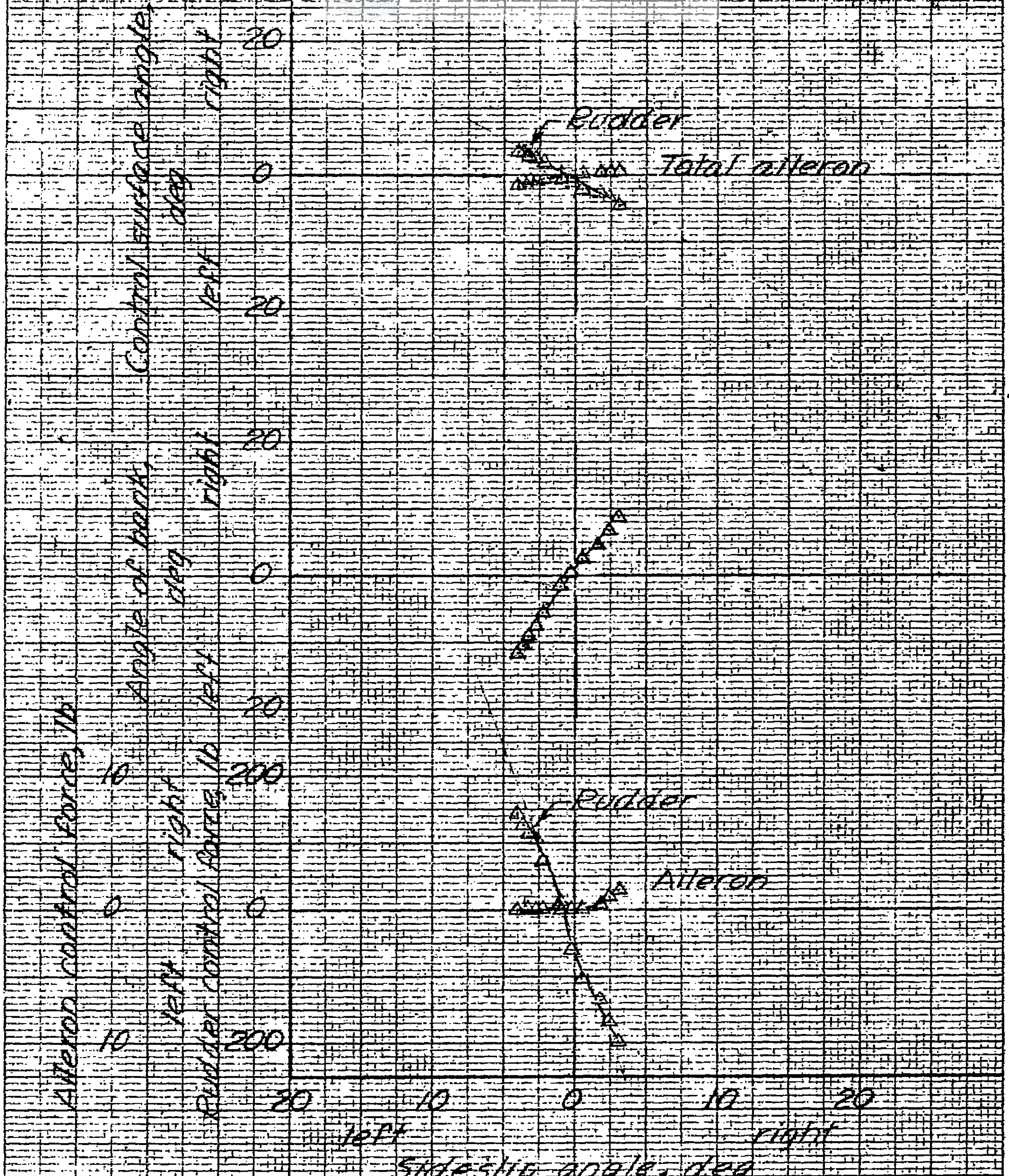

(g) Power-on clean V, 436 hp, 5,000.
Tanks off

Figure 7.- Continued

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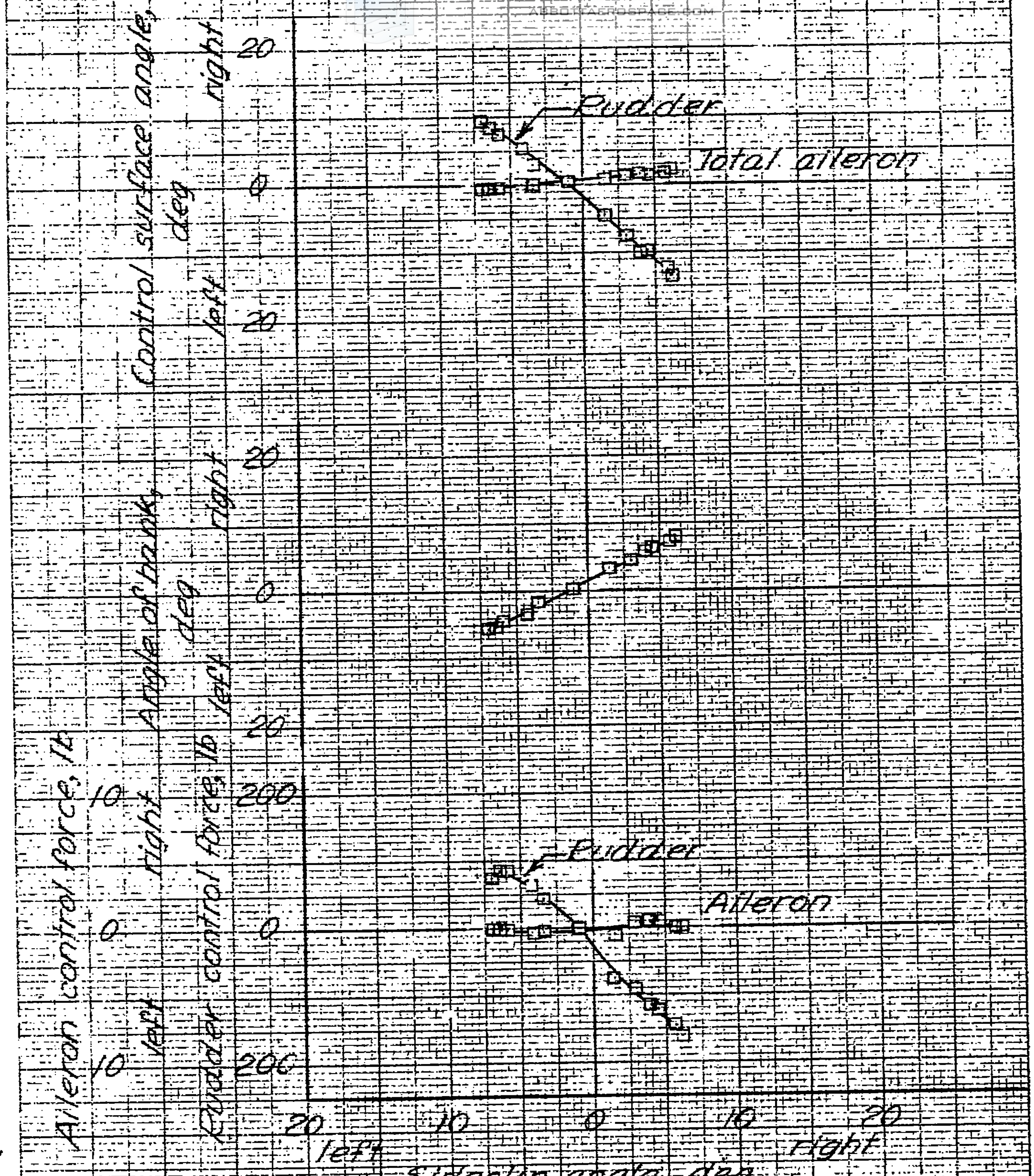

(b) Power-on clean, V_i, 247 hp, 35,000
tanks off

Figure 7 - Continued

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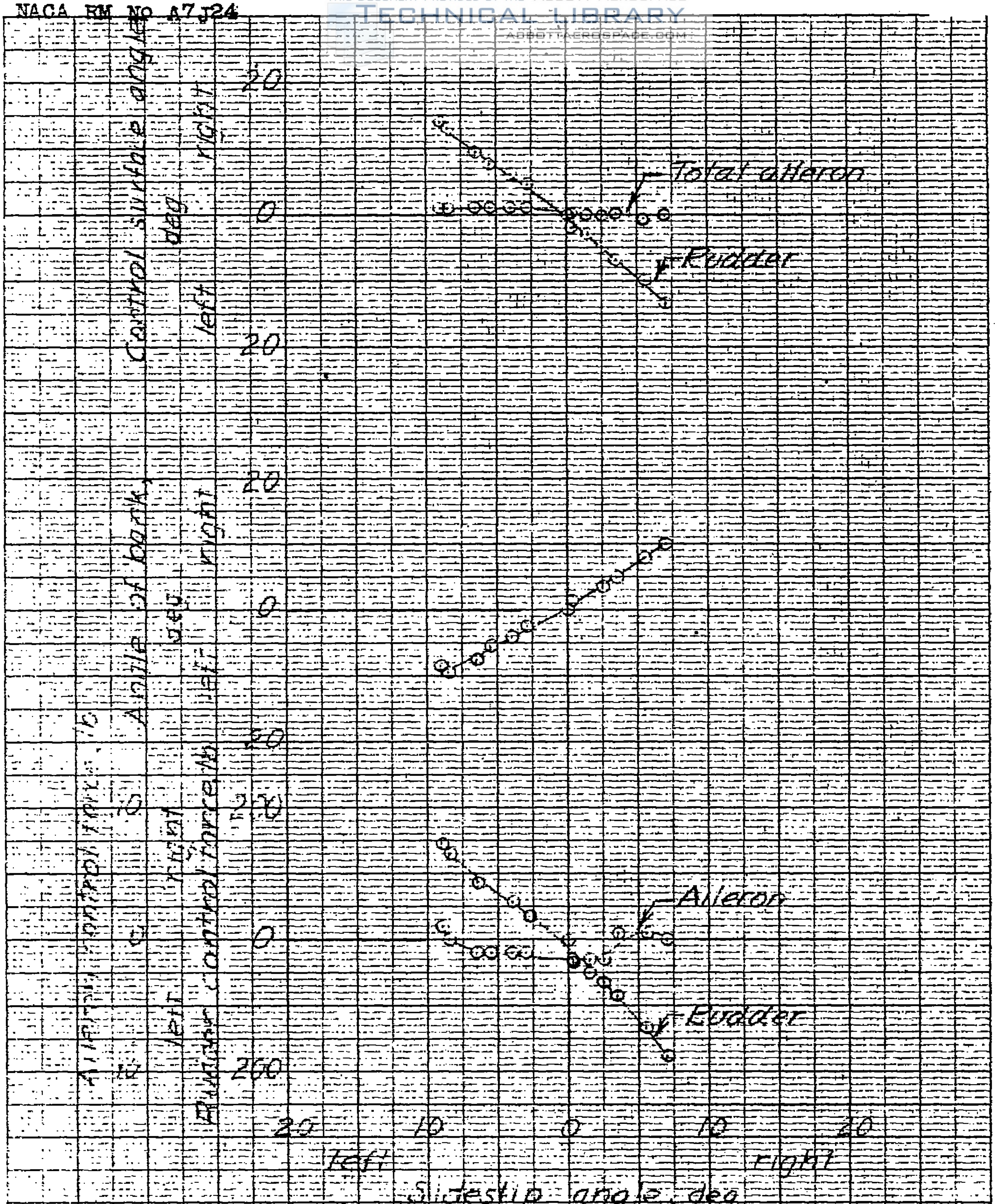

(i) Power-on clean V_i, 245 h_p, 35,200
tanks on

Figure 1 - Continued

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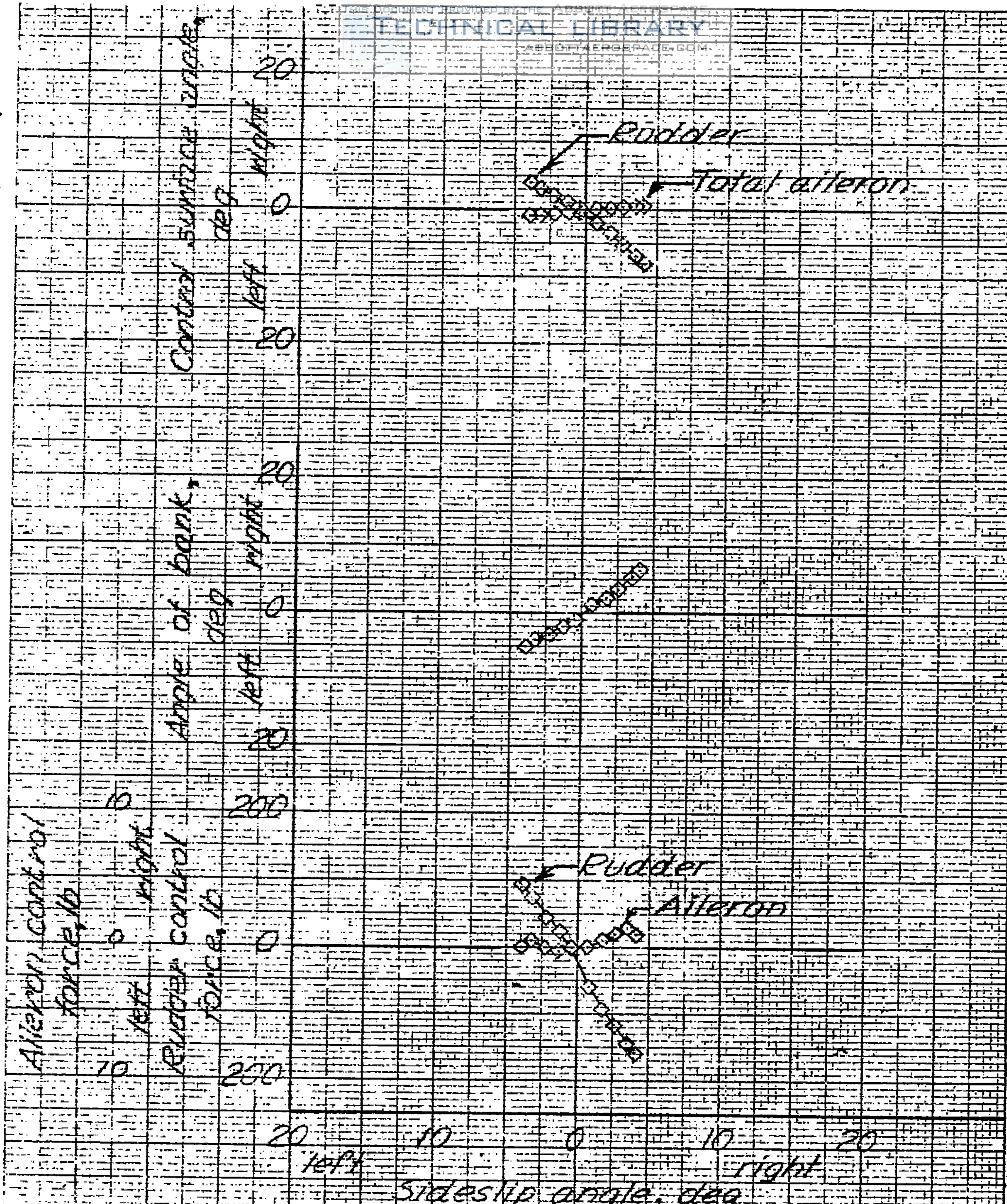

(j) Power on clean V, 300 hp, 34,600 tanks off

Figure 7 - Continued.

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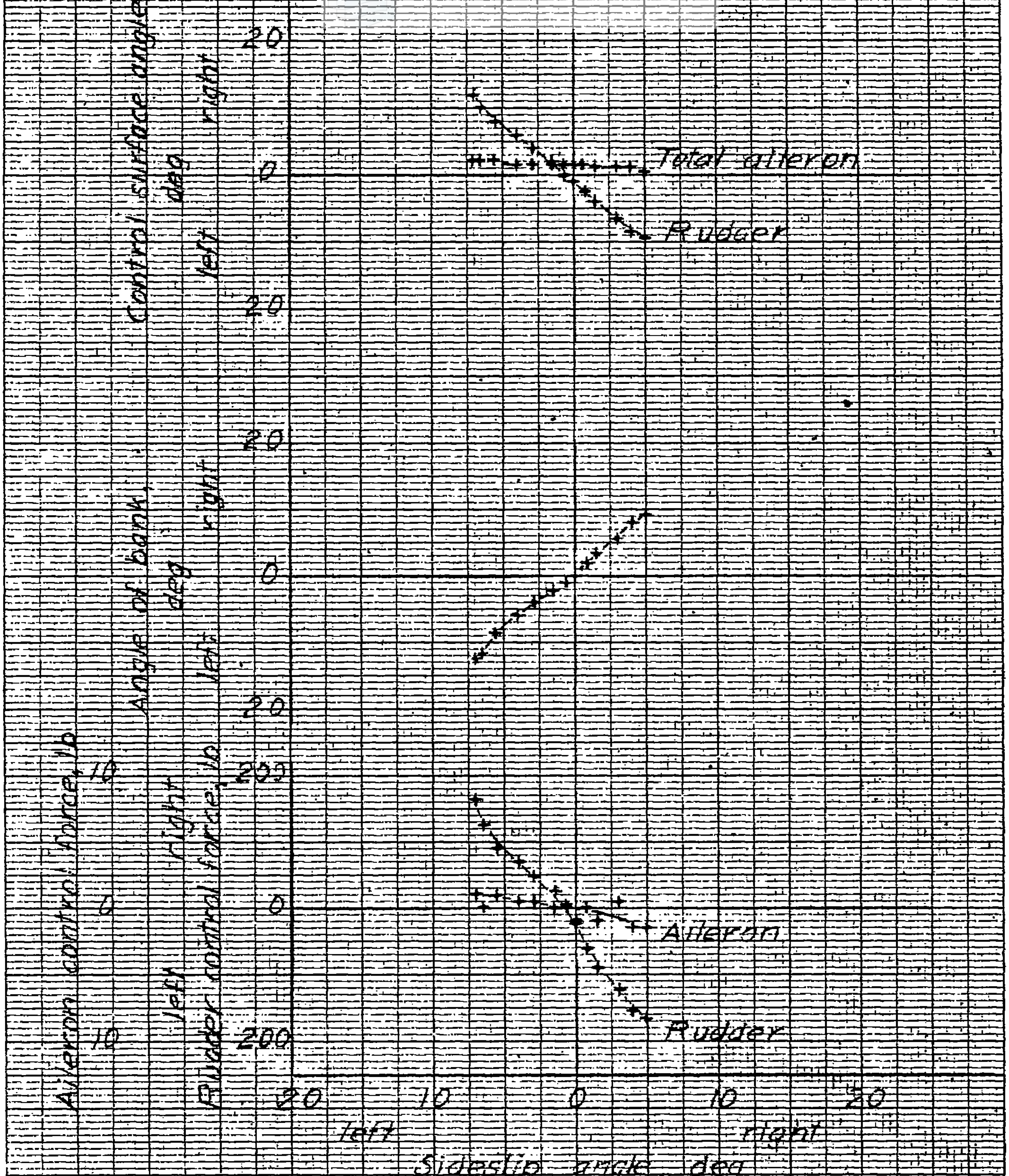

(k) Power on, clean V_i, 297 h_p, 32,100
Tanks on

Figure 7. Continued

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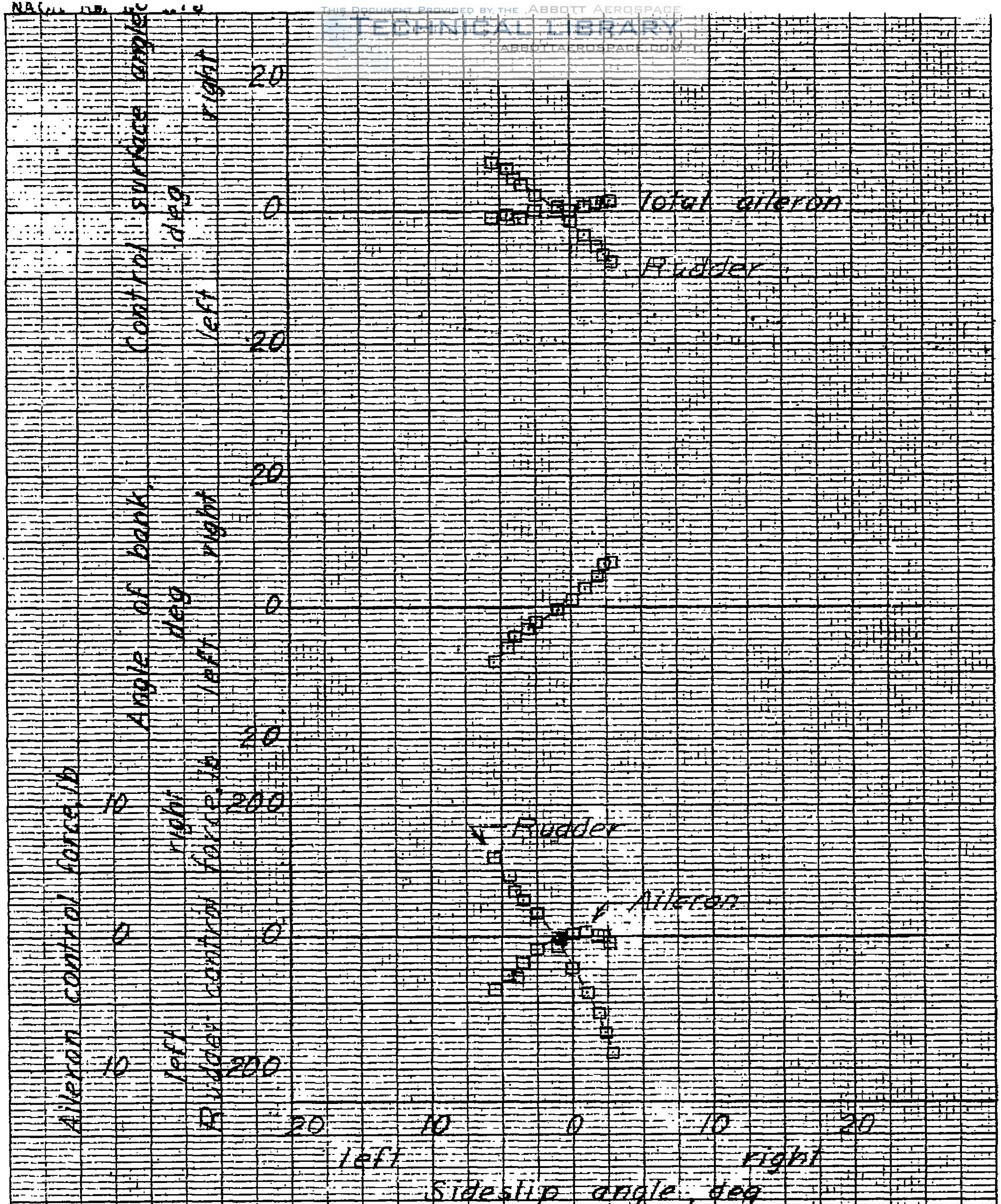

(I) Power on, clean V_i, 335 h_p, 31,400 ft
Tanks off.

Figure 7.- Continued

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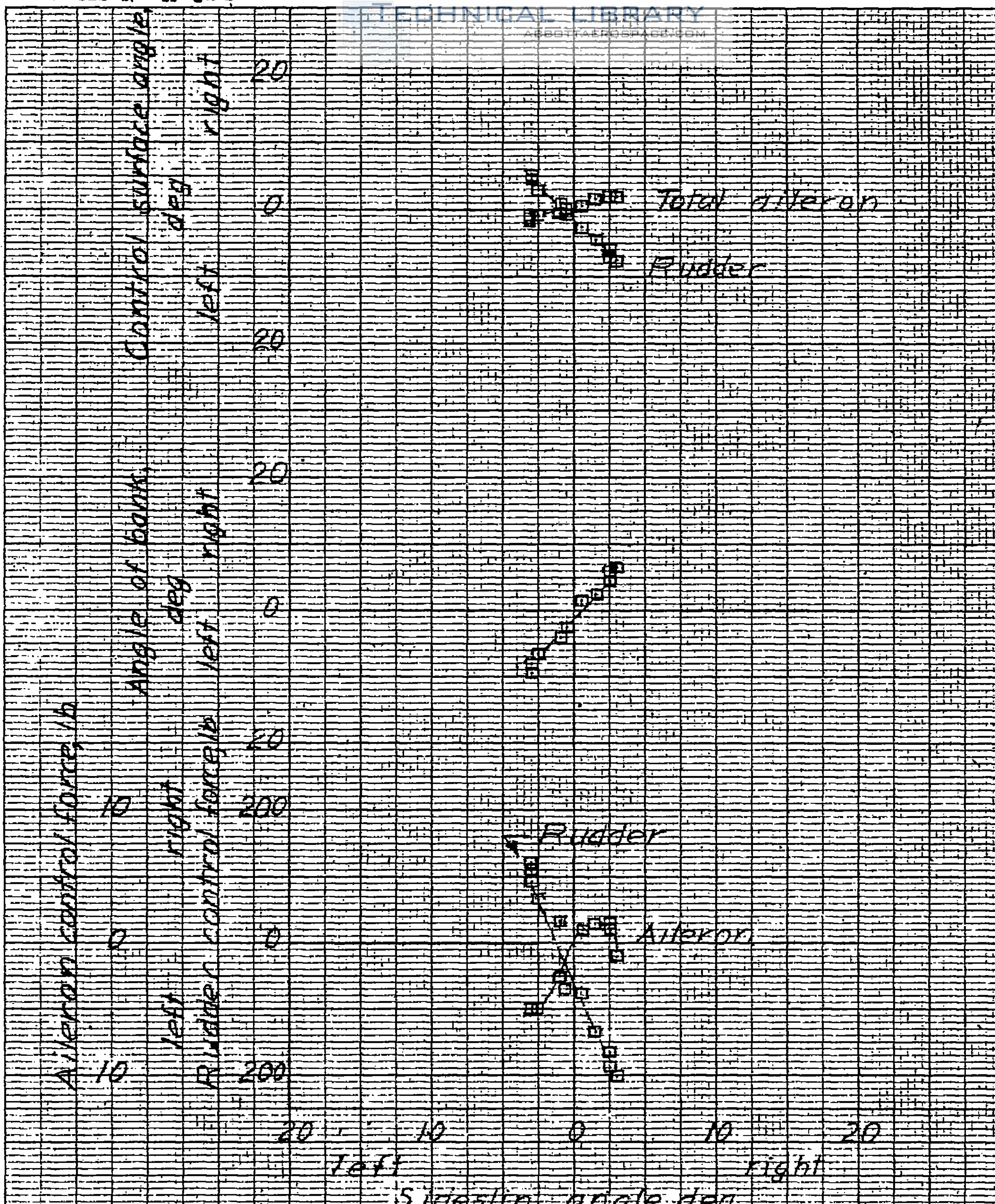

(n) Power on, clean V_i, 375 h_p, 27,500
tanks off

Figure 7 - Concluded

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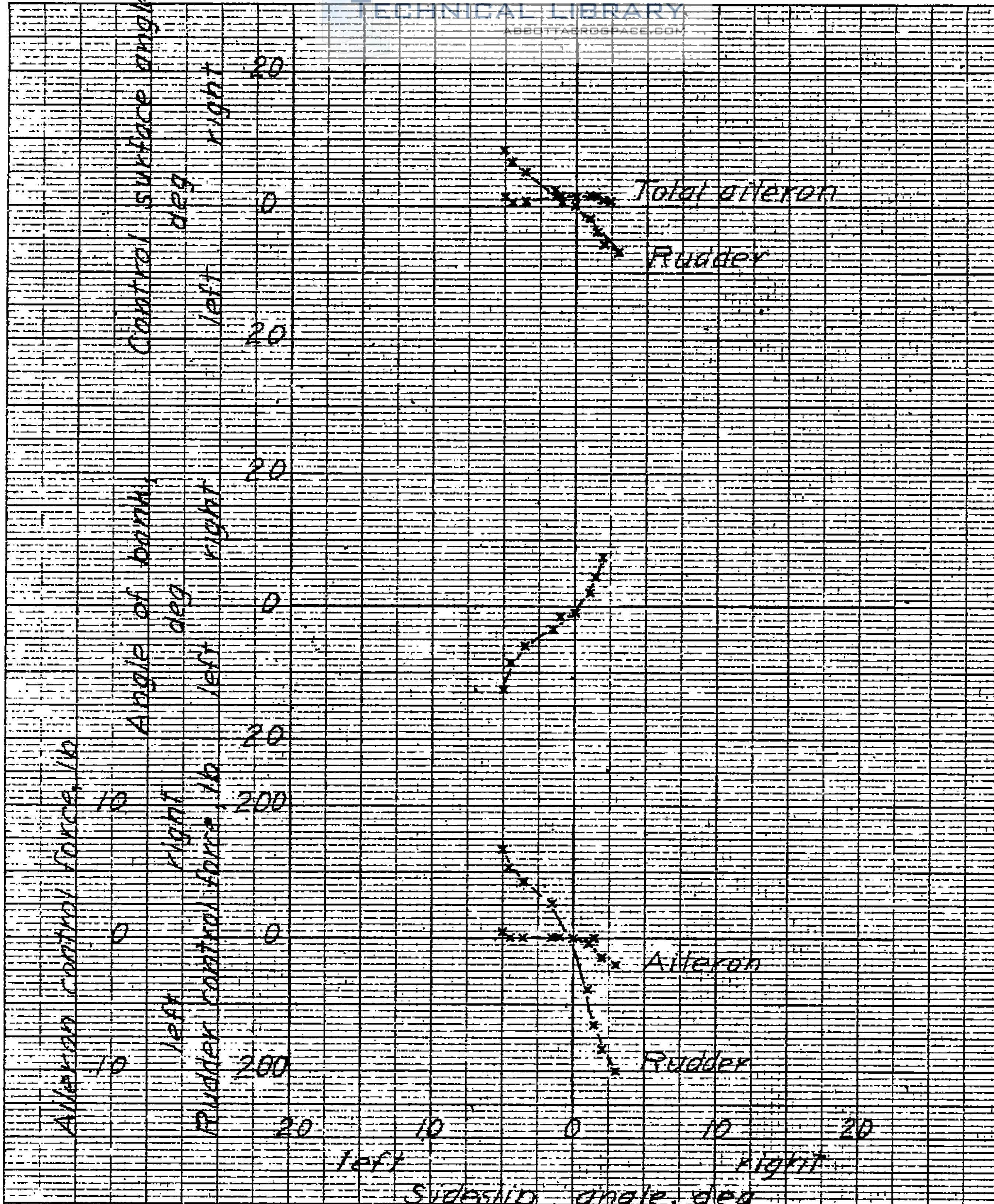

(m) Power-on, clean V_i, 358, hp, 27,000. Tanks on

Figure 1.- Continued.

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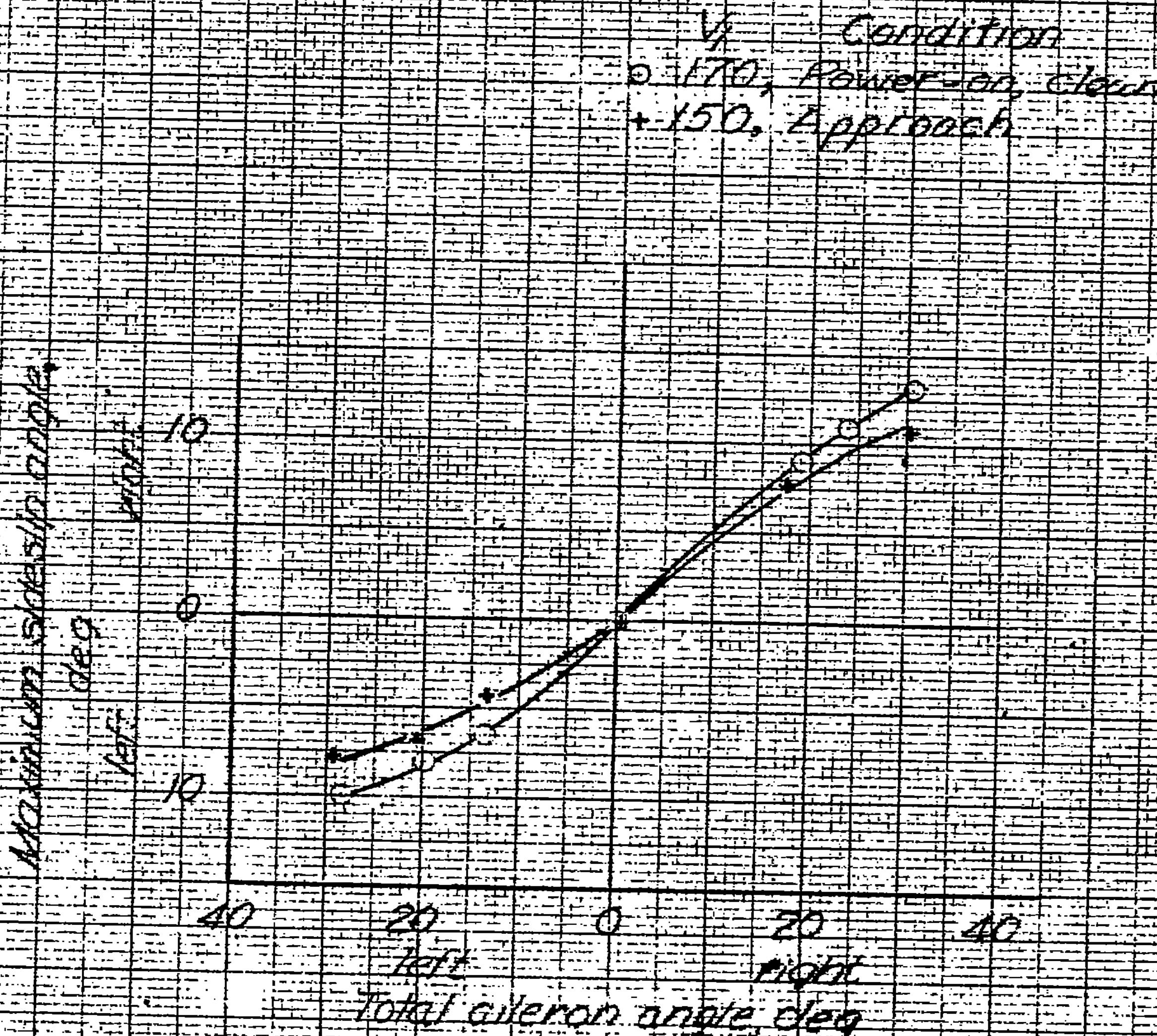

Figure 8 - Variation of sideslip angle with aileron deflection as obtained in rudder-fixed aileron rolls from 45° bank position. Power for level flight, h = 5300 [redacted]

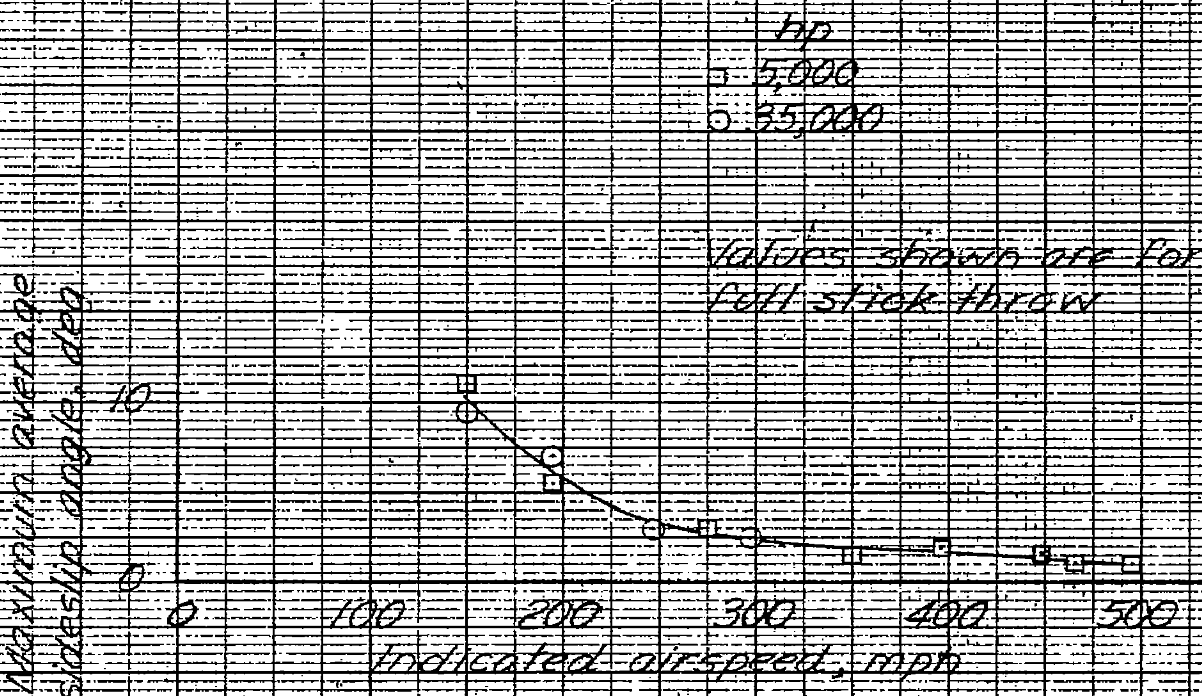

Figure 9.- Variation of sideslip angle with indicated airspeed as obtained in rudder-fixed aileron rolls. Power-on, clean.

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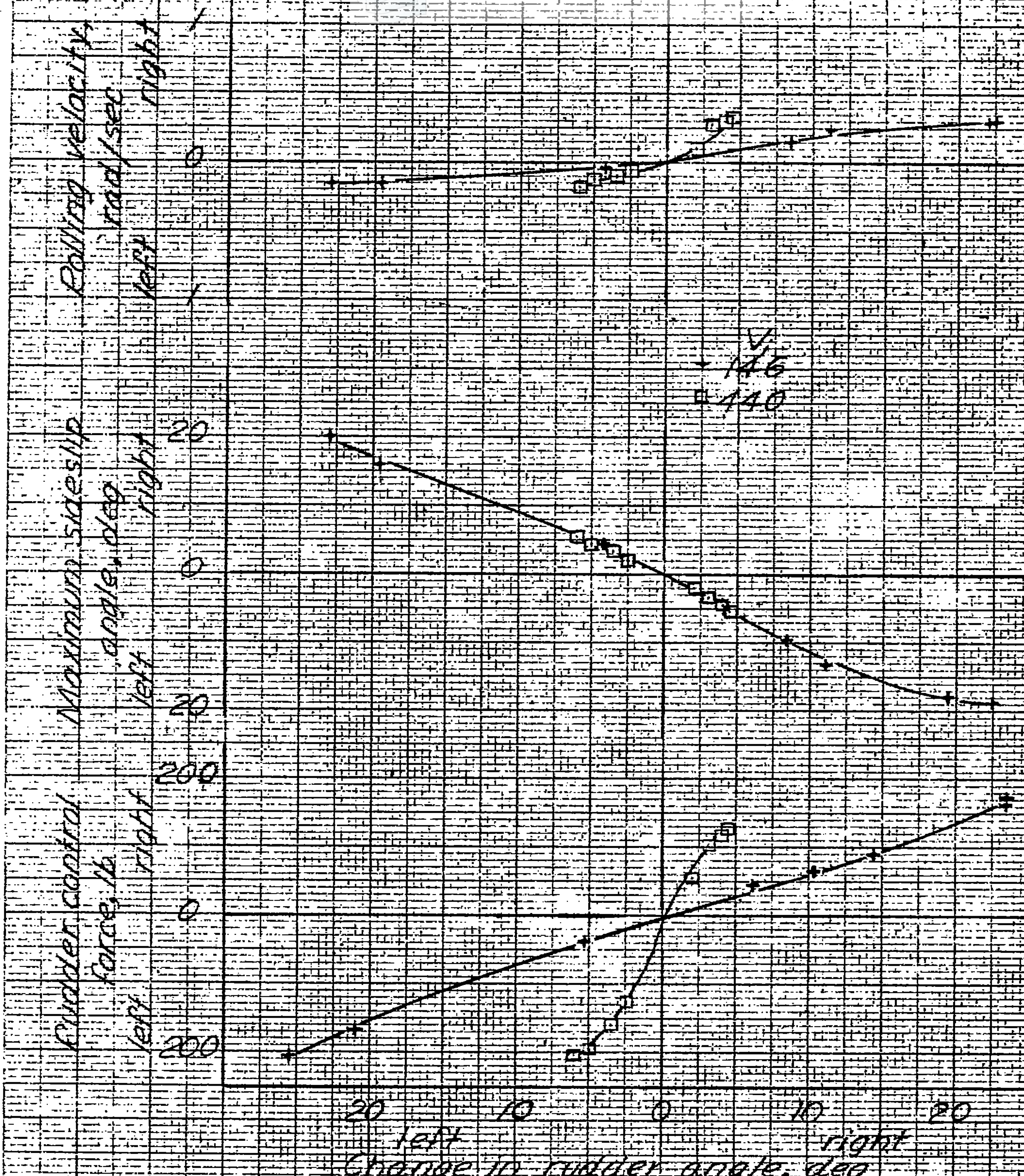
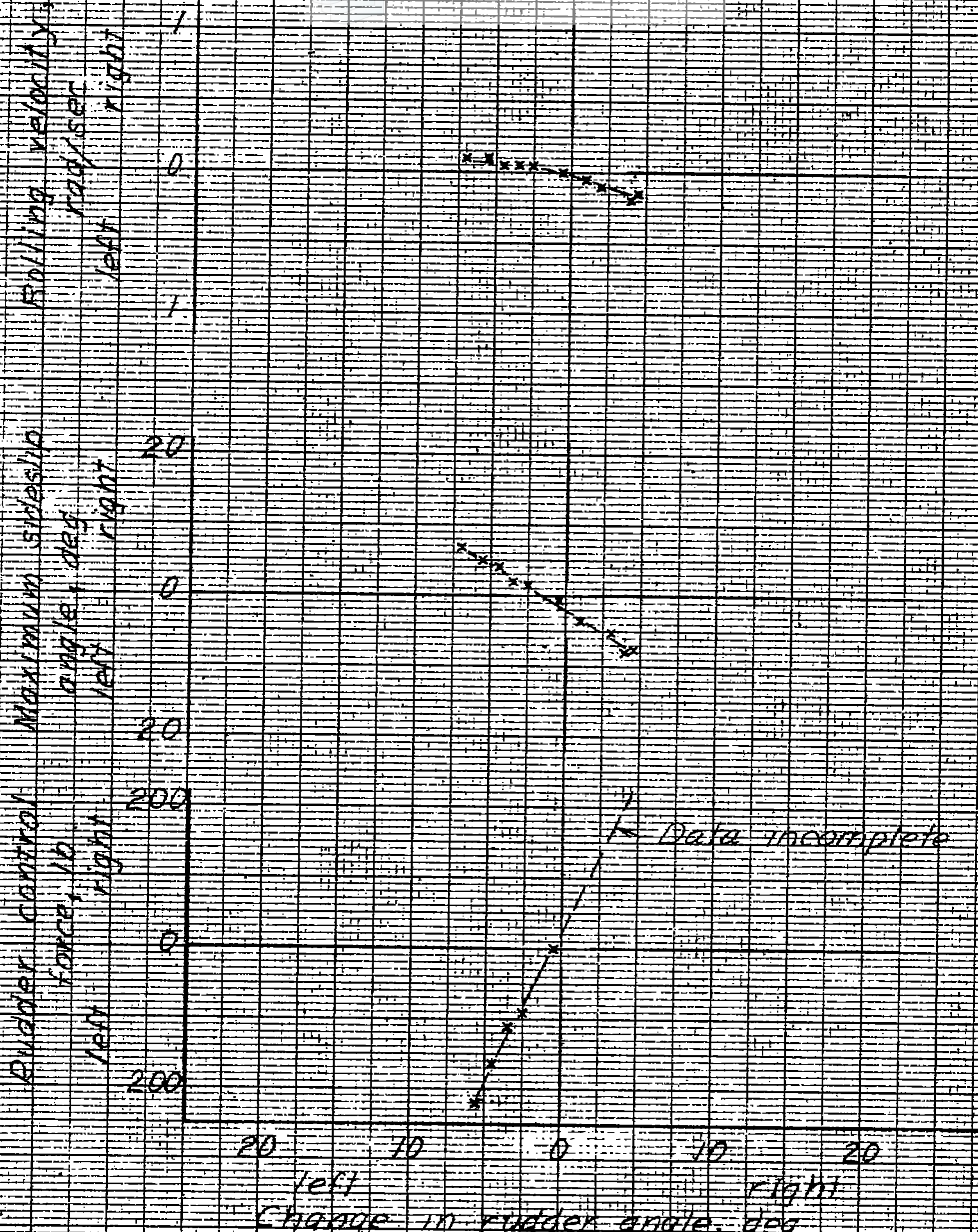


(a) Power on clean V_i, 146 and 440 hp, 5400 tanks off.

Figure 10 - Rudder control characteristics

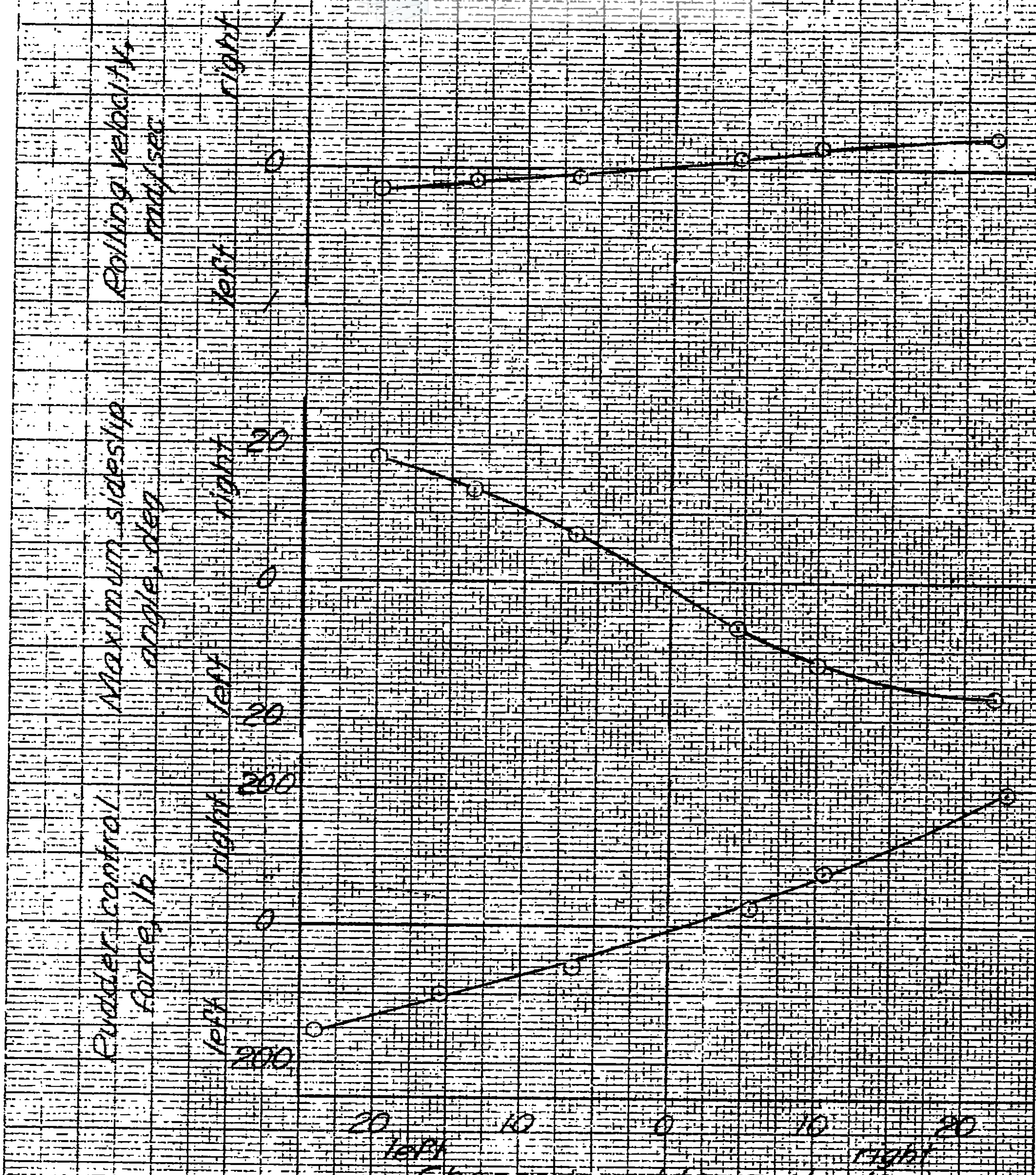
[redacted]



(b) Power-on, clean V_1, 420 hp, 4,500
Tanks on

Figure 10 Continued

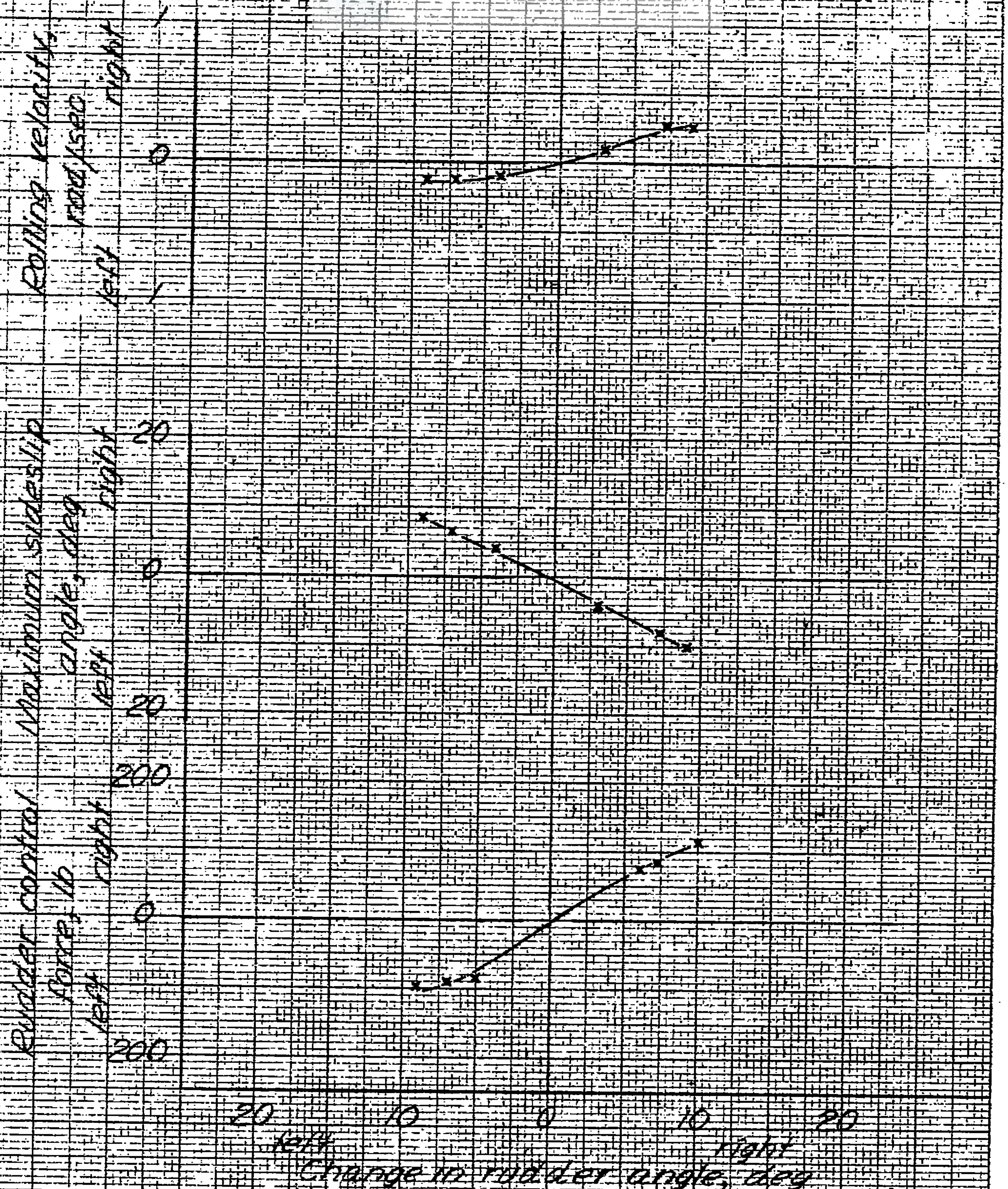
[redacted]



(c) Approach condition V, 150 hp, 1700.
Tanks off

Figure 10 – Continued.

[redacted]



(d) Power-on clean. V_i, 248, h_p, 34,800
Tanks off

Figure 10.- Continued.

[redacted]

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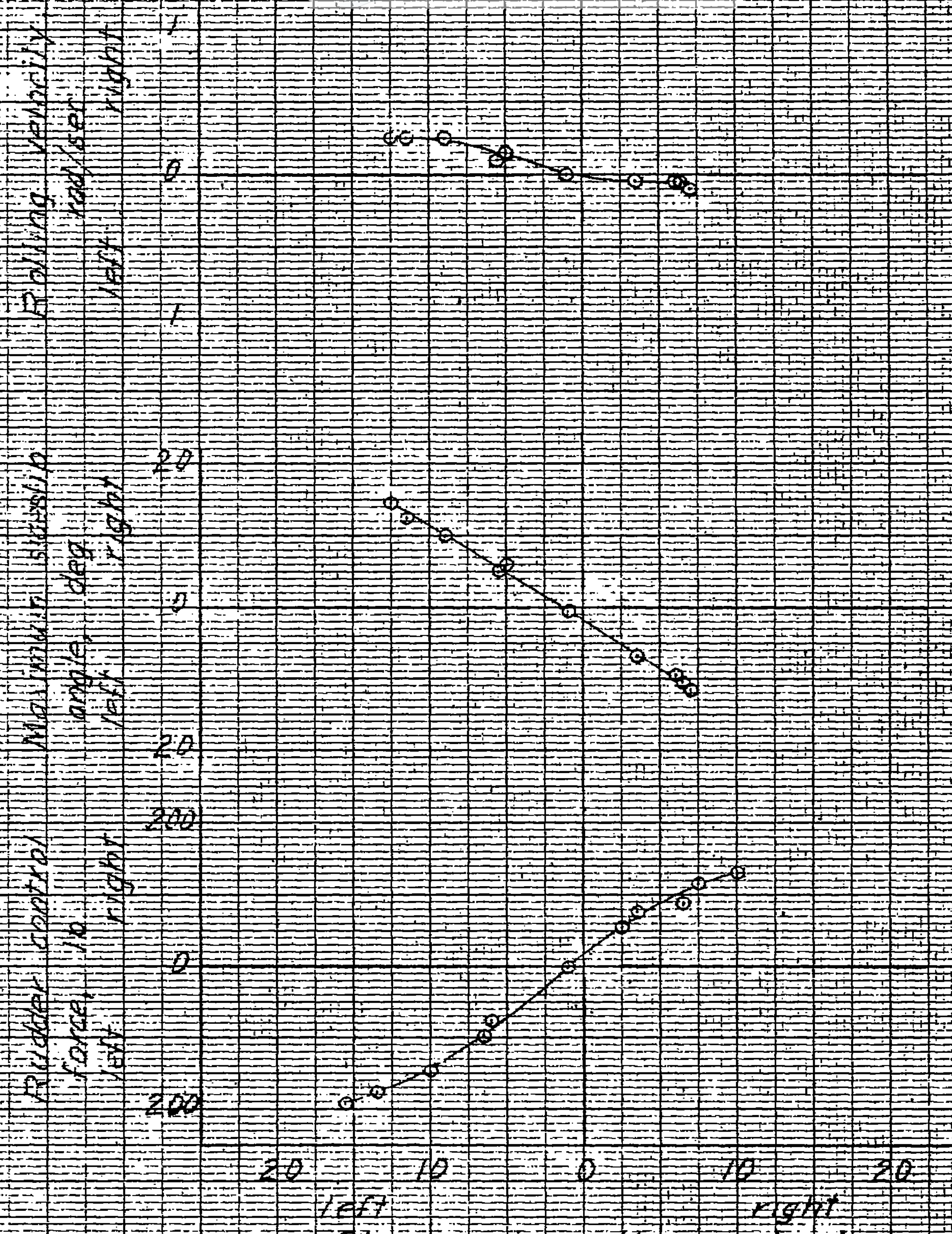
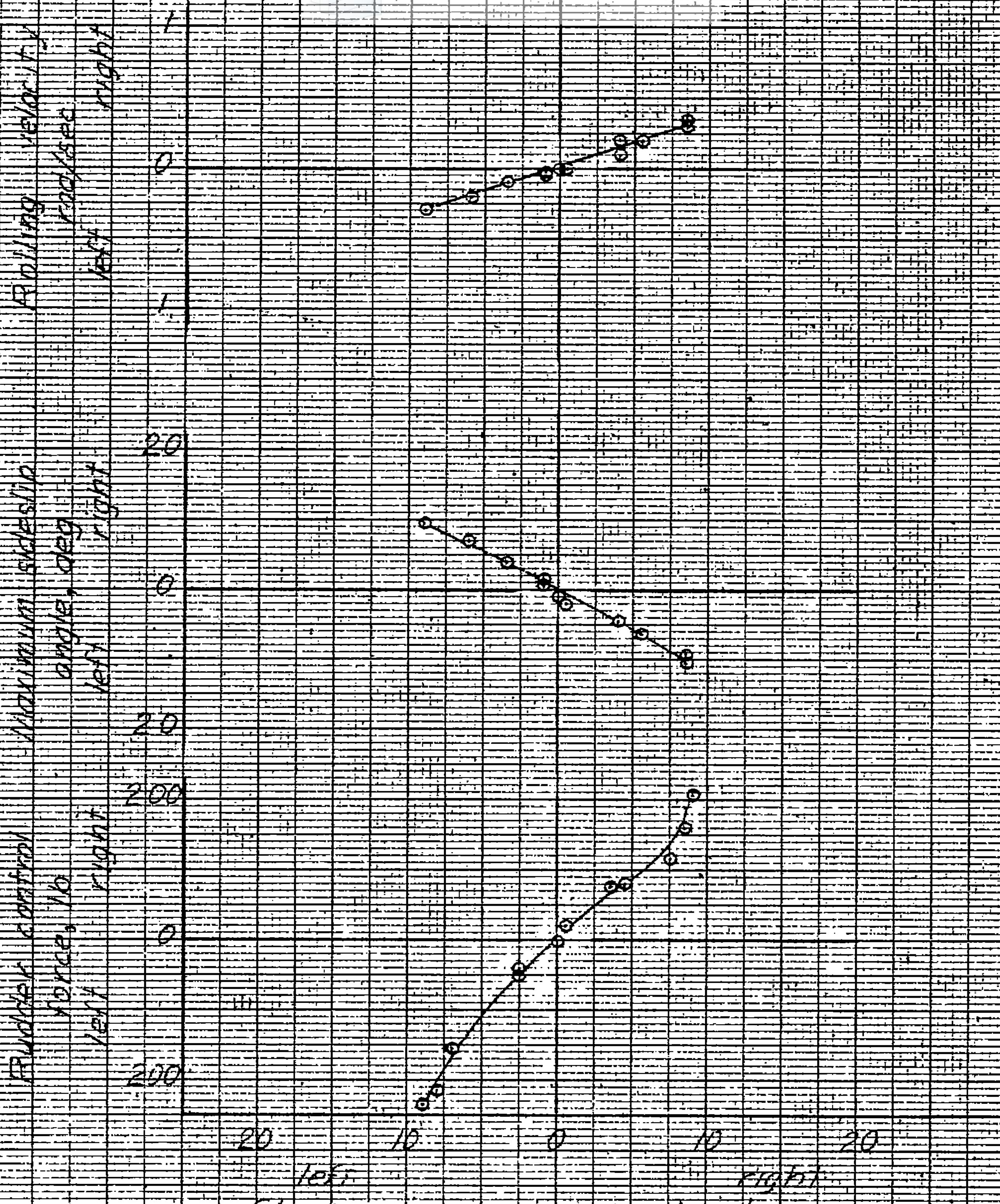


(e) Power on. clean V_i, 244 h_p, 35,900
Tanks on

Figure 10. Continued.

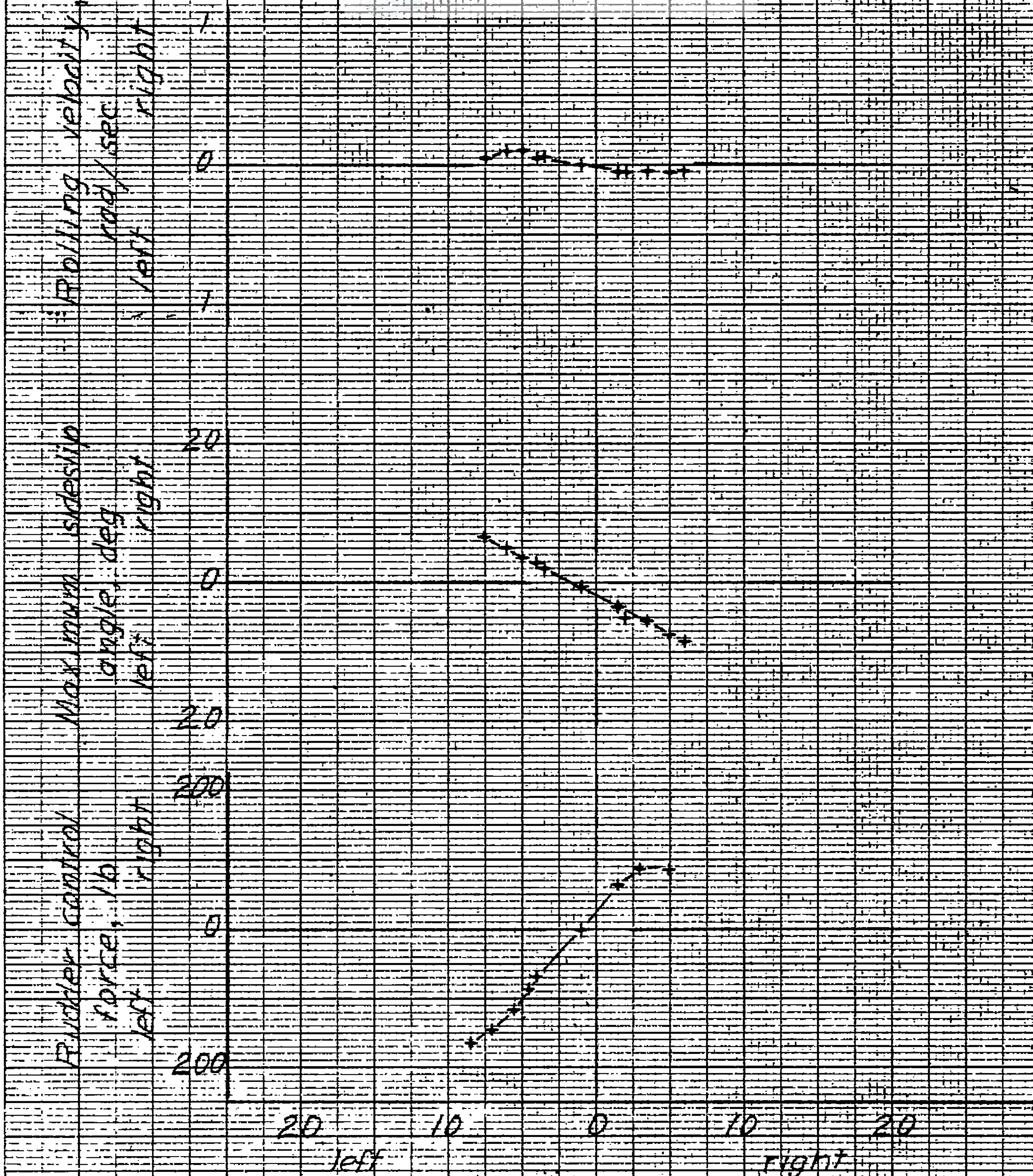
[redacted]



(f) Power-on, clean V1, 310 hp, 32,000
Tanks off

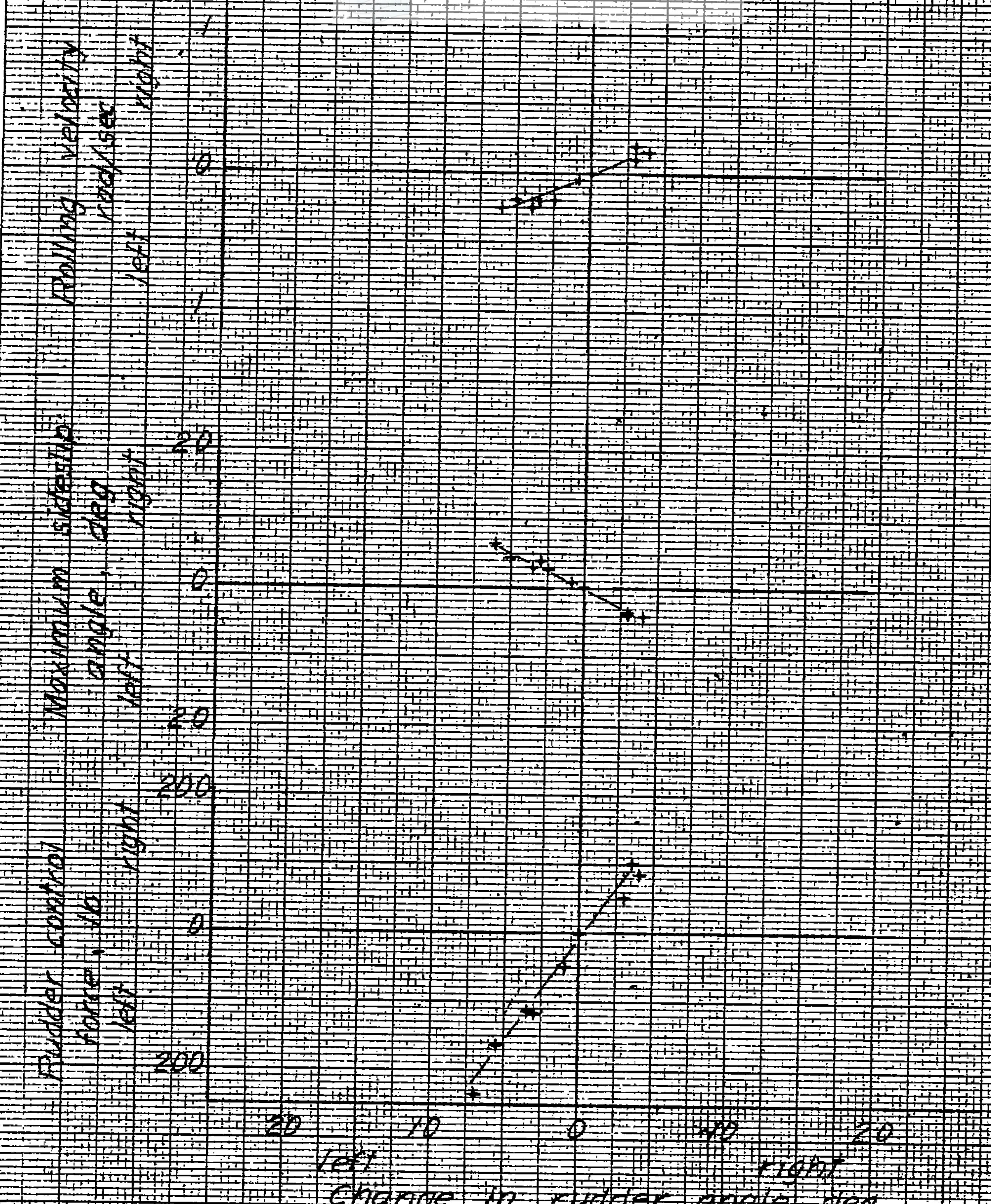
Figure 10. Continued.

[redacted]



(g) Power-on, clean V, 303, hp, 31,800.
Tanks on

Figure 10. Continued.



(h) Power-on, clean V, 361 hp, 27,200. Tanks off

Figure 10. Concluded

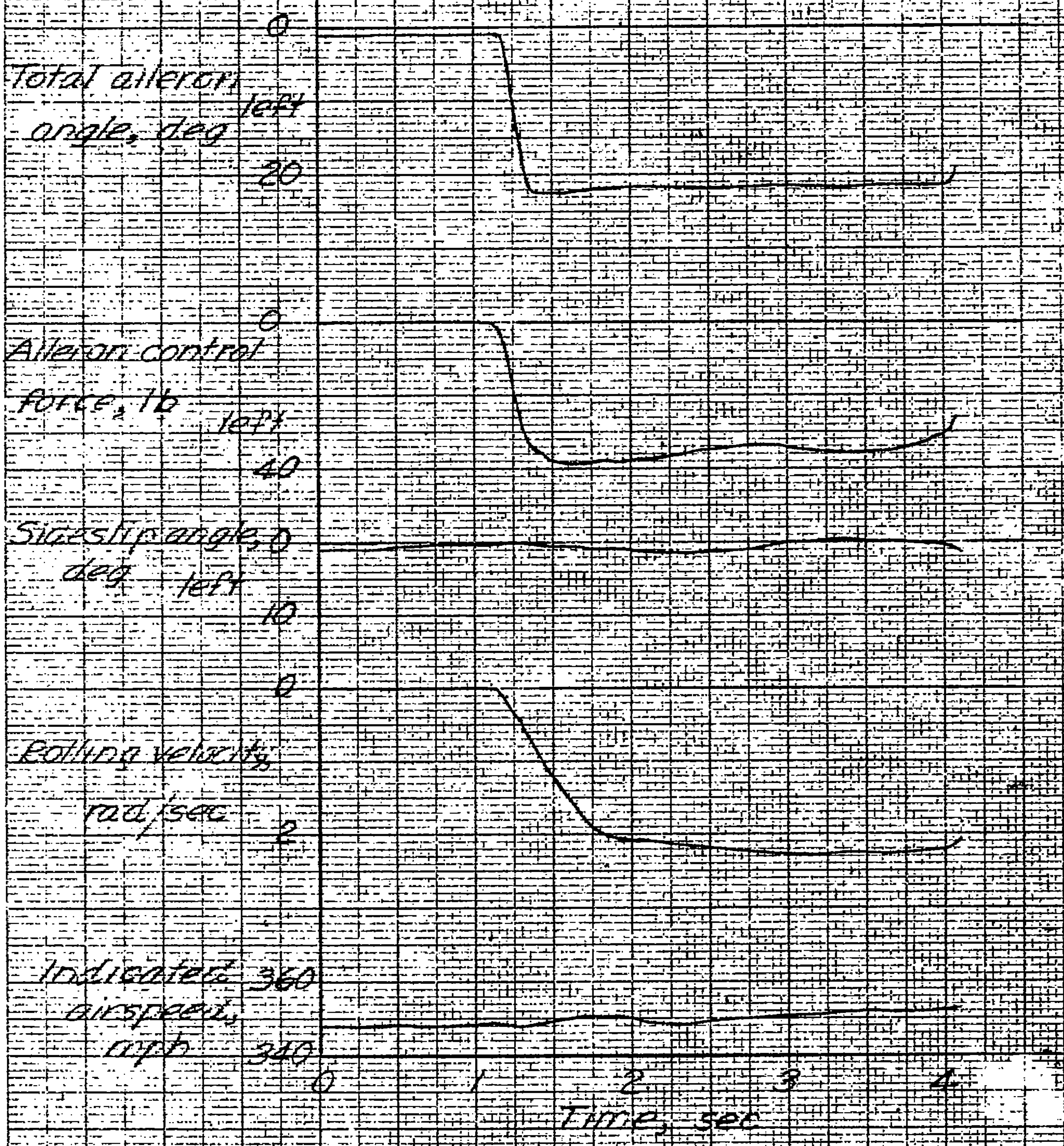
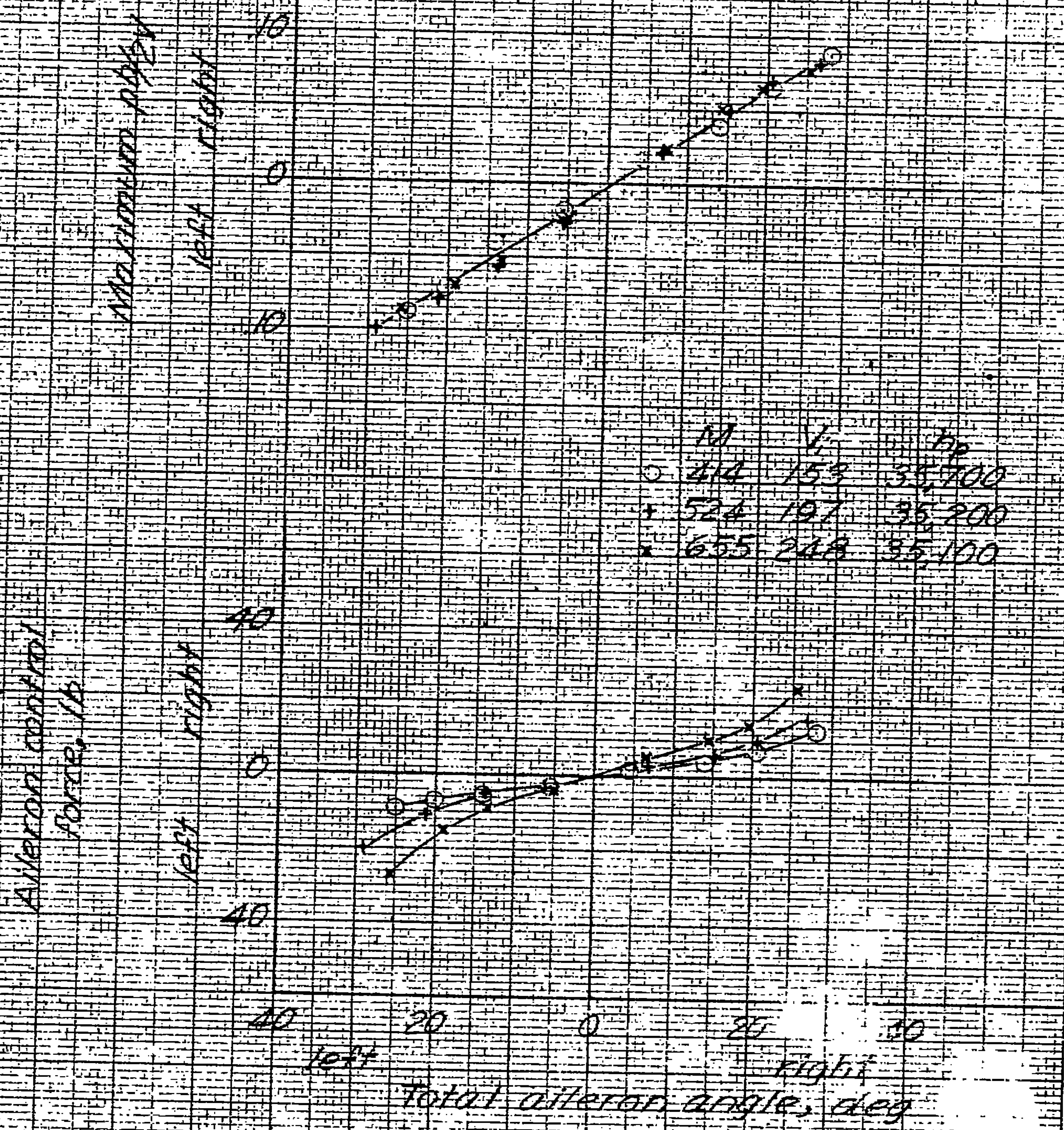
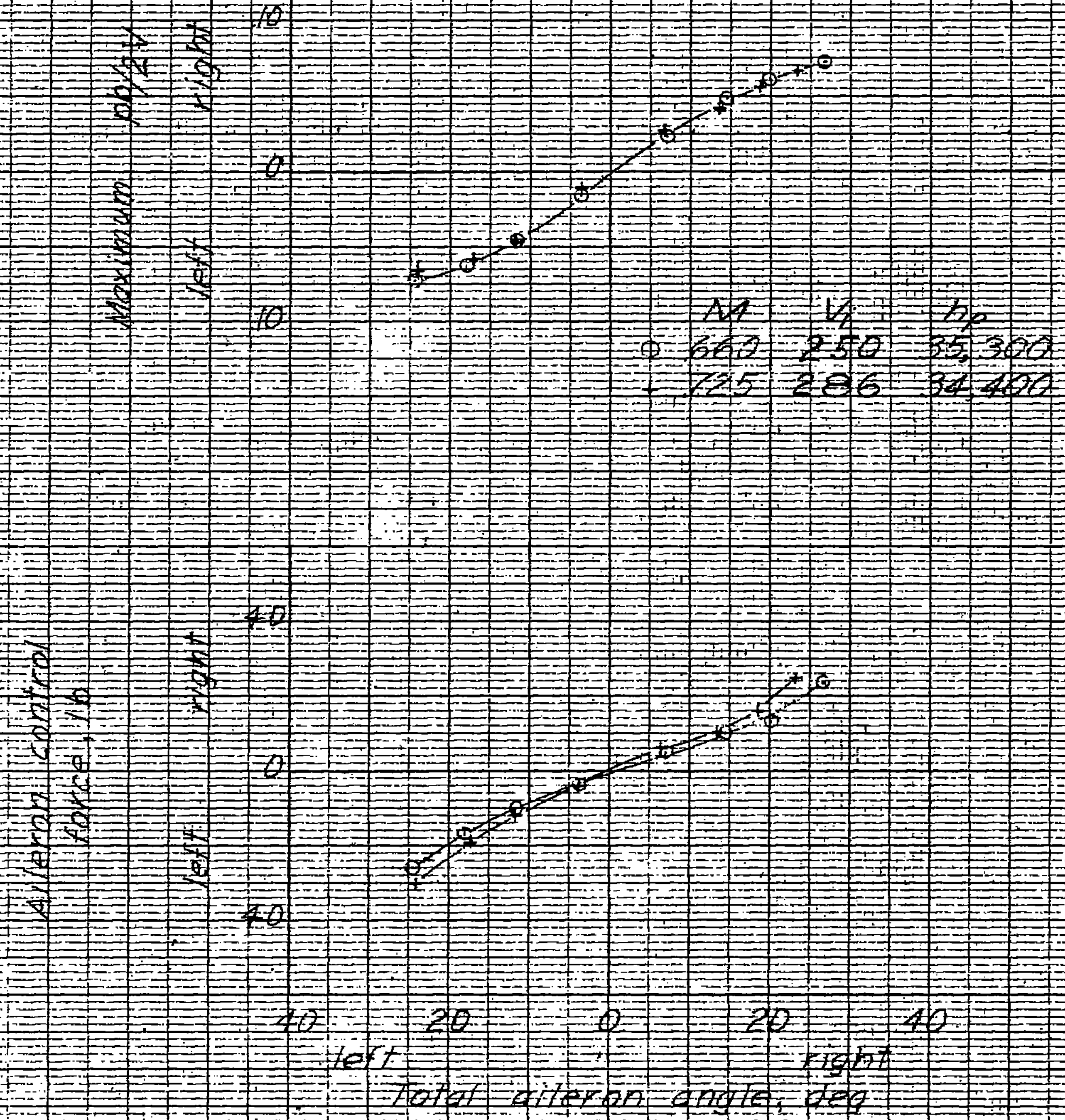


Figure 11 – Time history of a rudder fixed aileron roll. Power-on, clean



(a) V_i, 153, 197, 248 High altitude Tanks off

Figure 12 Aileron control characteristics. Power-on, clean [redacted]



(l) Vi, 250, 286. High altitude. Tanks on

Figure 12 - Continued

[redacted]

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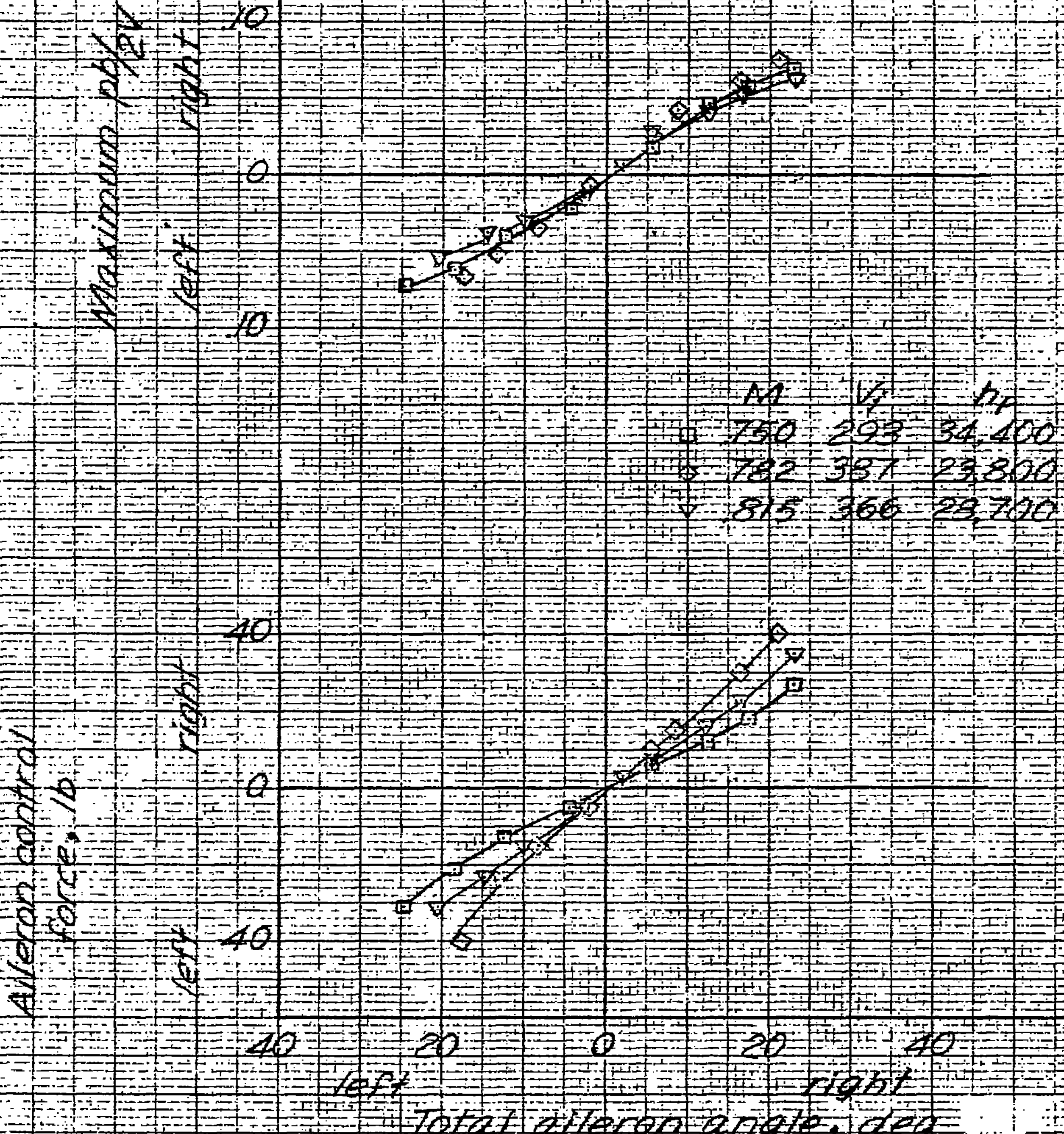
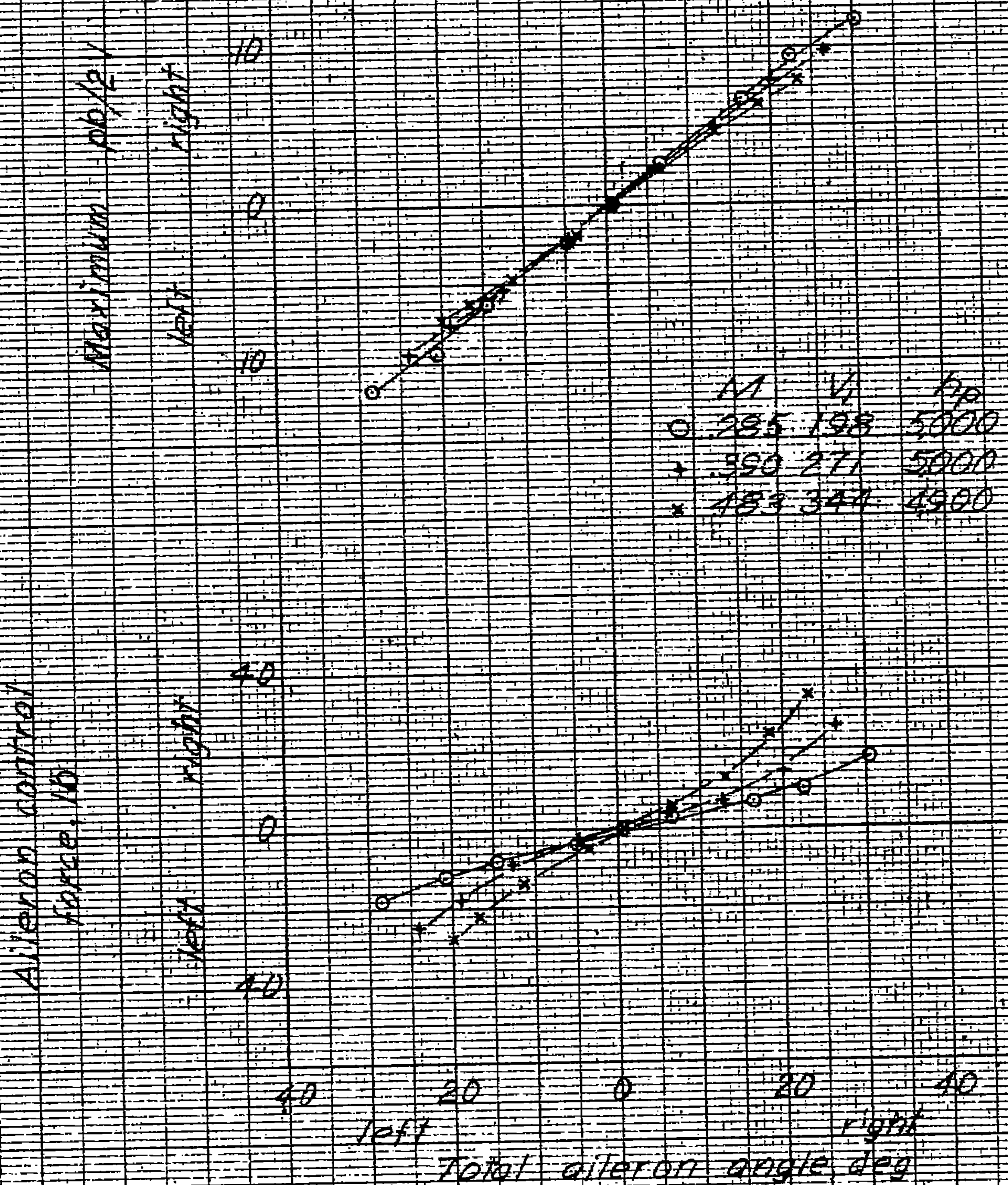


(c) Vi, 293, 366, 387. High altitude, tanks off

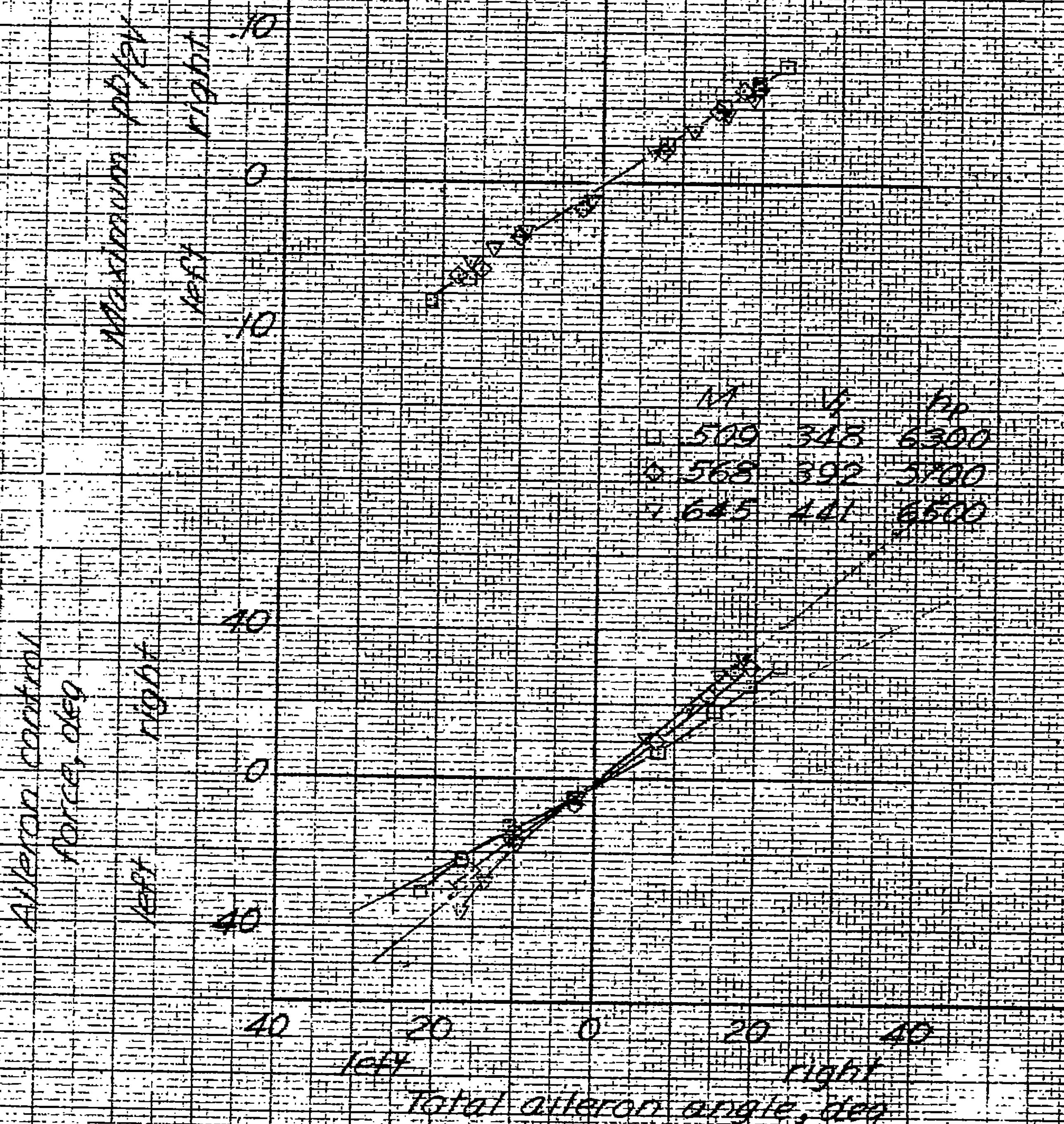
Figure 12 - Continued



(e) V_i, 198, 271, 344. Low altitude tanks on

Figure 12.- Continued

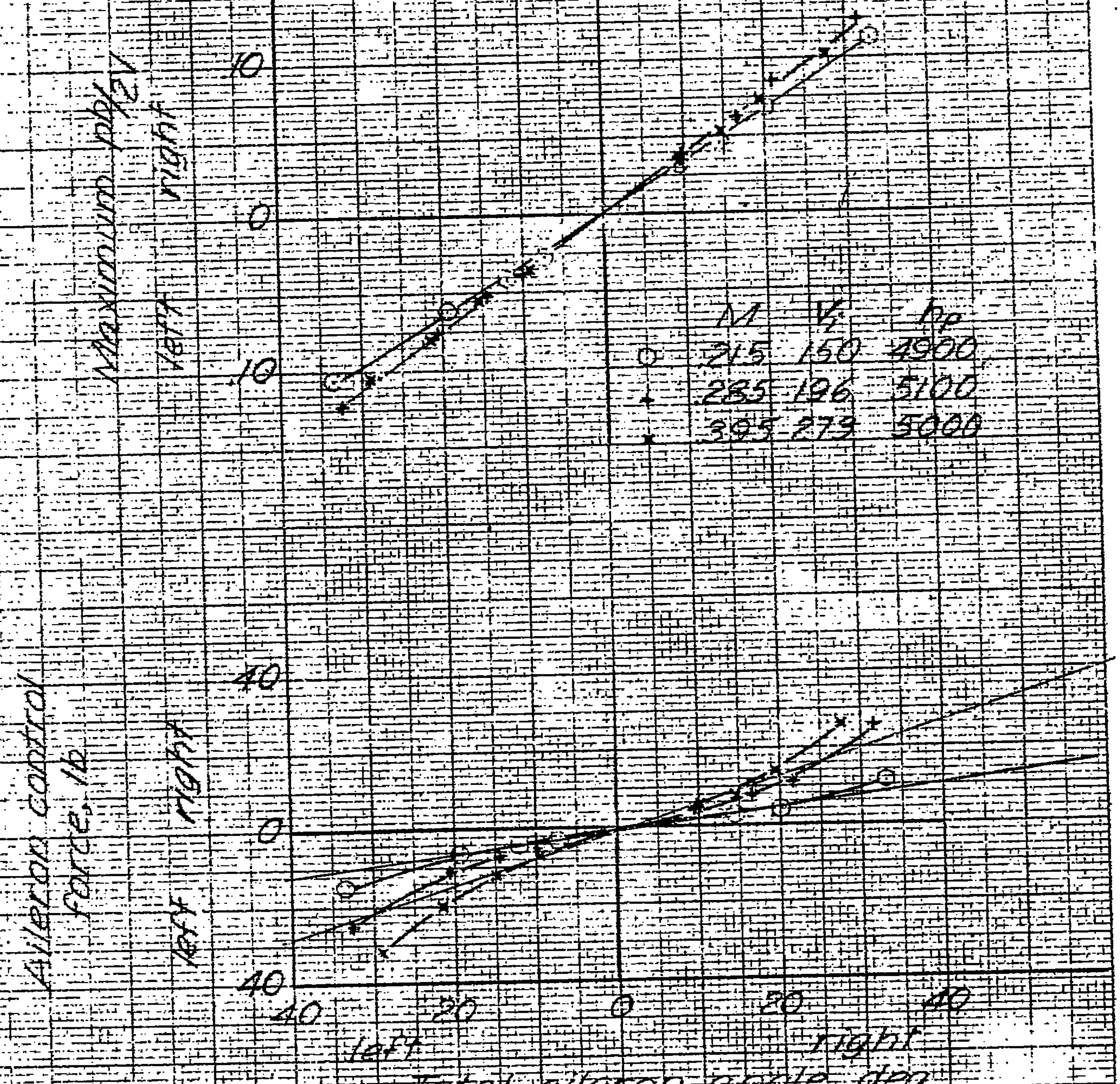
[redacted]



(f) V_i, 348, 392, 441 Low altitude tanks off

Figure 12 Continued

[redacted]



(a) V_i, 150, 196, 273. Low altitude tanks off

Figure 12. Continued

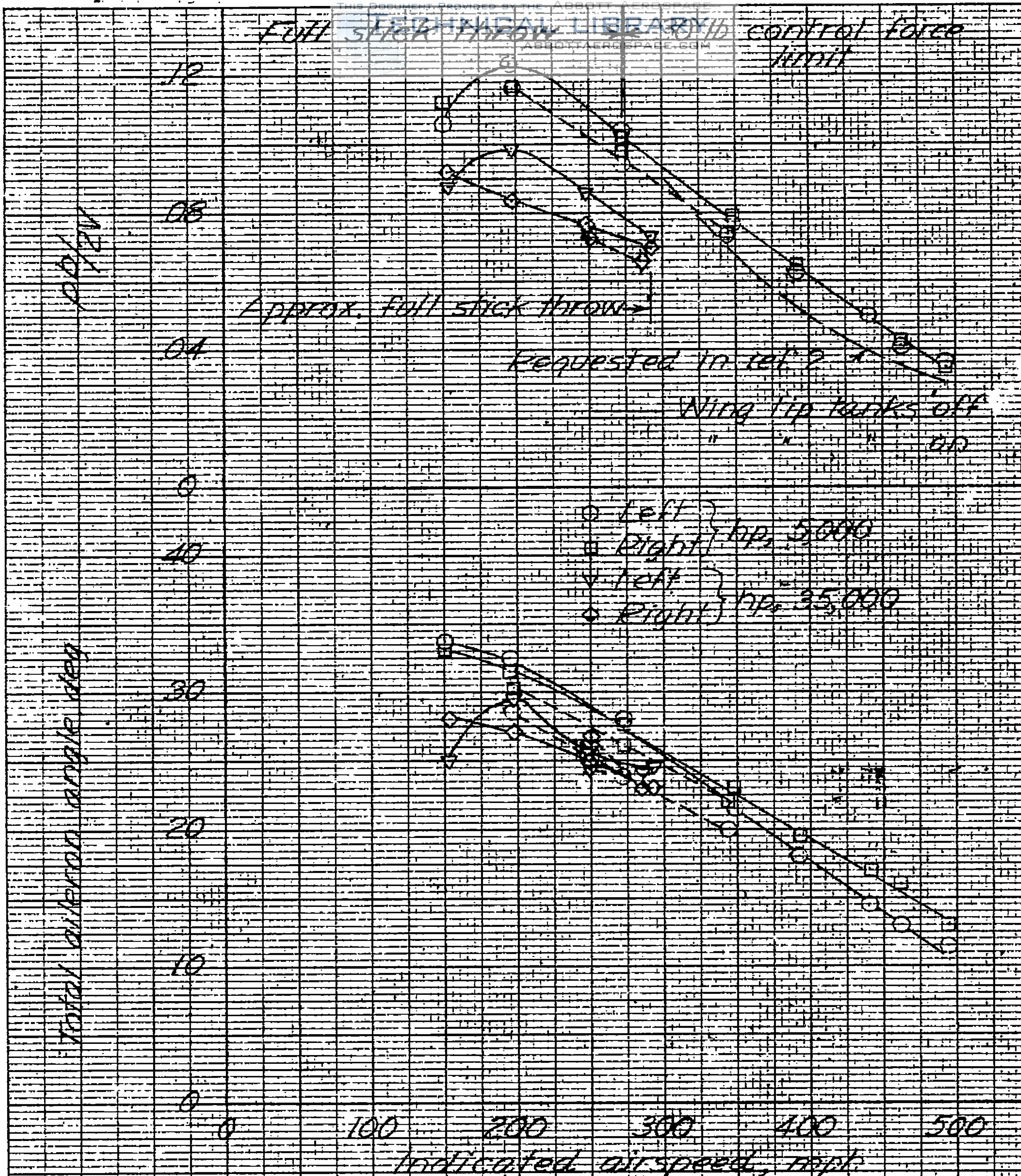


Figure 13 - Variation of pb/2V and aileron angle with indicated airspeed as limited by control stick position or 30 lb control force. Power

[redacted]

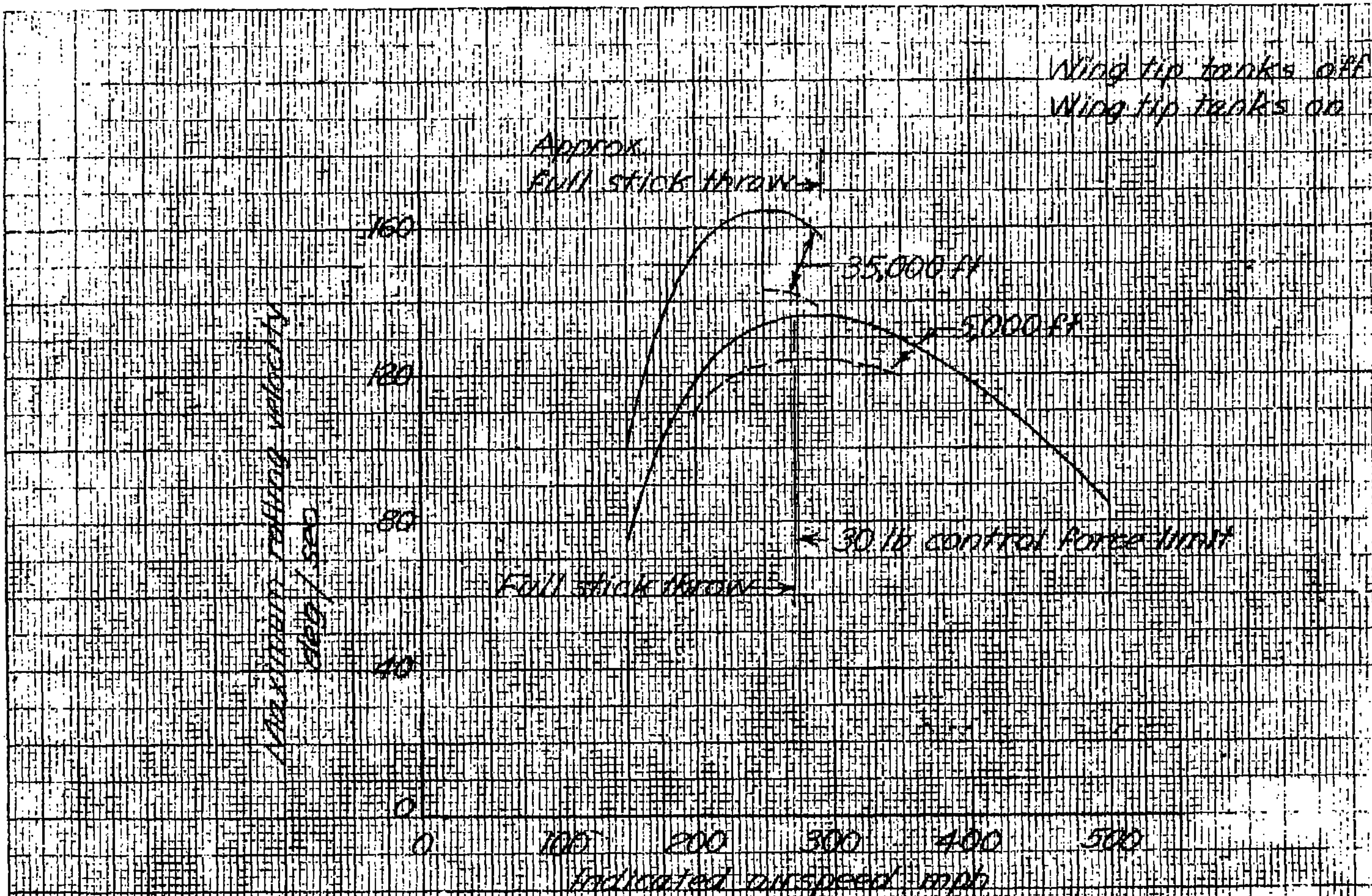


Figure 14.- Variation of maximum rolling velocity with airspeed as limited by full stick throw or 30 lb control force. Clean condition.

[redacted]

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