

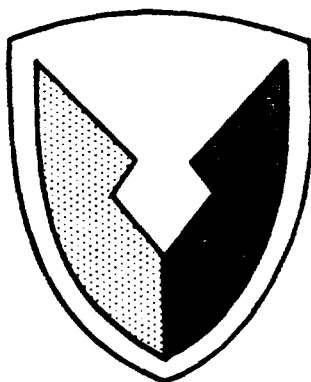
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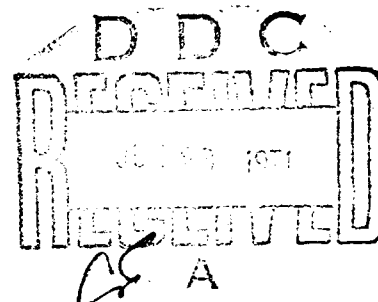


AD _____
RDTE PROJECT NO.
USAAVSCOM PROJECT NO. 69-16
USAASTA PROJECT NO. 69-16

HEIGHT-VELOCITY TEST OH-58A HELICOPTER

FINAL REPORT

JOSEPH C. WATTS
PROJECT OFFICER/PILOT



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JUNE 1971

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**US ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523**

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13. ABSTRACT

Height-velocity (H-V) tests were conducted on a production OH-58A helicopter to determine the validity of the H-V curve presented in the operator's manual, establish a practical operational H-V curve, and check compliance with the military specification, MIL-H-8501A. Testing was performed by the US Army Aviation Systems Test Activity, Edwards Air Force Base, California, between 1 June and 6 November 1970. The testing consisted of 52 flights totaling 61 hours, 18 of which were productive. Test results indicate that the H-V curve presented in the operator's manual can be achieved with the OH-58A helicopter. Achievement of such performance, however, requires training and proficiency beyond that normally acquired by the operational Army aviator. This report presents an operational H-V curve which can be safely duplicated by the operational aviator with minimum additional training. This additional training should consist of autorotational entries at airspeeds from zero to 90 knots indicated airspeed (KIAS) at low skid heights, and of airspeeds less than 60 KIAS at high skid heights. Rotor rpm decay rates were excessive in that rotor speed fell below the minimum published value after delaying movement of collective pitch for 2 seconds following throttle chop. An operational H-V curve, presented herein, was derived from the test data. Although this curve allows an adequate safety margin for the operational aviator, its use will require additional training. Future training should consist of autorotational entries from low skid heights and airspeeds from zero to 90 KIAS, and at high skid heights and airspeeds less than 60 KIAS. The operational H-V curve incorporating the pilot techniques presented in this report should replace the curve in the operator's manual at the earliest possible date.

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Height-velocity test OH-58A helicopter Operational H-V curve for operator's manual						

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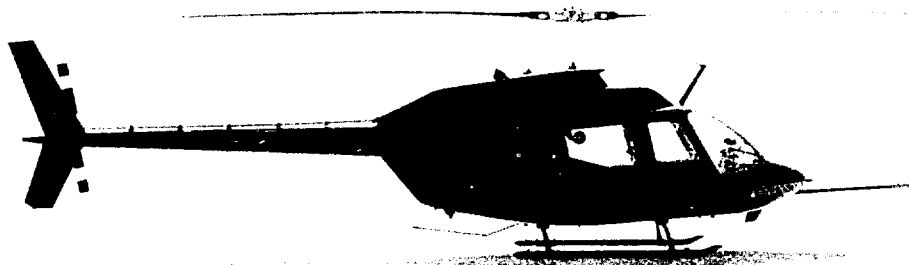
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Height-velocity (H-V) tests were conducted on a production OH-58A helicopter to determine the validity of the H-V curve presented in the operator's manual, establish a practical operational H-V curve, and check compliance with the military specification, MIL-H-8501A. Testing was performed by the US Army Aviation Systems Test Activity, Edwards Air Force Base, California, between 1 June and 6 November 1970. The testing consisted of 52 flights totaling 61 hours, 18 of which were productive. Test results indicate that the H-V curve presented in the operator's manual can be achieved with the OH-58A helicopter. Achievement of such performance, however, requires training and proficiency beyond that normally acquired by the operational Army aviator. This report presents an operational H-V curve which can be safely duplicated by the operational aviator with minimum additional training. This additional training should consist of autorotational entries at airspeeds from zero to 90 knots indicated airspeed (KIAS) at low skid heights, and of airspeeds less than 60 KIAS at high skid heights. Rotor rpm decay rates were excessive in that rotor speed fell below the minimum published value after delaying movement of collective pitch for 2 seconds following throttle chop. An operational H-V curve, presented herein, was derived from the test data. Although this curve allows an adequate safety margin for the operational aviator, its use will require additional training. Future training should consist of autorotational entries from low skid heights and airspeeds from zero to 90 KIAS, and at high skid heights and airspeeds less than 60 KIAS. The operational H-V curve incorporating the pilot techniques presented in this report should replace the curve in the operator's manual at the earliest possible date.



FOREWORD

Throughout the height-velocity test program, technical support was provided on request by the airframe manufacturer, Bell Helicopter Company, Fort Worth, Texas; and the engine manufacturer, Allison Division of General Motors Corporation, Indianapolis, Indiana. Instrumentation calibration, emergency fire fighting and medical support were provided by the US Air Force Flight Test Center, Edwards Air Force Base, California.

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INTRODUCTION

BACKGROUND

1. Height-velocity (H-V) tests were originally scheduled to be conducted during OH-58A Phase D testing. To facilitate timely completion of tests and report publication on the OH-58A Phase D test, the US Army Aviation Systems Test Activity (USAASTA) requested the OH-58A H-V test be conducted as a separate project. This authority was issued by the Directorate of Flight Standards and Qualification, US Army Aviation Systems Command (USAAVSCOM), in a test request dated 23 October 1969 (ref 1, app I). Height-velocity tests were subsequently conducted at auxiliary test sites near Bakersfield and Bishop, California.

TEST OBJECTIVES

2. The objectives of the OH-58A H-V test program were as follows:

a. Develop a safe operating H-V envelope for incorporation in the operator's manual. Special emphasis was placed on developing an envelope which would utilize normal piloting skills and would be usable by the operational Army aviator.

b. Determine the validity of the Federal Aviation Administration (FAA) approved H-V curve presented in the operator's manual (ref 2, app I).

c. Check compliance with paragraph 3.5.5 of the military specification, MIL-H-8501A (ref 3, app I).

DESCRIPTION

3. The OH-58A light observation helicopter (LOH) employs a single main rotor and an antitorque tail rotor of the two-bladed, semirigid, teetering type. The tail rotor has delta-three coupling. The cockpit provides side-by-side seating for a crew of two (pilot and copilot/observer), and the cargo compartment has provisions for two passengers. Dual flight controls are provided. The cyclic and collective controls are hydraulically boosted and irreversible while the antitorque control is unboosted. The main landing gear is of the fixed, energy-absorbing skid type. The helicopter is powered by an Allison T63-A-700 free gas turbine engine with a takeoff power rating of 317 shaft horsepower (shp) under sea-level (SL), standard-day, uninstalled conditions. The main transmission has a rating of 270 shp (maximum continuous) with a takeoff power limit of 317 shp (5-minute rating). Detailed aircraft information may be found in appendix II. Photographs of the aircraft and instrumentation are presented in appendix III.

SCOPE OF TEST

4. The H-V profiles of the OH-58A helicopter were evaluated in accordance with the test plan (ref 4, app I). The flight restrictions and operating limitations observed during this evaluation were stipulated in the operator's manual (ref 2) with exceptions specifically approved by USAAVSCOM.

5. Height-velocity tests were conducted only in the clean configuration with all doors installed. Gross weight (grwt) was varied from the minimum practical of 2450 pounds to a maximum allowable of 2900 pounds. To determine altitude effects, tests were conducted at pressure altitudes (Hp) ranging from SL to 9500 feet. A mission center-of-gravity (cg) location at an approximate fuselage station (FS) of 107 inches was used throughout the test program. Additional tests were conducted utilizing standardization instructor pilots (SIP's) from the US Army Aviation School, Fort Rucker, Alabama, to obtain a representative indication of the response of the general Army aviation population to OH-58A H-V maneuvers.

6. A total of 52 flights consisting of 61 hours (18 productive) were conducted at test sites near Bakersfield and Bishop, California.

METHODS OF TEST

7. Conventional H-V testing techniques were employed in conjunction with existing analytical procedures to obtain maximum safety of flight and minimum test time. Tests were conducted under nonturbulent atmospheric conditions, with a wind velocity of 3 knots or less, to preclude results being influenced by uncontrolled perturbations. All touchdowns were made on improved hard-surfaced runways.

8. To determine and quantify the autorotational techniques currently employed in Army aviator training on the OH-58A helicopter, the performance of two instructor pilots from the US Army Aviation School, Fort Rucker, Alabama, was observed. Without benefit of training in techniques utilized during H-V flight testing, these pilots demonstrated their normal autorotational techniques, and quantitative data were recorded. To determine their reaction in an unfamiliar flight condition, these pilots were placed in situations that differed from their normal operational training environment. Using their normal training technique, autorotational landings were performed without time delay prior to movement of the flight controls. The maximum pitch rates and attitudes acquired in accomplishing these maneuvers were recorded. These data were utilized as criteria for the development of an operational H-V curve.

9. The test techniques included a series of preliminary assessments to familiarize the test team with the helicopter's handling qualities and performance and to define test variables. These assessments were made prior to the determination of the H-V profiles and included: handling qualities following sudden engine failure; main rotor rpm decay characteristics as a function of flight control delay times, gross weight

and/or entry airspeeds; flare effectiveness as a function of airspeed and gross weight; and altitude required to reach flare airspeed as a function of pushover rates and attitudes. The test techniques used for these preliminary assessments are described in reference 5, appendix I. Additional discussion of test techniques is presented in appendix IV.

10. Standard test techniques were used to collect data for a compliance check of paragraph 3.5.5 of MIL-H-8501A. A 2-second time delay was employed prior to movement of the cyclic and collective controls. Since the pilot recognition cues in the yaw axis are so readily discernible during actual engine failure conditions, no time delay was employed prior to movement of the directional controls. Immediately following the 2-second delay, the collective stick was rapidly lowered to a minimum position. To quickly achieve an effective flare airspeed, the maximum usable pitch rate was employed to reach a maximum acceptable nose-down pitch attitude. Additional discussion of test techniques and data reduction procedures is presented in appendix IV. A summary of test conditions is presented in table 1.

Table 1. Test Conditions of the OH-58A, S/N 68-16706.

Gross Weight (lb)	Density Altitude (ft)	Center-of-Gravity Location (in.)	Referred Gross Weight (W/ σ) (lb)
2,455	1,300	107.1 (fwd)	2,550
2,905	1,360	106.6 (fwd)	3,020
2,450	6,100	107.0 (fwd)	2,940
2,800	4,800	107.0 (fwd)	3,230
2,455	10,760	107.0 (fwd)	3,405

11. The test OH-58A helicopter (S/N 68-16706) was equipped with sensitive, calibrated instrumentation. A detailed list of the test instrumentation is presented in appendix VI. Qualitative pilot comments were used to aid in analysis of data and to assist in the overall assessment of the H-V characteristics of the OH-58A.

CHRONOLOGY

12. The chronology of the OH-58A H-V test program is as follows:

Test request received	14	November	1969
Letter test plan submitted	8	December	1969
Test aircraft available	17	February	1970
Instrumentation completed	10	March	1970
Test initiated	1	June	1970
Test completed	6	November	1970
Advance copy of report submitted		March	1971

RESULTS AND DISCUSSION

GENERAL

13. Test results indicate that the height-velocity (H-V) curve presented in the operator's manual can be achieved with the OH-58A helicopter. Achievement of such performance, however, requires training and proficiency beyond that normally acquired by the operational Army aviator. This report presents an operational H-V curve which can be safely duplicated by the operational aviator with minimum additional training. This additional training should consist of autorotational entries at airspeeds from zero to 90 knots indicated airspeed (KIAS) at low skid heights, and of airspeeds less than 60 KIAS at high skid heights. Although the H-V tests were conducted only in the clean configuration with all doors installed, the data presented are considered valid for any configuration (including armed) with a corresponding gross weight and cg location.

14. The rotor rpm decay rates of the OH-58A did not meet the requirements of paragraph 3.5.5 of MIL-H-8501A (ref 3, app I). Rotor speed fell below the published minimum value after delaying movement of collective pitch for 2 seconds following throttle chop. Paragraph 3.5.5 stipulates that:

"The helicopter shall be capable of entering into power-off autorotation at all speeds from hover to maximum forward speed. The transition from powered flight to autorotative flight shall be established smoothly, with adequate controllability and with a minimum loss of altitude. It shall be possible to make this transition safely when initiation of the necessary manual collective-pitch control motion has been delayed for at least 2 seconds following loss of power. At no time during this maneuver shall the rotor speed fall below a safe minimum transient autorotative value (as distinct from power-on or steady-state autorotative values)...."

This specification noncompliance could result in a dangerous situation if it were encountered by the operational Army aviator. Since the engine-out audio warning signal presently incorporated is not actuated in less than 2 seconds after engine failure, a low rotor rpm warning system should be installed on the OH-58A.

MAXIMUM PERFORMANCE HEIGHT-VELOCITY PROFILE

15. To generate data for the near maximum performance H-V profiles utilized to check the validity of the H-V curve presented in the operator's manual, movement of the collective and cyclic controls was delayed for 2 seconds following throttle chop. In addition, the following preestablished boundary conditions were observed:

- a. Maximum touchdown vertical velocity of 3 feet per second (ft/sec).
- b. Maximum touchdown horizontal velocity of 15 knots true airspeed (KTAS).
- c. A minimum flare airspeed of 46 KIAS for all entries above the knee of the curve.

A comparison of the test results and the handbook curve is presented in figure 1, appendix V. It should be noted that the 2-second time delay and achievement of horizontal touchdown velocities less than 15 KTAS were not criteria utilized to establish the handbook curve. Despite this difference in criteria, under similar conditions the test curves and handbook curves are essentially the same in the low-altitude high-speed region and the high-altitude low-speed region.

16. Prior to the initiation of the test program, the manufacturer was consulted to determine the probability of encountering difficulty when exceeding the stated rotor speed limits of 330 rpm for steady-state and 304 rpm for transient conditions. According to the chief flight test engineer, damage to the aircraft should not be encountered during engineering flight test, but the limiting factor would be the degradation of the aircraft handling qualities. Minimum rotor limits were exceeded during certain entry conditions; however, handling quality degradation did not result in uncontrolled flight. Severe mast bumping was encountered when longitudinal pitch rates in excess of 16 degrees per second (deg/sec) were generated. Frequent or prolonged mast bumping could result in fatigue failure of the main rotor mast or main rotor components. To avoid this condition, longitudinal pitch rates were limited to a maximum of 16 deg/sec at rotor speeds below 310 rpm. These rates limited the acceleration available to achieve minimum effective flare airspeed. Mast bumping should be anticipated if the rotor rpm is allowed to exceed the minimum operating limits, and rapid pitch rates are attempted.

17. In establishing the H-V profiles presented in figures 2 through 5, appendix V, the boundaries listed in paragraph 15 were observed. Along with these boundary conditions, the maximum rotor rpm achieved, the time of collective application, and the rotor rpm remaining after touchdown were the parameters considered in establishing the curve. To insure maximum safety, incremental build-up points were flown at each entry airspeed tested. A discussion of the build-up procedure is included in appendix IV. Typical time histories utilized to determine the criticality of a point are presented in figure 6, appendix V. As shown in figure 6, the maximum flare pitch rate and attitude were held relatively constant.

18. Low touchdown velocities were easily achieved under all conditions tested. Regardless of gross weight or density altitude, the average vertical touchdown velocity was less than 1 ft/sec. The average horizontal touchdown velocity was approximately 8 knots at entry conditions above the knee of the curve. At entry conditions below the knee, the average horizontal velocity at touchdown was approximately 12 knots.

GROSS WEIGHT EFFECTS

19. The effects of gross weight on the H-V envelope at two pressure altitudes are presented in figures 2 and 3, appendix V. Near sea level (fig. 2), a gross weight increase of 350 pounds required a 96-foot increase in skid height above ground level at the high hover point. As the entry airspeed increased, the heavy gross weight curve approached that of the light gross weight until, at the knee, both skid heights were equal. However, the entry airspeed at the heavy gross weight was 5 knots greater than the light gross weight airspeed. Below the knee, both curves converged to equal skid heights at the low hover point. The gross weight effect at a higher altitude (fig. 3) was much less than at sea level. An increase in skid height of 26 feet was required at the high hover point for a 455-pound increase in gross weight. The curves remained parallel with increasing entry airspeed until the knee, where a 5-knot increase was required for the heavy gross weight. From the knee, both curves converged to equal skid heights at the low hover point.

20. The increases in gross weight did not appreciably affect touchdown rate of descent and ground run distance. However, the increase in gross weight did require greater pilot skill in the landing portion of the maneuver. This is illustrated in the time histories of collective position and rotor speed at light and heavy gross weights presented in figure 7, appendix V. At the heavy gross weight, frequent collective control adjustments were required to prevent overspeeding of the main rotor during the flare. Thus, the timing of the collective application was more critical than at the light gross weight in order to prevent the main rotor from overspeeding while retaining enough rotor energy to ensure a safe landing.

DENSITY ALTITUDE EFFECTS

21. Envelopes depicting density altitude effects on the H-V envelopes are presented in figures 4 and 5, appendix V. At the light gross weight (fig. 4) skid height at the high hover point increased with increasing density altitude. However, the increases in skid height were not directly proportional to the increases in density altitude. Entry airspeed at the knee also increased with increasing density altitude, and the airspeed increments were roughly proportional to density altitude increments. The curves converged to the same skid height at the low hover point. For the heavy gross weight (fig. 5), the density altitude effect was minimal. The curves varied with density altitude in the same manner as did the light gross weight curves, but to a lesser degree.

22. Touchdown characteristics were unaffected by density altitude increases. However, the increases in density altitude affected the amount of pilot skill required, just as increased gross weight did. Figure 8, appendix V, shows typical time histories of the effects of density altitude on collective control and rotor speed. Again, an earlier application and increasing variation in collective was needed to control rotor speed as density altitude increased, implying greater skill required of the pilot. Figure 9 shows the effect of density altitude on rate of descent encountered for high-hover entry conditions. An increase in density altitude increases rate of

descent. Consequently, the skid height and rate of descent at which collective was applied increased with density altitude. However, the pilot was able to manipulate the collective pitch to reduce the rate of descent during landing to the same touchdown descent speed regardless of density altitude.

REFERRED GROSS-WEIGHT/DENSITY RATIO

23. Height-velocity profiles for five discrete gross weight and altitude combinations were evaluated with gross weight corrected for altitude to determine if the resulting trends could be used to generalize H-V performance. The data are presented in figure 10, appendix V, in terms of skid height above the ground versus advance ratio (true airspeed/main rotor tip speed) for each of five referred gross weights (W/σ). The curves presented generally show an increasing envelope area with an increase in W/σ . At the high hover point, skid height is seen to vary with W/σ . The advance ratio at the knee also increases with an increase in W/σ , as does the skid height at the knee. The increments in advance ratio are approximately proportional to increments in W/σ , and the skid height appears to increase directly with the advance ratio. Further testing and analysis should be performed to determine the usefulness of this type of presentation in interpolating and extrapolating H-V data beyond tested regions.

OPERATIONAL HEIGHT-VELOCITY PROFILE

24. The operational H-V curve resulting from this test program is presented in figure 11, appendix V. This upper curve should be incorporated into the operator's manual at the earliest possible date to replace the published H-V curve which does not incorporate an adequate safety margin for operational use. It should be noted, however, that these test results do not include performance margins to compensate for maneuvering effects during the descent or landing (ref 6, app I). Test results indicate that the low-altitude high-air-speed portion of the H-V curve does not warrant a change from the presently published values. However, the operational aviator requires additional training to accomplish newly specified performance. This training should consist of autorotative entries at airspeeds from zero to 90 KIAS at low skid heights, and airspeeds below 60 KIAS at high skid heights. The technique demonstrated by the SIP's was utilized to collect data for construction of the operational H-V curve. The SIP's technique was modified only by employment of a 2-second time delay prior to movement of the cyclic and collective controls.

25. A comparison of the operational H-V curve recommended for incorporation in the operator's manual and the maximum performance H-V curve is presented in figure A and also in figure 12, appendix V. As illustrated, the additional altitude required to accomplish the operational curve can be attributed to achieving a higher flare airspeed of 60 KIAS and using slow pitch rates and low pitch attitudes during the flare. Moderate flare pitch rates and attitudes were utilized for the maximum performance curve with a flare airspeed of 46 KIAS. Operational aviators can realize

a significant improvement in the performance achieved with the OH-58A by altering the current technique. This technique alteration should consist of acceptance of a lower flare airspeed with utilization of faster pitch rates and increased attitudes during the flare. To illustrate the conservatism of the operational curve, the techniques used in acquiring data for the maximum performance curve should be demonstrated at the US Army Aviation School, Fort Rucker, Alabama, by engineering flight test personnel.

OPERATIONAL VS MAXIMUM PERFORMANCE COMPARISON
OH-58A S/N 68-16706

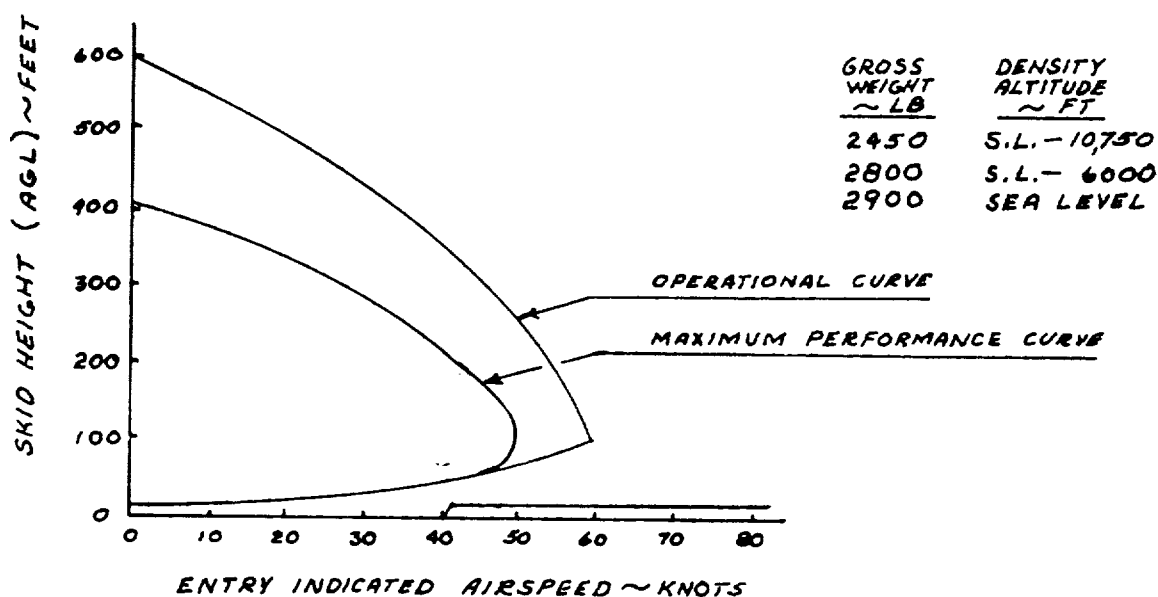


Figure A. Height-Velocity Profile.

26. Figure 13, appendix V, presents a comparison of the H-V curve presently incorporated in the operator's manual and the operational curve resulting from this test program. As shown in figure 13, a large difference exists between the two curves. It also shows that the current H-V profile does not provide sufficiently for the aviator's safety. The operational aviator cannot be expected to overcome this disparity without additional training.

CONCLUSIONS

27. The H-V curve presented in the operator's manual is technically valid for the OH-58A helicopter. However, the training and proficiency required to accomplish such performance are beyond that normally acquired by the operational aviator (paras 13, 25 and 26).

28. The OH-58A rotor rpm decay characteristics do not comply with paragraph 3.5.5 of MIL-H-8501A (paras 14 and 16).

29. The operational curve recommended as a result of this test program can be duplicated by the operational aviator with some additional training (para 24).

RECOMMENDATIONS

30. As a result of this evaluation, the recommendations are:

- a. That the operational H-V curve presented in this report be incorporated in the operator's manual at the earliest possible time (para 24).
- b. That a low rotor rpm audio warning signal be incorporated into the OH-58A helicopter (para 14).
- c. That H-V flight test techniques be demonstrated at the US Army Aviation School, Fort Rucker, Alabama, by trained flight test personnel (para 25).
- d. That the current autorotational instructional techniques be changed to obtain improved performance with the OH-58A (para 25).

APPENDIX I. REFERENCES

1. Letter, USAAVSCOM, 23 October 1969, subject: Request for Test, OH-58A Height Velocity.
2. Technical Manual, TM 55-1520-228-10, *Army Model OH-58A Helicopter*, July 1969.
3. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities, General Requirements For*, 5 November 1952.
4. Test Plan, USAASTA, Project No. 69-16, *OH-58A Height-Velocity*, August 1970.
5. Paper, *The Development of an Improved Method of Conducting Height-Velocity Testing on Rotary Wing Aircraft*, Journal of American Helicopter Society, Vol. 15, No. 2, April 1970.
6. Final Report, US Army Aviation Test Activity, USAAVNTA Project No. 68-04, *Special Study of Autorotational Procedures*, February 1968.

APPENDIX II.

GENERAL AIRCRAFT INFORMATION

DIMENSIONS AND DESIGN DATA

Overall Dimensions

Aircraft length (rotor turning)	40 ft, 11.8 in.
Aircraft length (nose to tail skag)	32 ft, 2.0 in.
Width (rotor turning)	35 ft, 4 in.
Width (rotor static)	6 ft, 5.4 in.
Height (over main rotor blades at rest)	9 ft, 7.0 in.
Height (top of vertical stabilizer)	8 ft, 1.5 in.

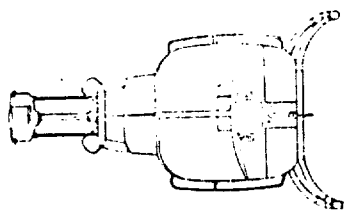
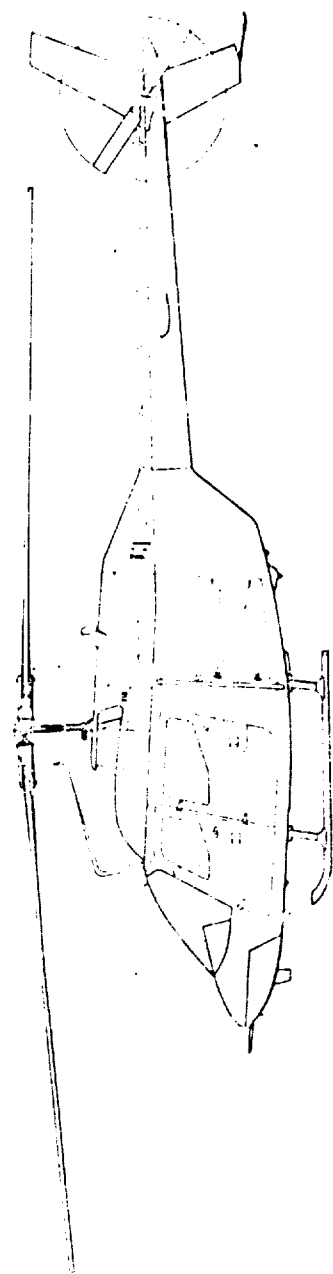
Main Rotor

Number of blades	2
Diameter	35 ft, 4 in.
Blade chord (constant)	1.08 ft
Solidity	0.0390
Blade twist angle	-10.6 deg linear
Hub precone angle	3.0 deg
Airfoil section thickness	11.3 percent
Airfoil type	Modified "droop-snot" airfoil

Tail Rotor

Number of blades	2
Diameter	5 ft, 2 in.
Blade chord	0.4375 ft
Blade twist angle	Zero deg

Hub precone angle	Zero deg
Airfoil section designation and thickness (constant)	NACA 0012.5
<u>Control Travel</u>	
Cyclic stick (measured at center of grip):	
Longitudinal	6.0 in. forward 6.0 in. aft
Lateral	5.15 in. right 5.15 in. left
Collective stick (measured at center of grip)	10.15 in.
Antitorque pedals (from neutral)	3.43 in. forward 3.43 in. aft
<u>Gear Ratio</u>	
Engine to main rotor	17.44:1
Engine to tail rotor	2.353:1
<u>Operating Limitations</u>	
Power turbine speed (N ₂)	101 to 103 percent
Turbine outlet temperature (TOT)	693°C (cont), 749°C (5 min)
Rotor rpm (power on)	347 to 354
Rotor rpm (power off)	330 to 390
Maximum airspeed (V _{max}), SL	120 KIAS
Torque	79 psi (cont), 92 psi (max)



OH-58A Three-View Drawing.

Power Plant

1. Aircraft power is provided by an Allison T63-A-700 free gas turbine engine which has a nominal rating of 270 shp at 100-percent N₂. As installed in the OH-58A, the engine is limited by either the output shaft torque or the gas producer TOT. For maximum continuous operation, these limits are 249 ft-lb torque (270 shp) at 6000 rpm or 693°C TOT, whichever is reached first. The takeoff power (maximum of 5 minutes continuous operation) limits are 293 ft-lb torque (317 shp) or 749°C. The engine consists of a multistage axial-centrifugal flow compressor, a single combustion chamber, a two-stage gas producer turbine, and a two-stage power turbine which supplies the output power of the engine.

Fuel System

2. The helicopter fuel system incorporates a single-bladder type, self-sealing fuel cell with a total usable capacity of 73 United States gallons. The cell is located below and aft of the passenger seat. Mounted in the bottom of the cell is one boost pump, one fuel quantity transmitter, one low-fuel transmitter and one fuel sump drain and defuel valve. Installed in the top of the cell is one fuel quantity transmitter, a vent line, a boost pump pressure switch and a governor return line. A fuel filler cap is located on the right side just aft of the passenger door. The fuel shut-off valve is mounted on the right side of the aircraft above the fuel cell cavity and is manually operated.

Electrical System

3. The OH-58A electrical systems consist of a 28-volt direct current (DC) dual bus system and a 115-volt, 400 Hertz alternating current (AC) system.

4. The DC system is normally powered by a vented 24-volt, 13-ampere-hour, nickel-cadmium battery and a starter-generator. The starter-generator is used to start the aircraft engine, recharge the battery and provide primary 28-volt DC power for the aircraft electrical system. During ground operations, external DC power may be connected to the aircraft through a polarized, external power receptacle located on the right side of the fuselage below the baggage compartment.

5. The AC system is powered by a 65-volt, 65-ampere, solid-state inverter. The inverter delivers 115 volts AC and 400 Hertz to the AC bus. The AC power is used to energize the attitude gyro and gyro compass.

APPENDIX III. PHOTOGRAPHS

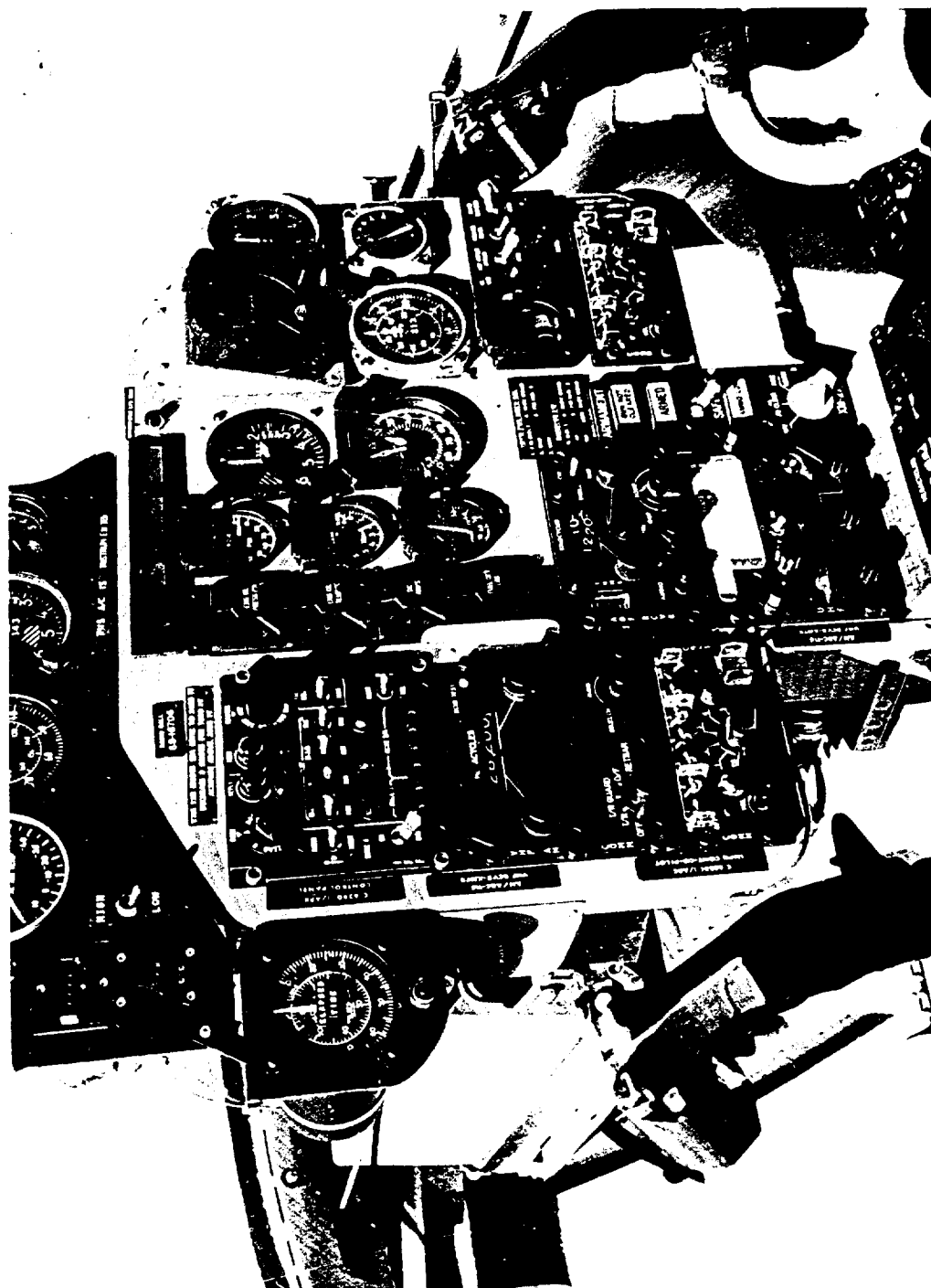


Photo 1. Cockpit Instrument Panel.

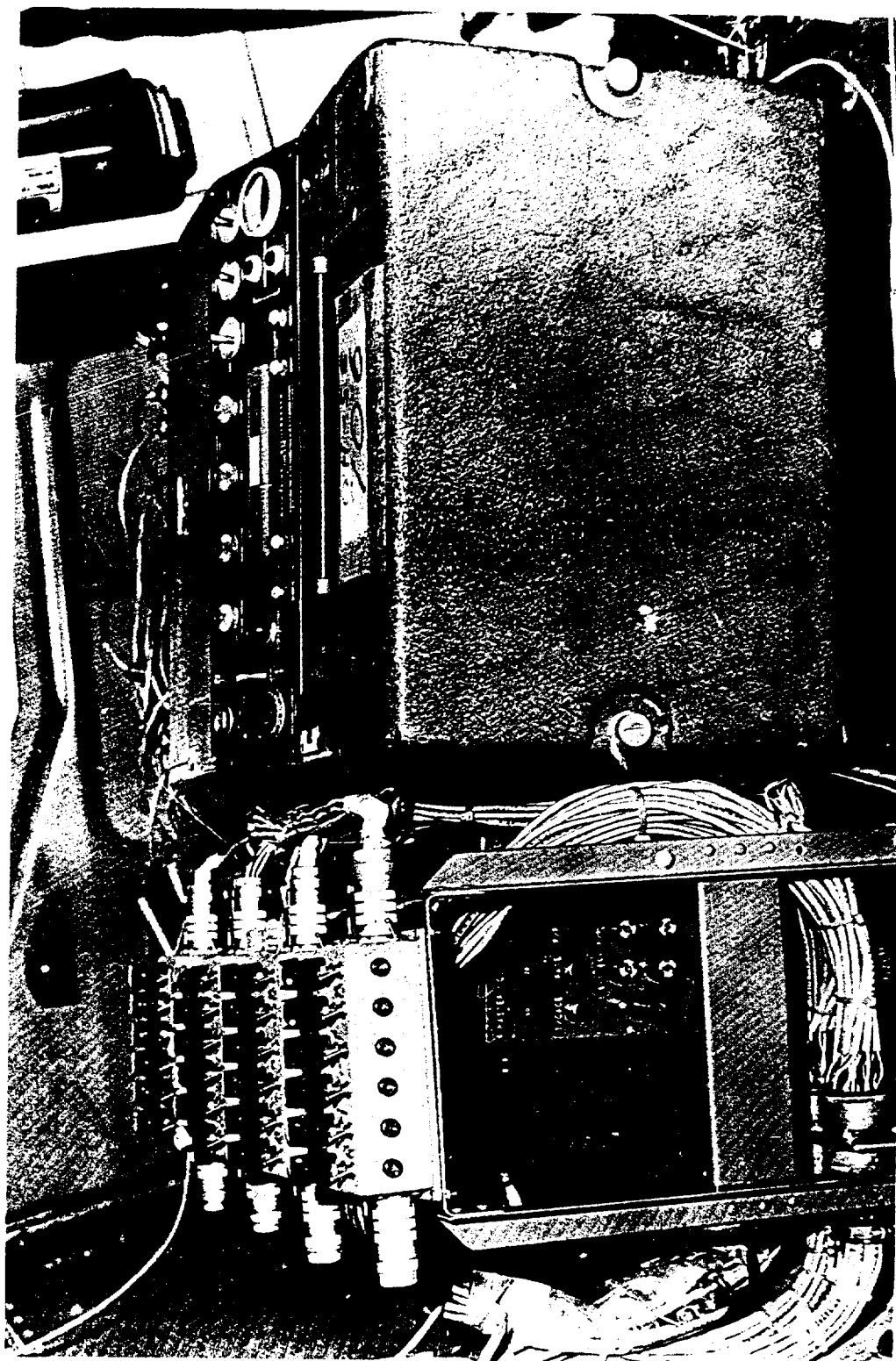


Photo 2. Oscillograph.



Photo 3. Touchdown Wand.

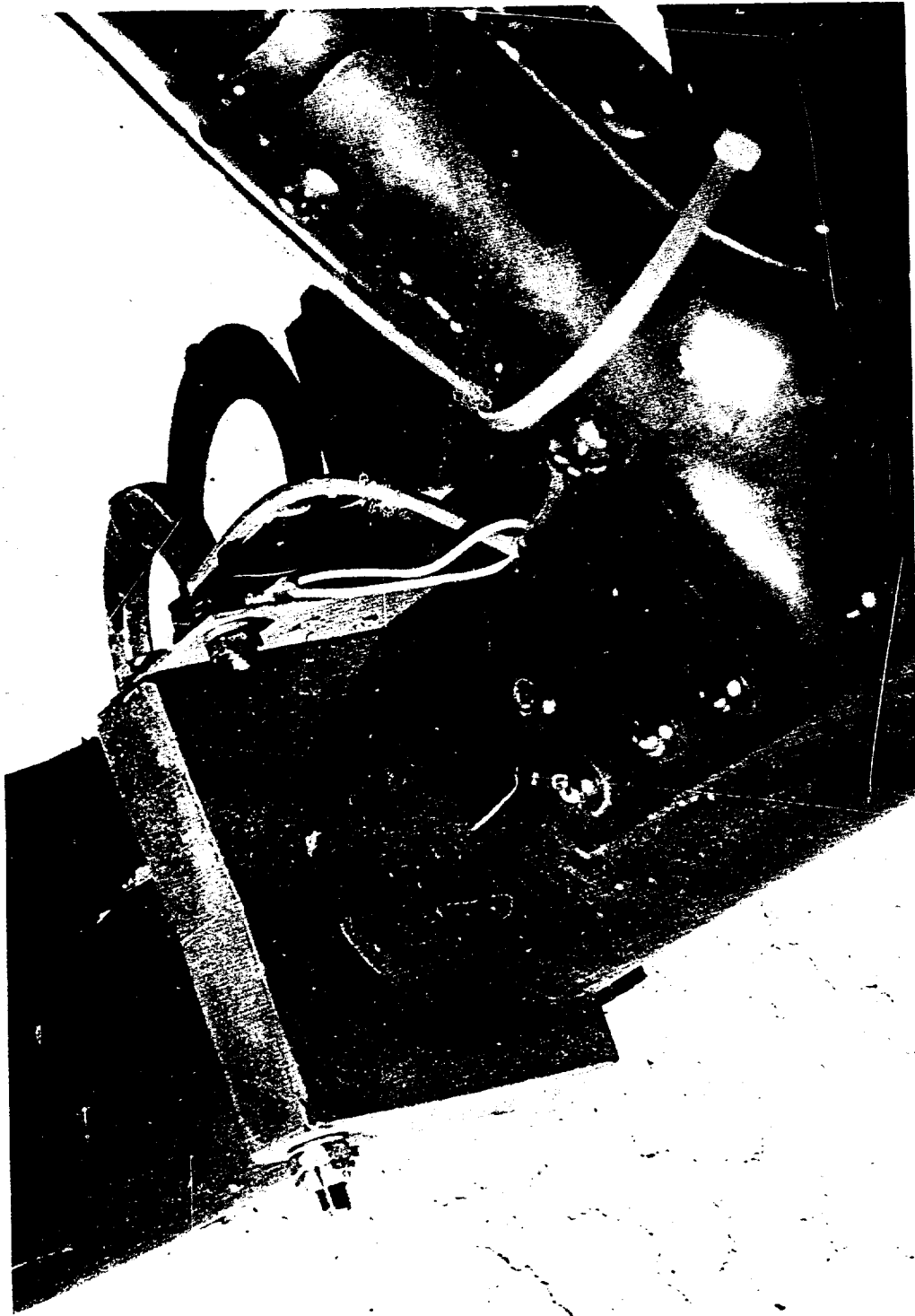


Photo 4. Skid Touchdown Switch.

APPENDIX IV. TEST TECHNIQUES AND DATA REDUCTION PROCEDURES

TEST TECHNIQUE

General

1. Safety of flight was the primary consideration during the height-velocity profile testing. A build-up method was used to obtain the final values for the H-V curve. Normally, 27 test points were flown at each test condition, with nine being used to define the H-V profile. The initial points were based on computer predictions, experience gained from previous data, and test team judgement. The second build-up points and the final curve points were based primarily on pilot judgement after the previous maneuver had been discussed with the ground observer. For constant entry airspeeds of zero, 20, 30 and 40 KIAS, entry heights were decreased in 10- to 25-foot increments, starting at the high hover point and working down to the knee. Skid heights were increased in 5- to 10-foot increments starting from the low hover point and working up to the knee. At the knee (100 feet), this technique was altered to maintain the entry height constant and decreasing airspeed in 2- to 4-knot increments until the critical curve point was obtained.
2. Additional procedures which contributed to the overall safety of the test operations included the following:
 - a. A second test pilot (with H-V testing experience) was utilized as a technical observer and stationed on the ground with the control group. Immediately following each autorotation, qualitative comments on the entire maneuver were interchanged between the pilot flying and the pilot acting as the observer.
 - b. Each maneuver was recorded on video tape. This enabled the test pilot to review his techniques immediately following the completion of the test flight.
 - c. A phototheodolite recorder was used to supplement the Fairchild flight analyzer. The recorder facilitated greater data reduction accuracy of the maneuver at skid heights below 50 feet. This also permitted an accurate time correlation between the Fairchild flight analyzer and the oscillograph.
3. Prior to initiation of data acquisition for H-V profile determination, the minimum airspeed for flare effectiveness was determined to be 46 KIAS. At altitudes above ground level, sufficient to effect safe power recovery, a series of autorotational entries and descents was executed. From various stabilized level-flight airspeeds, the throttle was rapidly retarded to the flight-idle position. The cyclic and collective controls were held fixed for 2 seconds or until a minimum safe transient rotor rpm was reached. The average rotor decay rate was approximately 22 rpm per second. As collective pitch control was rapidly lowered, the helicopter was simultaneously pitched nose down at various rates to obtain preselected descent airspeeds in the minimum amount of time. Flares were executed from various

airspeeds, utilizing a constant pitch rate, to obtain desired aircraft pitch attitudes. The minimum airspeed that produced the desired maximum rotor rpm was then established as the minimum effective flare airspeed and was subsequently utilized throughout the test program.

TECHNIQUE CONSISTENCY

4. Throughout the test program, an attempt was made to use a constant pilot technique while defining a particular point on the envelope regardless of entry height, gross weight, and density altitude. The parameters used for the consistency check were pitch attitudes and rates in pushover and flare, delay times from throttle chop to reduction of collective, rates of sink at touchdown, and ground speed at touchdown. Deviations shown in table A were based on the ability of the pilot to judge or sense changes in these parameters.

Table A. Significance Levels.

Parameter	Significance Level (from mean value)
Pitch attitudes	±5 degrees
Pitch rates	±3 deg/sec
Rotor speeds	±5 rpm
Delay times	±0.3 second

OPERATIONAL HEIGHT-VELOCITY PROFILE

5. To determine and quantify the autorotational techniques currently being utilized to train Army pilots in the OH-58A helicopter, two pilots from the US Army Aviation School, Fort Rucker, Alabama, were used: one from the Flight Standardization Department and one from among the working instructor pilots. The first phase of this portion of the test program was for these pilots to demonstrate their normal autorotational techniques which were recorded on the Fairchild flight analyzer, video tape, and oscillograph.

6. The second phase of the standardization instructor pilot (SIP) program was designed to deviate from the normal entry conditions of 80 knots and 500 feet. The pilots were placed in an unfamiliar flight regime to determine how they would react to the different conditions. Three entry airspeeds (40, 20 and zero knots) were flown at light (2500 lb) and heavy (2900 lb) gross weights. The results were recorded on the Fairchild flight analyzer, video tape, and oscillograph. The data were reduced and mean values determined for pushover and flare pitch attitudes, pitch rates, rotor speed, rpm build rate at collective pull, and rotor speed at touchdown.

7. From the SIP program, it was determined that Army aviators are being instructed to aim for an airspeed-altitude combination, or "slot" position, of 60 knots at 100 feet above the ground for any combinations of entry airspeed and heights greater than 100 feet while flying the OH-58A helicopter. The mean pushover pitch rates and attitudes utilized, and rotor rpm achieved at the slot position were determined for later use in developing an acceptable H-V profile for operational pilots.

8. It is worthwhile to note that the maximum pushover rates and attitudes achieved during the SIP program closely approached those of the USAASTA test phase. However, there were substantial differences in slot position and flare and touchdown technique.

9. The technique used to determine an operational H-V profile simulated the pushover pitch attitudes and rates used by the SIP's. At a desired entry airspeed, the pitch rates and attitudes utilized in reaching an indicated airspeed of 60 knots with an acceptable level of rpm were recorded. These oscillograph traces were checked against those used by the SIP's. The maximum pitch rates and attitudes utilized are presented in figure I. As shown in this figure, the maximum pitch rates and attitudes were a function of entry airspeed and decreased with increasing airspeed. The height lost in reaching 60 knots was recorded on the Fairchild flight analyzer. The point on the H-V profile was derived by adding 100 feet to the height lost in reaching 60 knots, thus simulating the SIP slot position. Additional conservatism was built into the operational H-V profile by using a 2-second delay time from throttle chop to collective reduction.

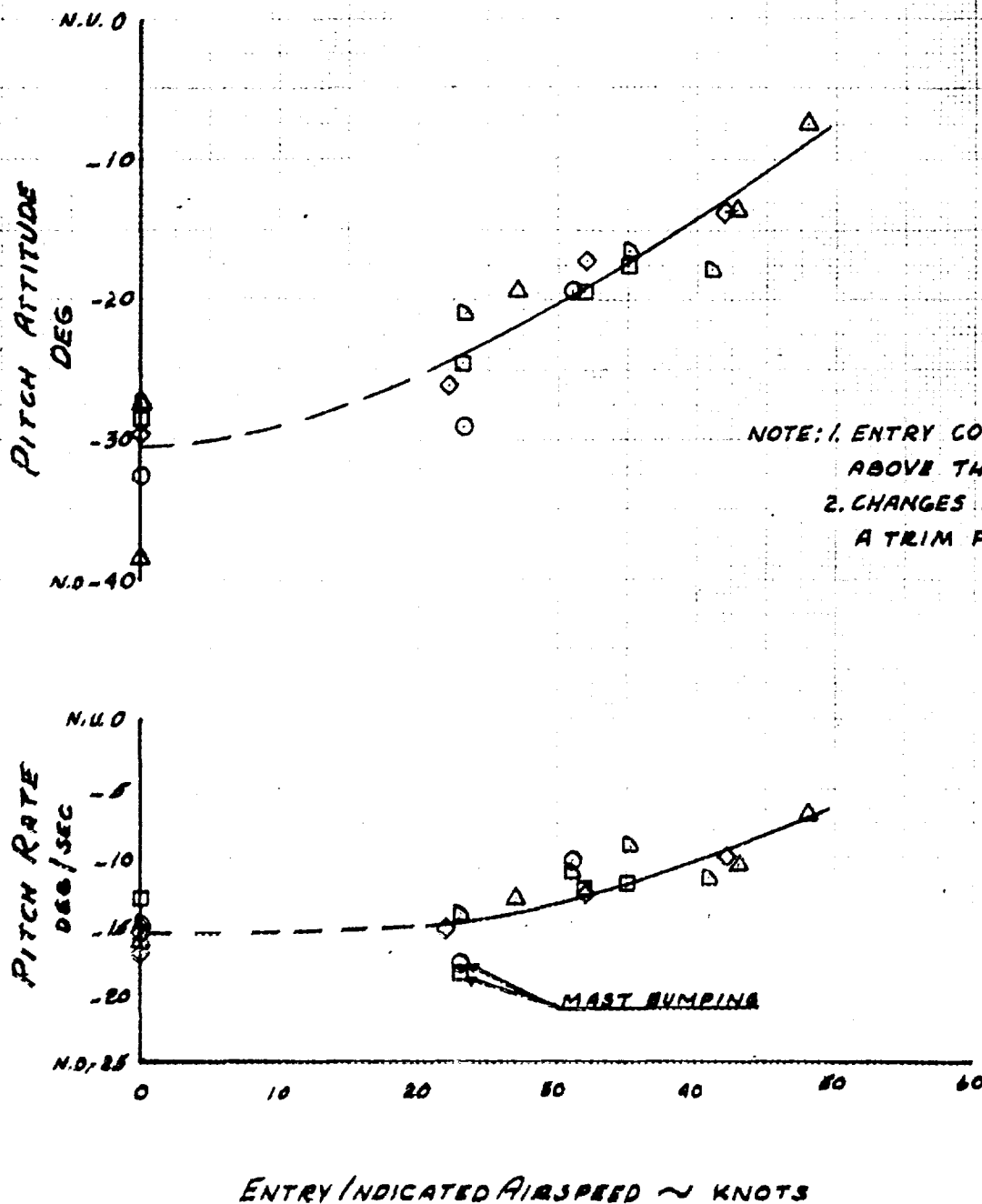
10. Representative curves showing the effects of varying entry nose-down pitch rates and pitch attitudes on H-V profiles are presented in figure II. The dashed curves (1 and 2) represent lesser pitch rates and pitch attitudes. These lesser pitch rates and attitudes result in a significant increase in the amount of altitude loss during acceleration to minimum effective flare airspeed. The effect of lesser pitch rates and attitudes on a typical H-V envelope is shown in figure III.

DATA REDUCTION METHOD

11. The method used for data reduction was identical for all test points. Initially, time histories from the oscillograph record were drawn for selected parameters: pitch attitude, pitch rate, rotor speed, and collective stick position. The time histories showed at which times the magnitudes of specific discrete parameters should be read and evaluated. These magnitudes were used for checking technique consistency and for trend analysis. The entry heights were read from the Fairchild plates while indicated entry airspeed was recorded by the flight engineer in the cockpit. Touchdown rates of sink and ground roll were taken from the phototheodolite records.

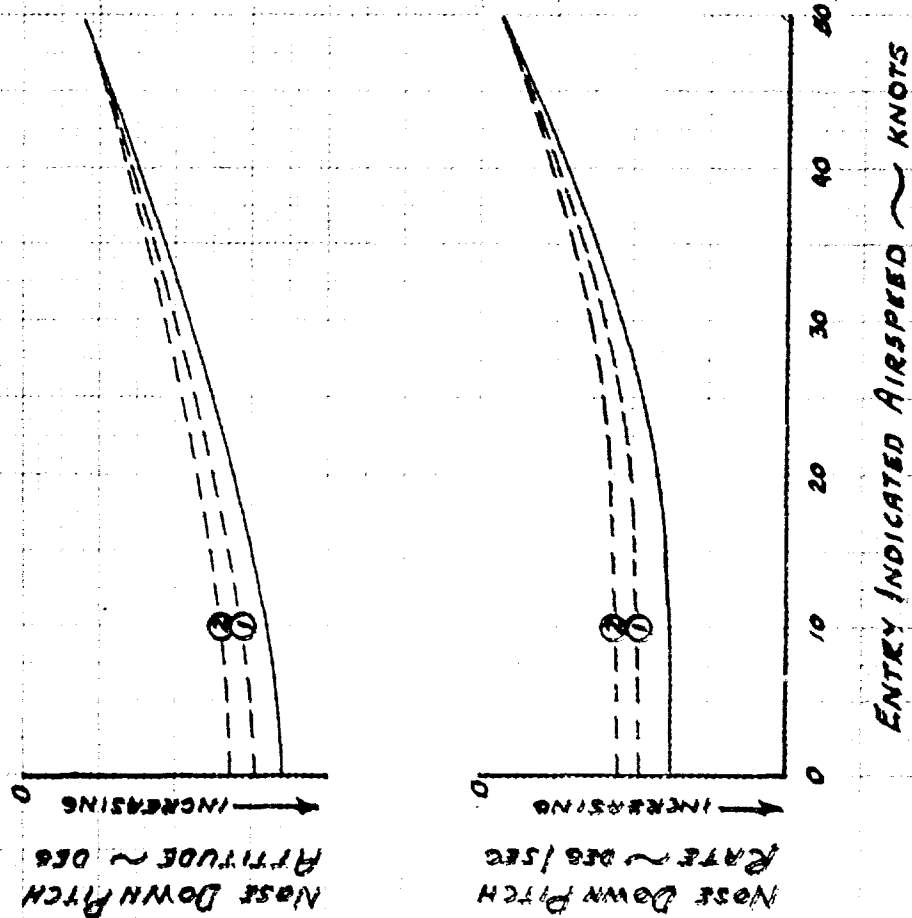
FIGURE I
MAXIMUM PITCH ATTITUDE AND PITCH RATE VS
INDICATED AIRSPEED DURING PUSHOVER
OH-58A S/N 68-16706

SYMBOL	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FT	CENTER OF GRAVITY ~ IN	Gr Wt G ~ LB
○	2455	1300	107.1	2550
◻	2905	1360	106.6	3020
◻	2450	6100	107.0	2940
◊	2800	4800	107.0	3230
△	2955	10,760	107.0	3400



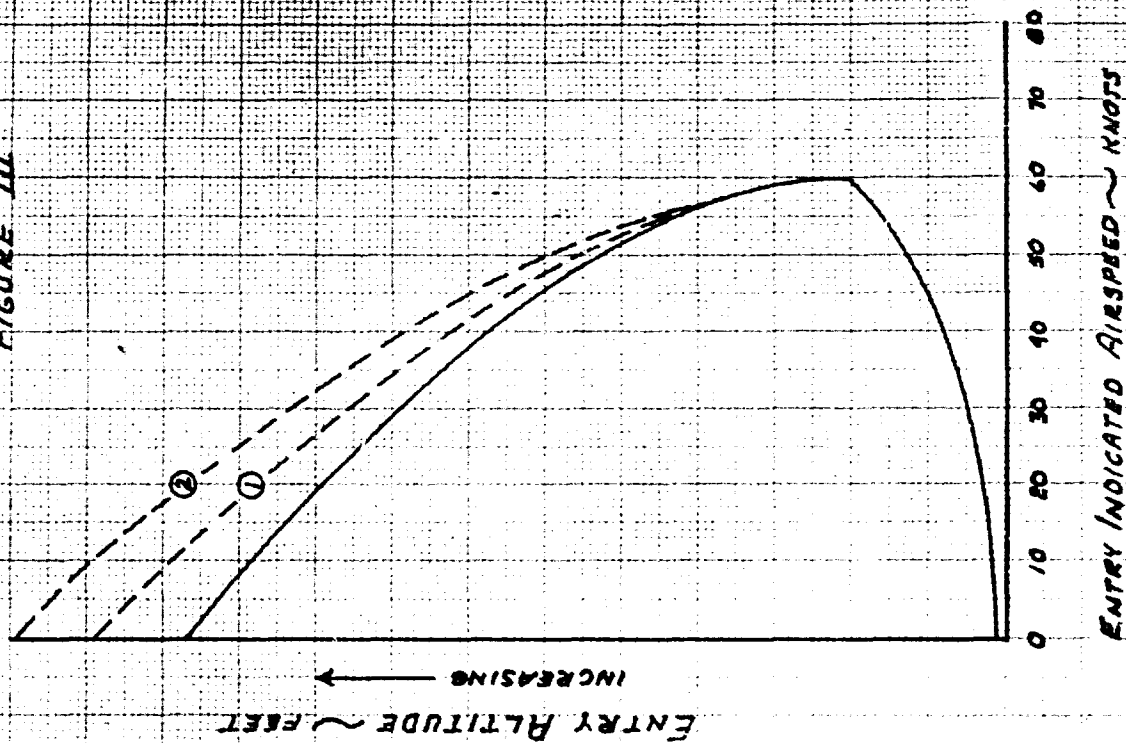
PUSHOVER PITCH RATES AND ATTITUDES VS ENTRY AIRSPEED

FIGURE II



TYPICAL HEIGHT VELOCITY ENVELOPE

FIGURE III



APPENDIX V. TEST DATA

FIGURE 1
HEIGHT VELOCITY PROFILE
HANDBOOK — USAASTA COMPARISON
OH-58A S/N 68-16706

NOTE: 1. HANDBOOK CURVES UTILIZE NO
DELAY TIME FROM THROTTLE
CHOP TO COLLECTIVE REDUCTION.
2. USAASTA PROFILES UTILIZED
2 SECOND DELAY TIME FROM
THROTTLE CHOP TO COLLECTIVE
REDUCTION.

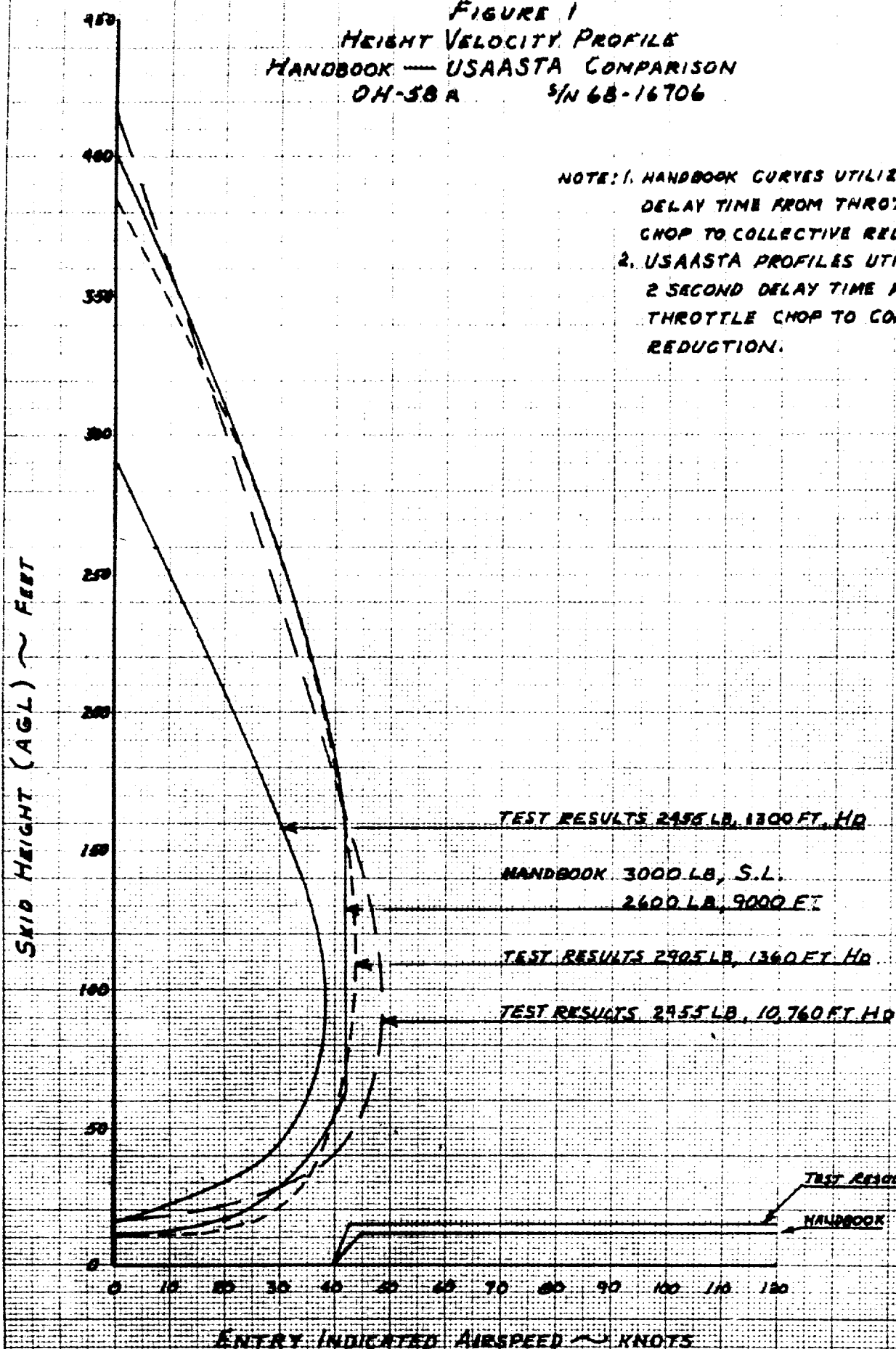


FIGURE 2
 HEIGHT VELOCITY PROFILE
 MAXIMUM PERFORMANCE
 GROSS WEIGHT EFFECT
 OH-58A 3/N68-16706

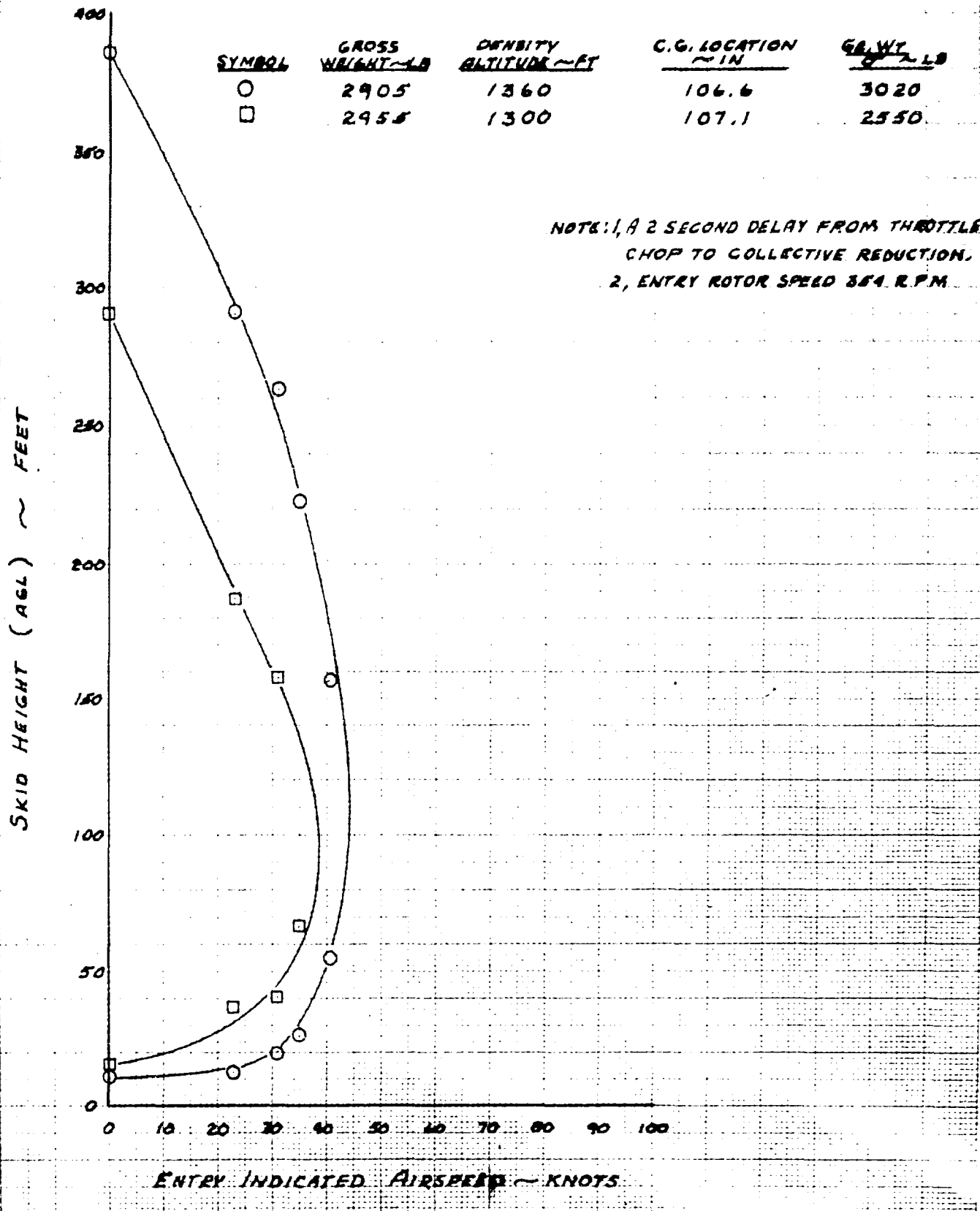


FIGURE 3
HEIGHT VELOCITY PROFILE
MAXIMUM PERFORMANCE
GROSS WEIGHT EFFECT
OH-58A S/N LB-16706

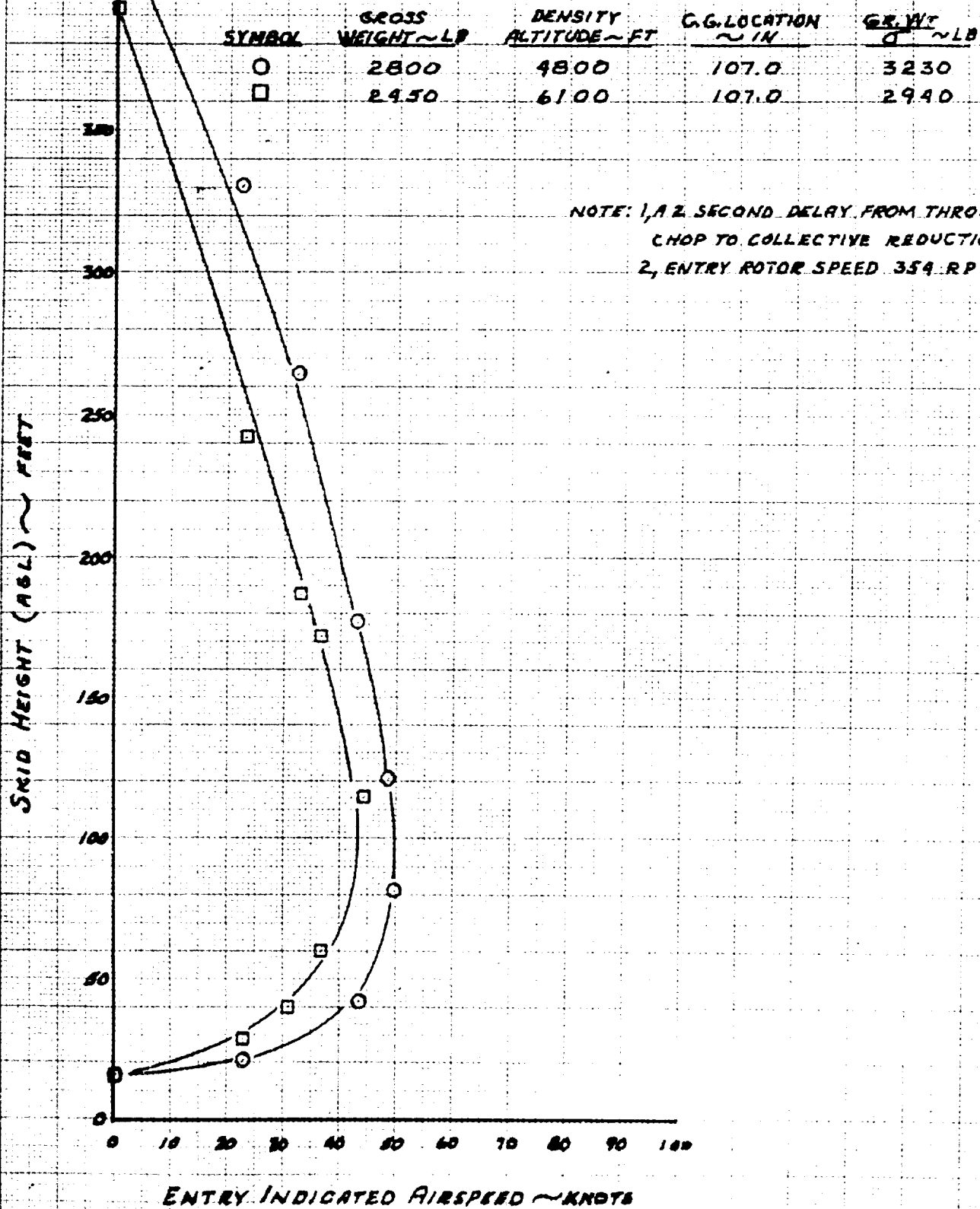


FIGURE 4
HEIGHT VELOCITY PROFILE
MAXIMUM PERFORMANCE
DENSITY ALTITUDE EFFECT
ON-58A 3/168-16706

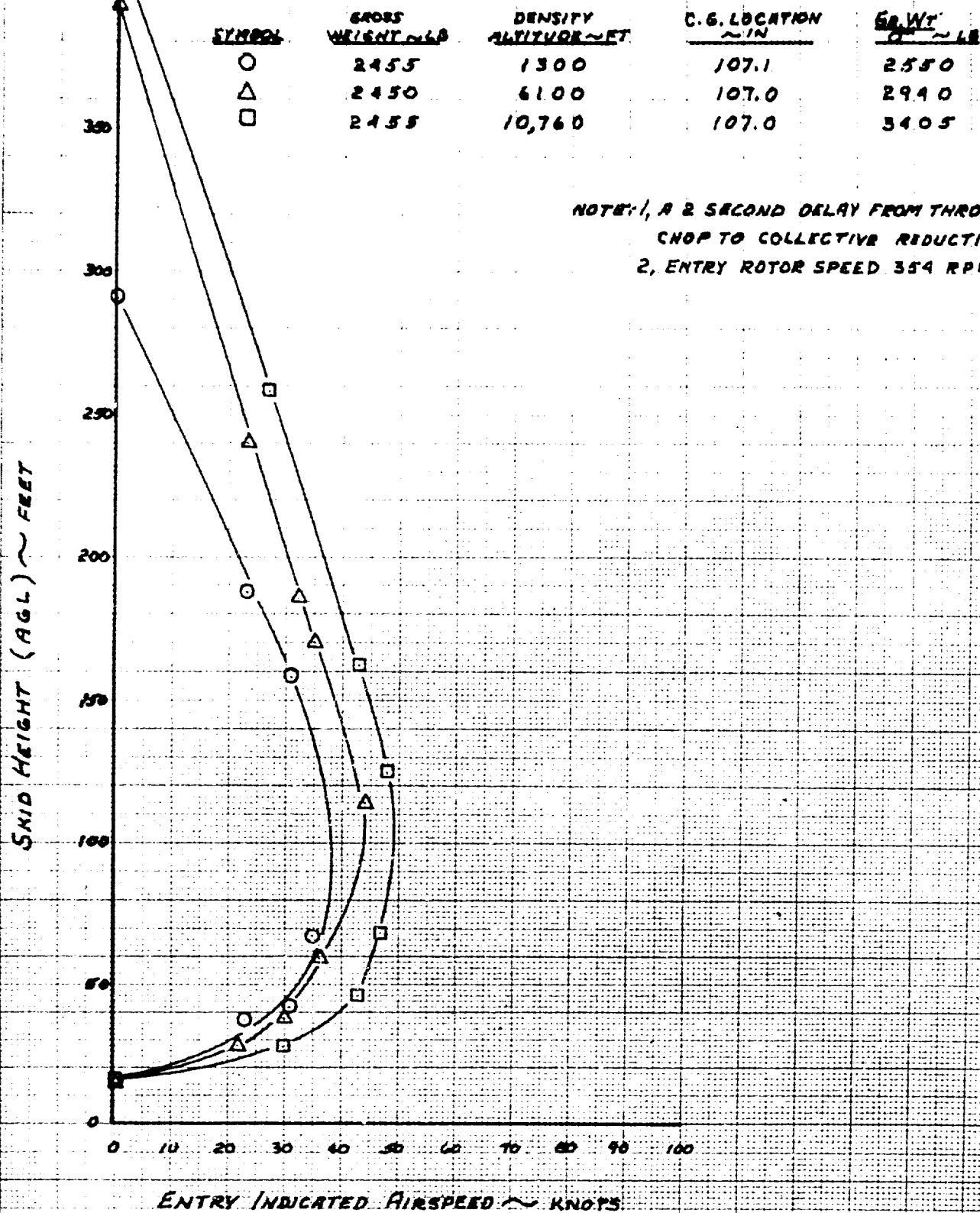


FIGURE 5
HEIGHT VELOCITY PROFILE
MAXIMUM PERFORMANCE
DENSITY ALTITUDE EFFECT
OH-58A 5N68-16706

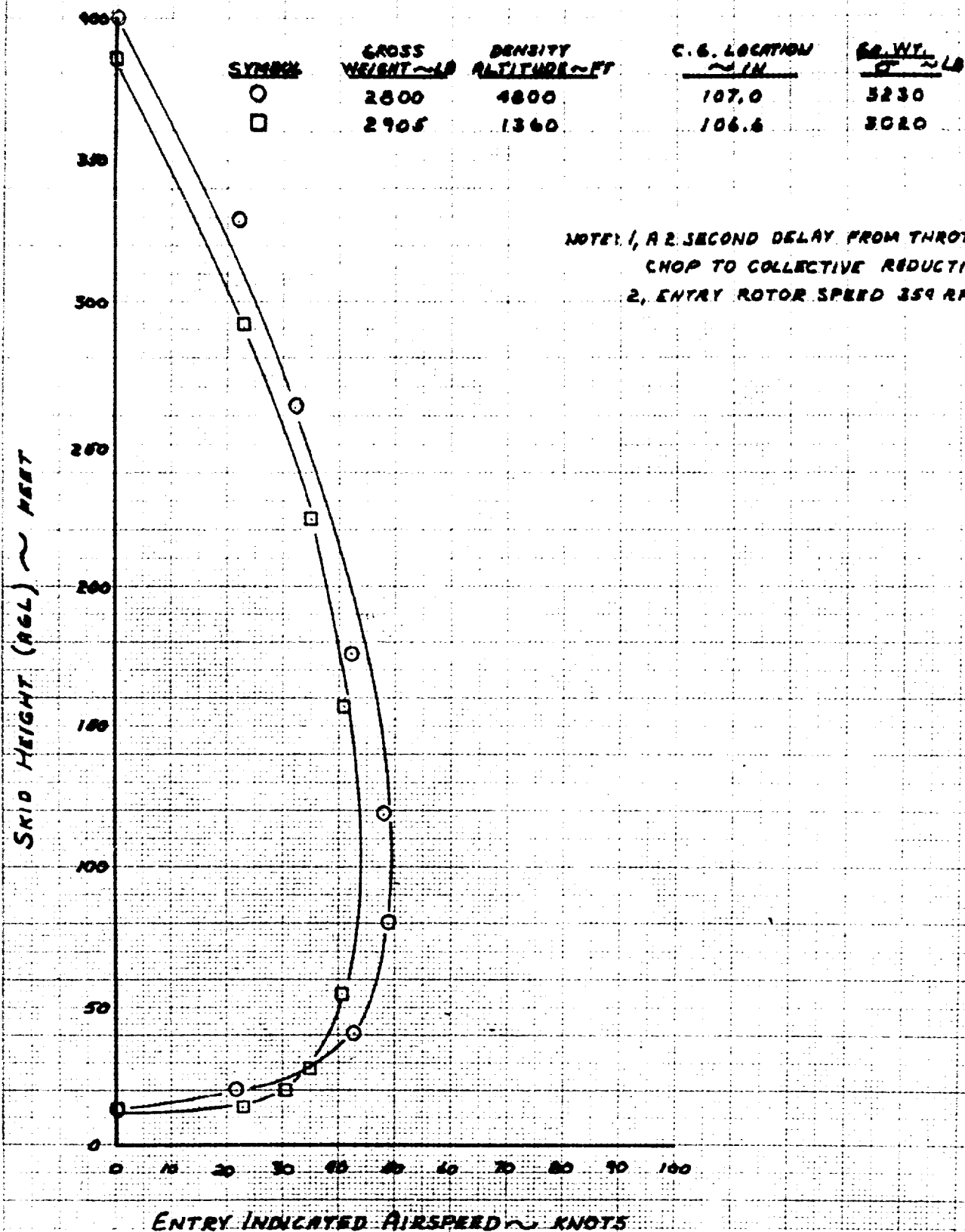
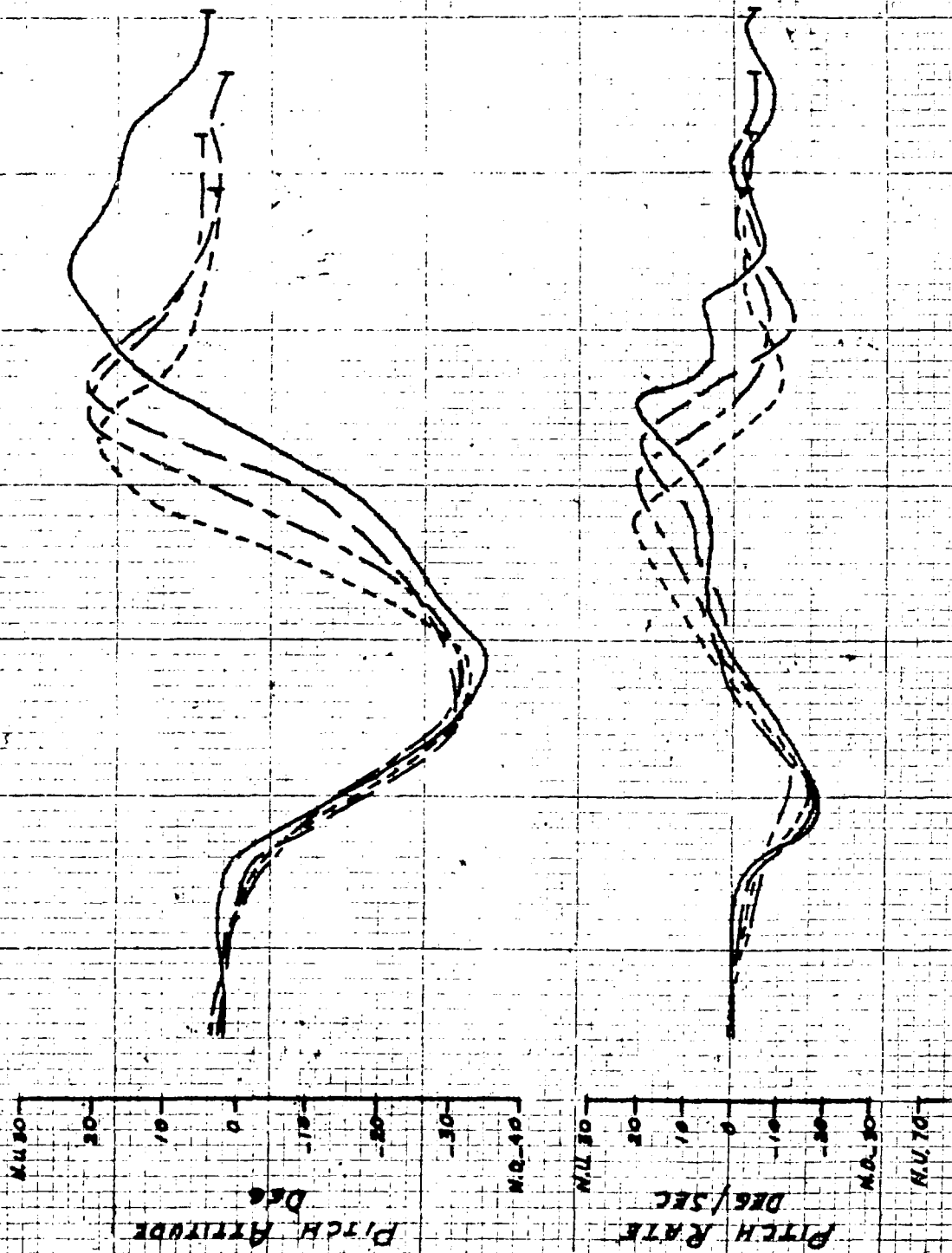


FIGURE 6
 HEIGHT VELOCITY TIME HISTORY
 OH-50A 5W60-16706

SYMBOL	ENTRY AIRSPEED ~ KNOTS	ENTRY ALTITUDE ~ FEET	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FEET	C.G. LOCATION ~ INCHES	GRWT ~ LB
—	0	400	2450	1800	107.15	2500
—	0	385	2450	1800	107.1	2500
—	0	305	2450	1800	107.3	2500
—	0	240	2450	1800	107.37	2500



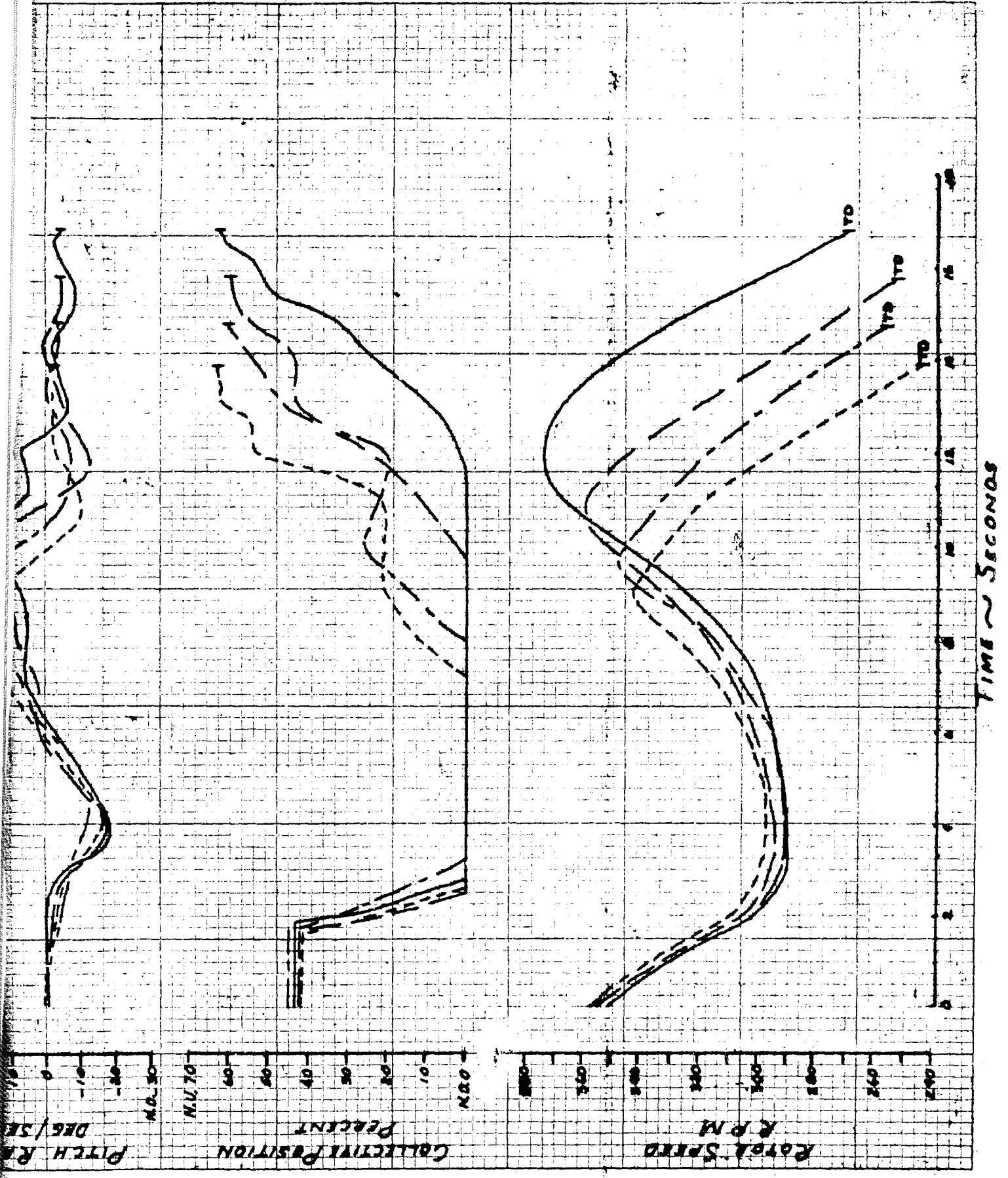


FIGURE 7
GROSS WEIGHT EFFECT ON ROTOR SPEED
OH-58A **S/N 68-16706**

SYMBOL	ENTRY AIRSPEED ~ KTS	ENTRY ALTITUDE (AB) ~ FT	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FT	CENTER OF GRAVITY ~ IN	GROSS WEIGHT ~ LB
—	0	400	2465	1500	107.1	2550
---	0	400	2905	1360	106.6	3020

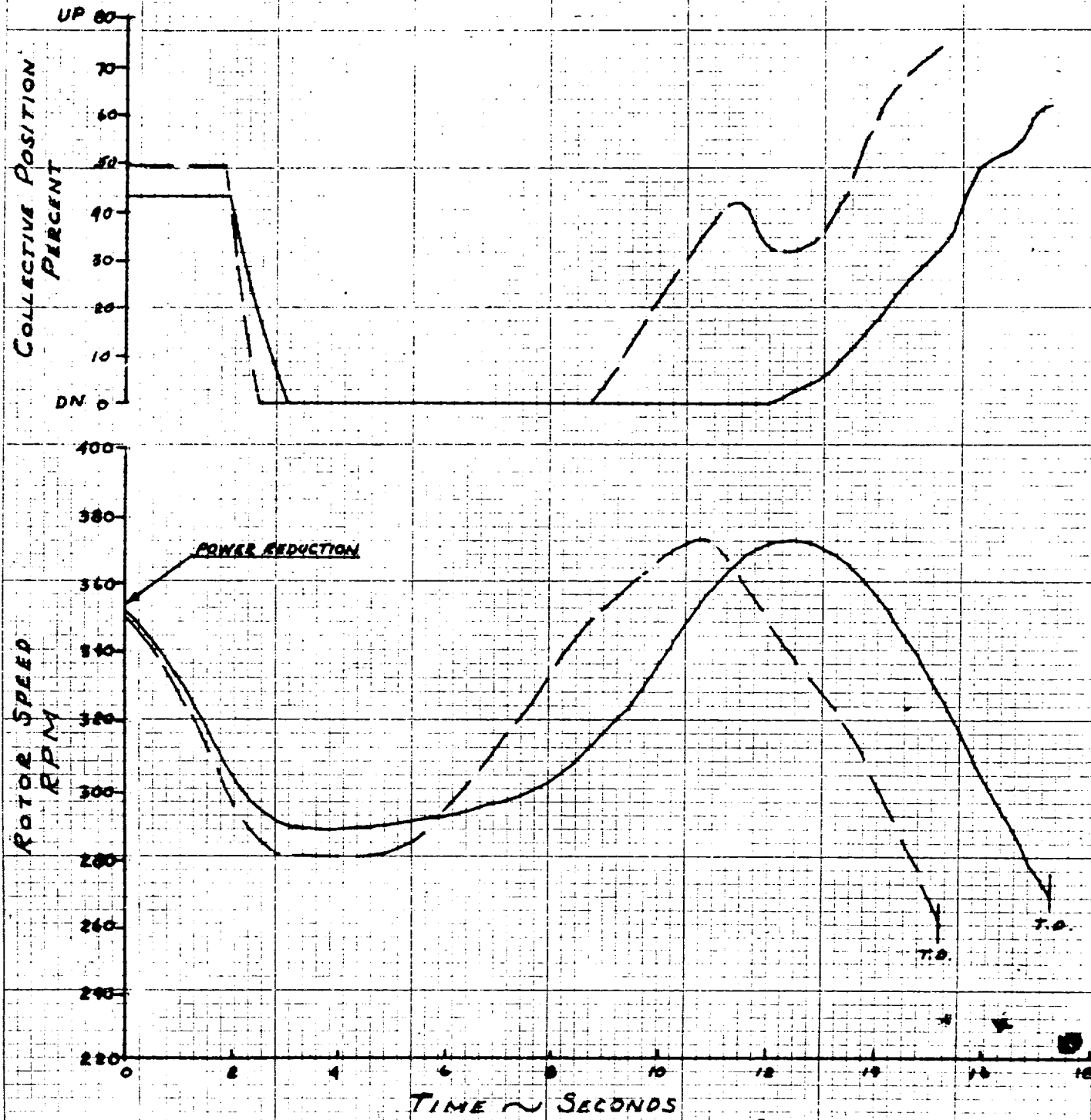


FIGURE 8
DENSITY ALTITUDE EFFECT ON ROTOR SPEED
OH-58A S/N 68-16706

SYMBOL	ENTRY AIRSPEED ~ KTS	ENTRY ALTITUDE (AGL) ~ FT	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FT	CENTER OF GRAVITY ~ IN	GR WT ~ LB
—	0	400	2455	1300	107.1	2560
- - -	0	404	2450	6100	107.0	2940
- - -	0	415	2455	10,760	107.0	3400

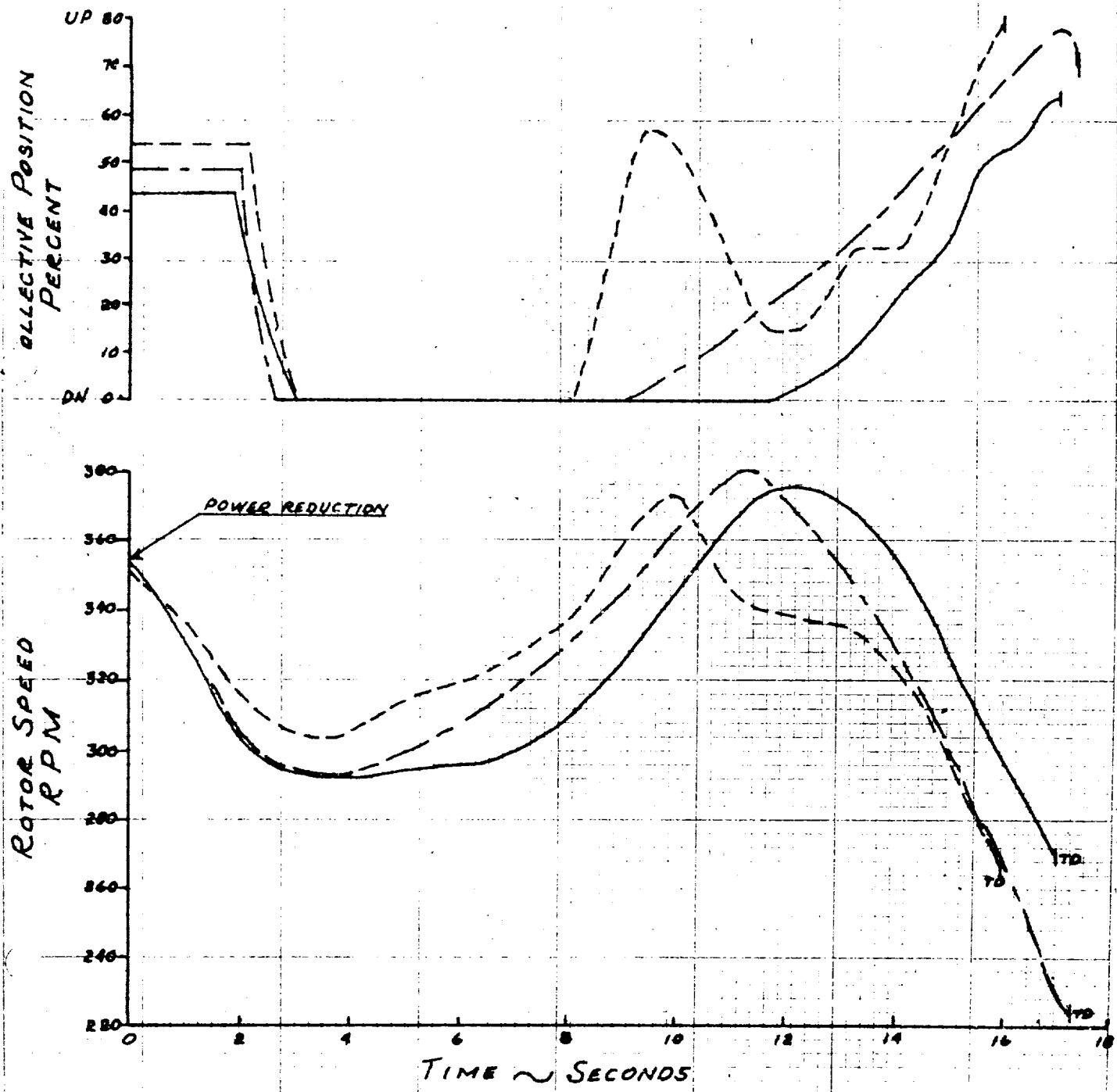


FIGURE 9
DENSITY ALTITUDE EFFECT ON RATE OF DESCENT
OH-58A **3/N 68-16706**

SYMBOL	ENTRY AIRSPEED ~ KTS	ENTRY ALTITUDE (AGL) ~ FT	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FT	CENTER OF GRAVITY ~ IN	GROSS WEIGHT ~ LB
—	0	400	2455	1300	107.1	5550
— — —	0	404	2450	6100	107.0	2940
- - - - -	0	415	2455	10,760	107.0	5400

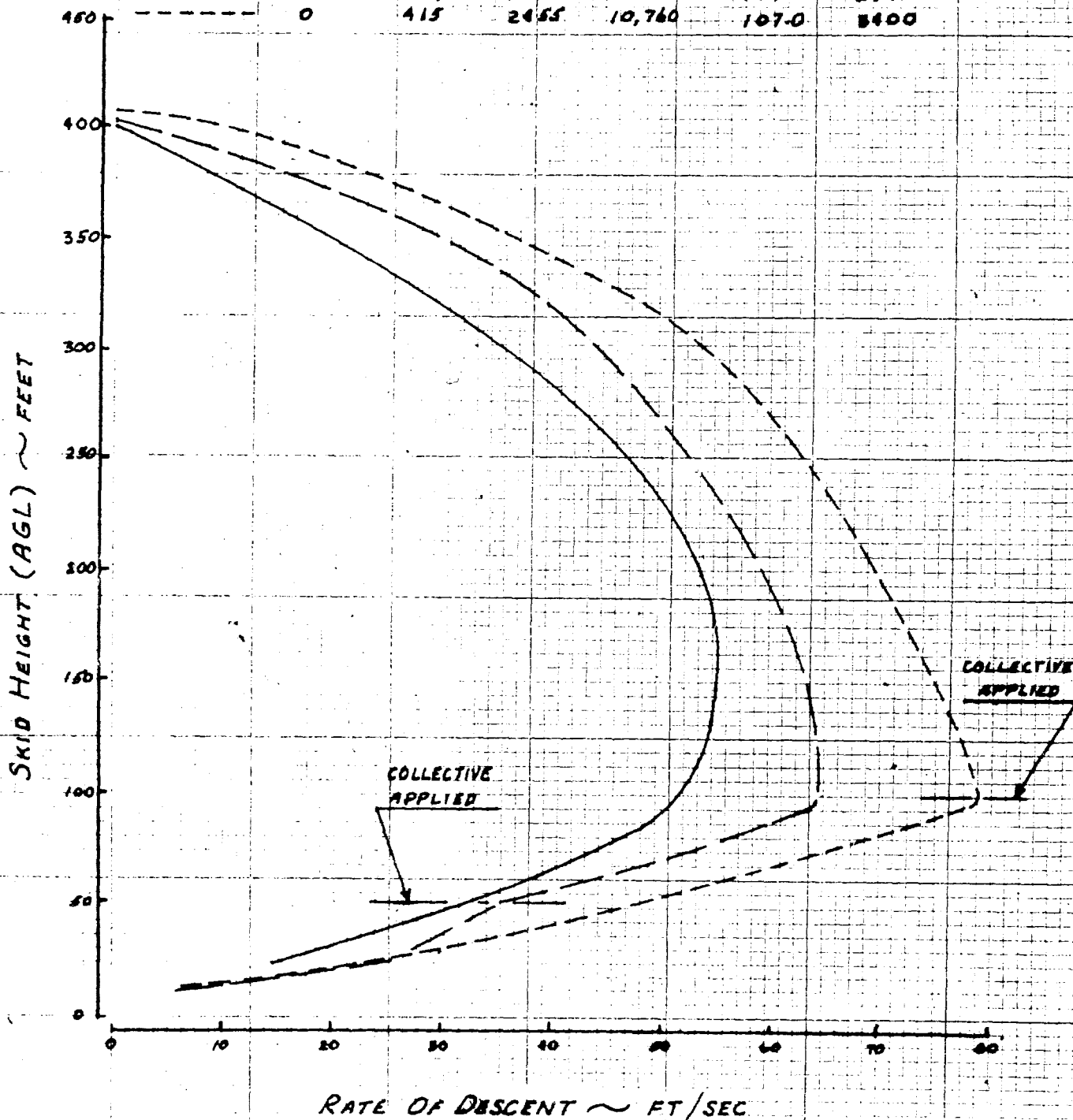


FIGURE 10
HEIGHT. VELOCITY PROFILES
VARIATION OF REFERED GROSS WEIGHT
OH-58A 3/168-16706

SYMBOL	GROSS WEIGHT ~ LB	DENSITY ALTITUDE ~ FT	CENTER OF GRAVITY ~ IN	GR WT ~ LB
○	2455	1300	107.0	2550
◻	2905	1360	106.6	3020
◻	2450	6100	107.0	2940
◊	2800	4790	107.0	3230
△	2455	10,760	107.0	3400

NOTE: A 2 SECOND DELAY FROM THROTTLE CHOP TO COLLECTIVE REDUCTION.

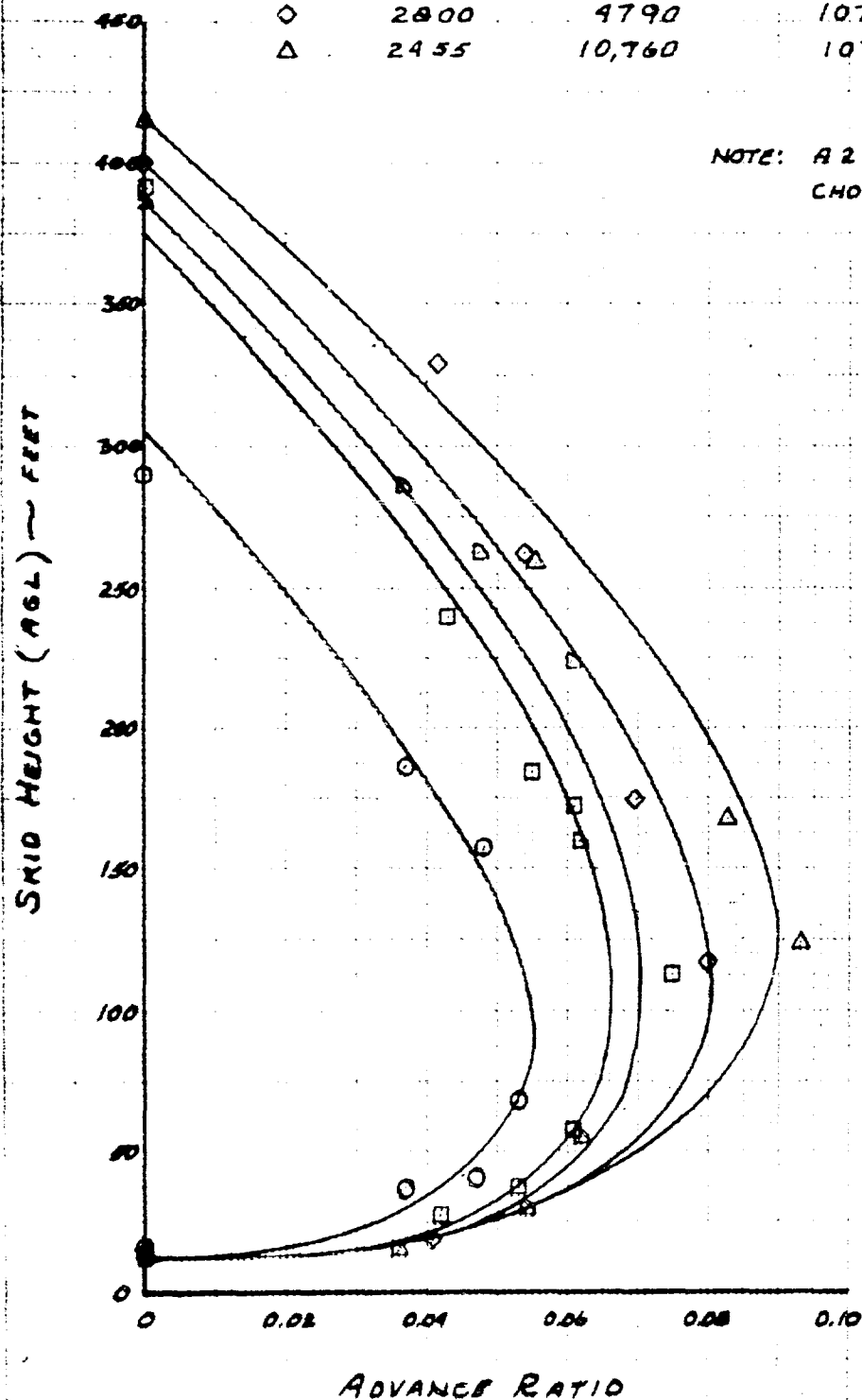


FIGURE 11
RECOMMENDED OPERATIONAL HEIGHT VELOCITY PROFILE
OH-58A SN 68-16706

NOTE: 1. BASED ON SIMULATION OF PITCH
ATTITUDES AND PITCH RATES
UTILIZED BY OPERATIONAL ARMY
AVIATORS.

2. A 2 SECOND DELAY FROM THROTTLE
CHOP TO COLLECTIVE REDUCTION.
3. 2450 LB — S.L. TO 10,750 FT HD
2800 LB — S.L. TO 6000 FT HD
2900 LB — S.L. HD

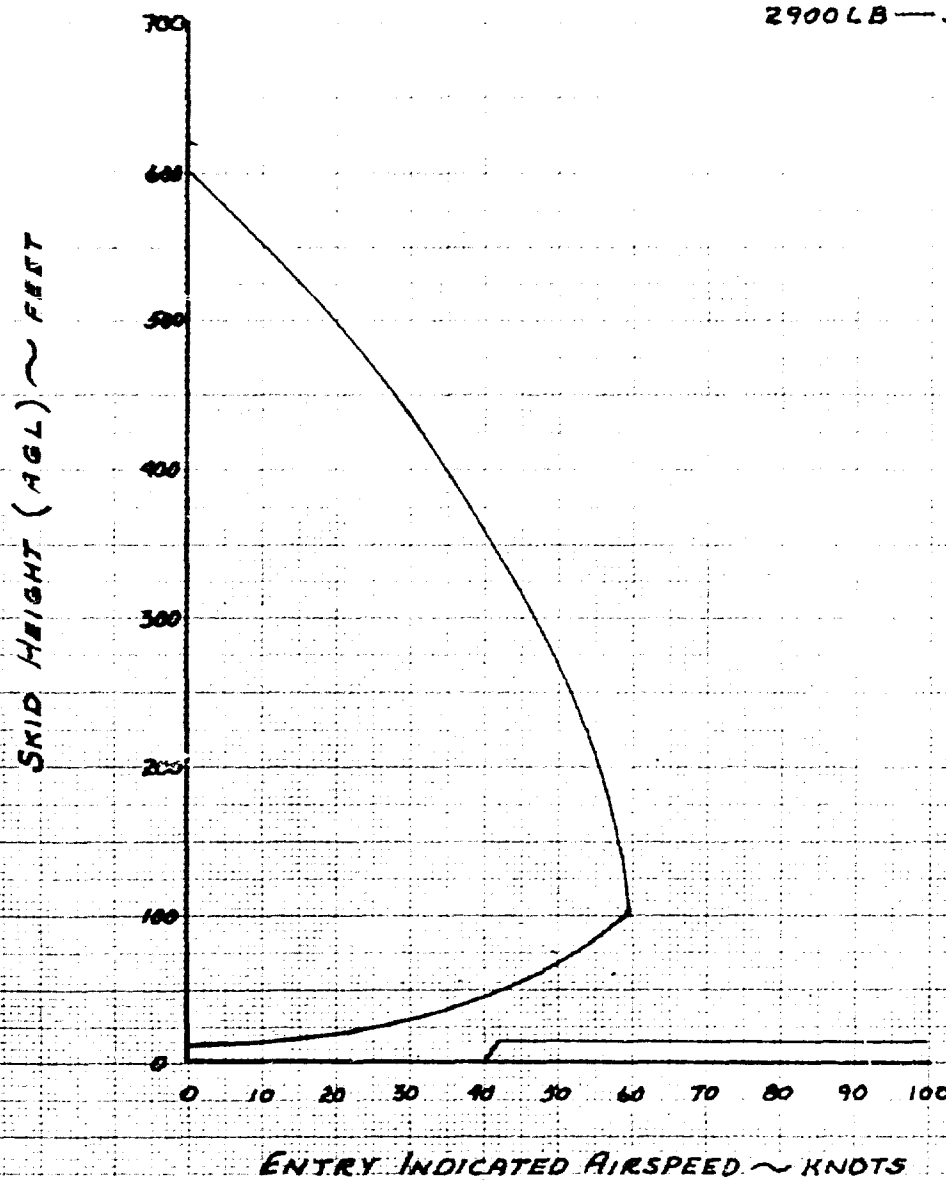


FIGURE 12
HEIGHT VELOCITY PROFILE
OPERATIONAL VS. MAX PERFORMANCE
OH-58A SIN 68-16706

NOTE: 1. PERFORMANCE DEGRADATION RESULTING
FROM PILOT TECHNIQUE.

2. 2450 LB — S.L. TO 10,750 FT HD

2800 LB — S.L. TO 6,000 FT HD

2900 LB — S.L. HD

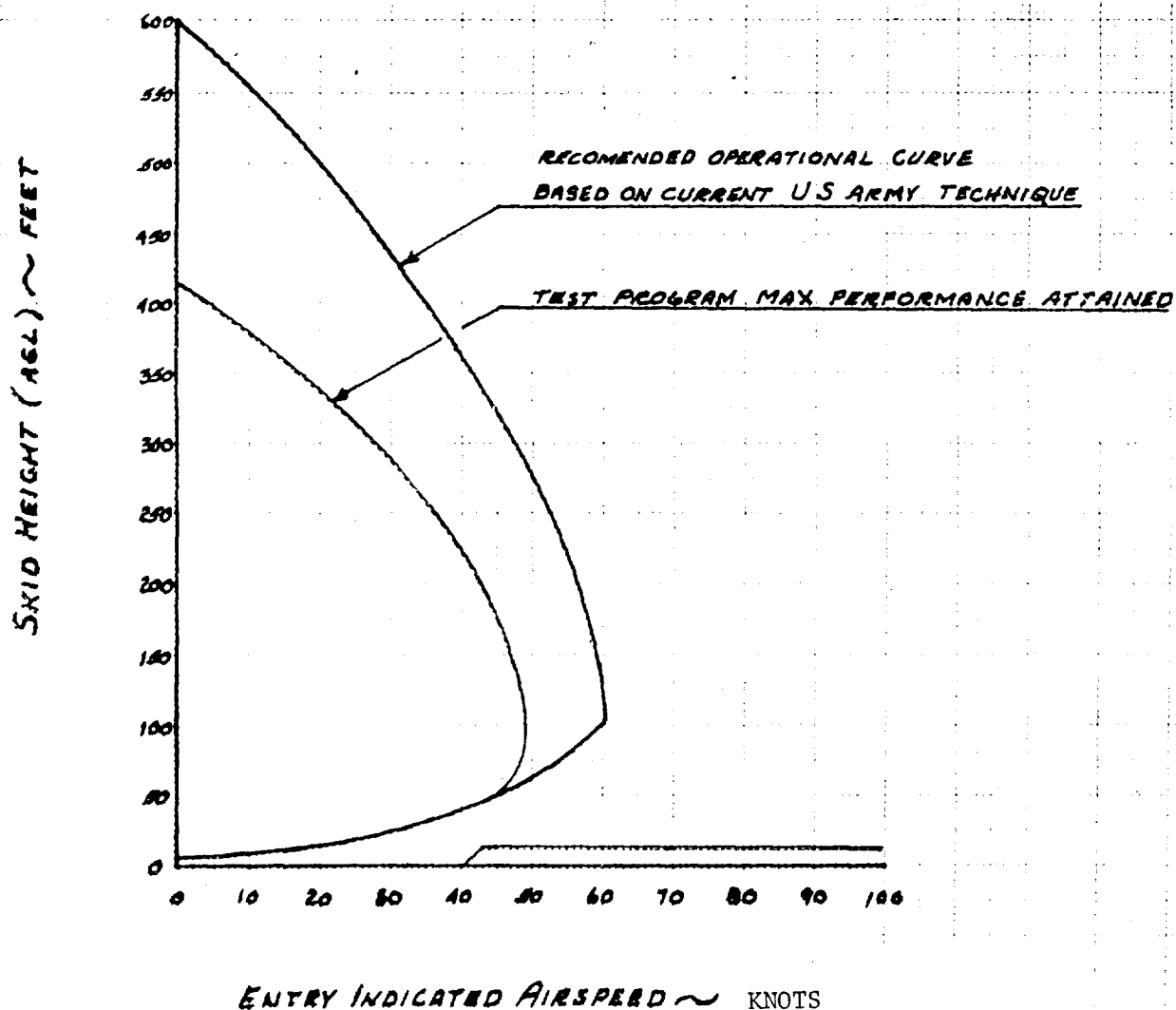
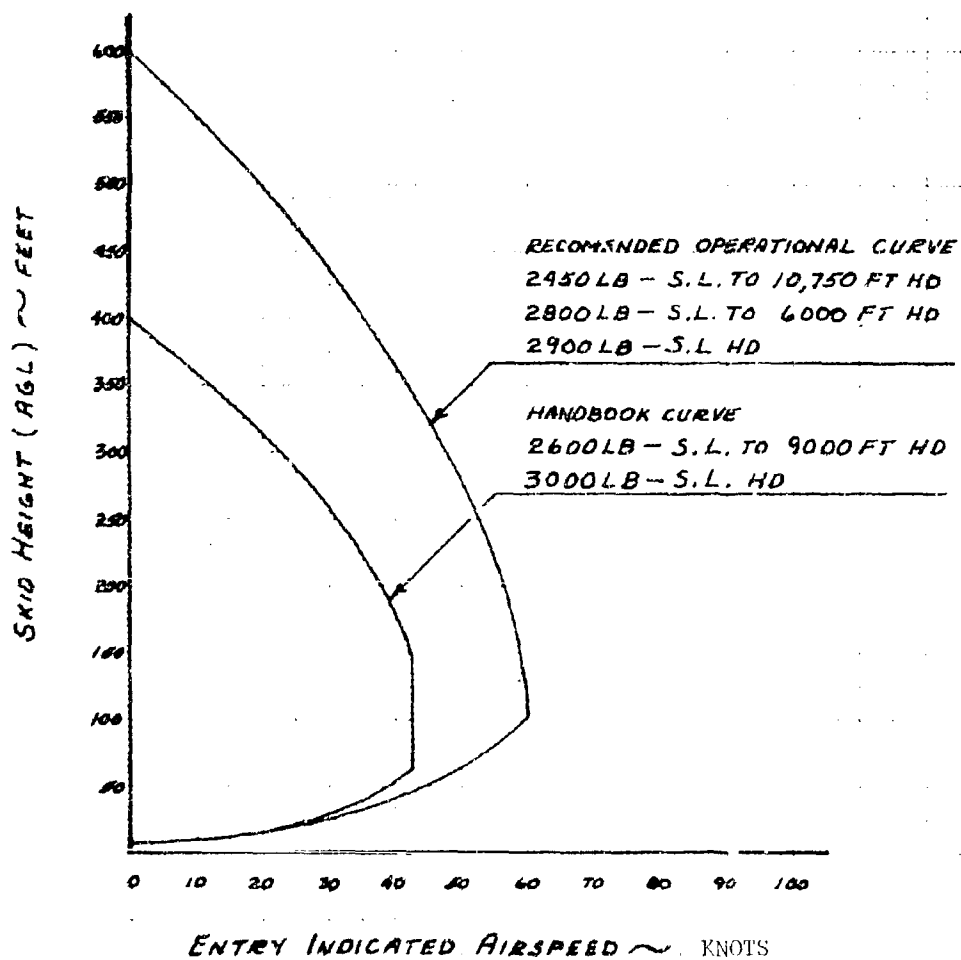


FIGURE 13
 CURRENT HANDBOOK CURVE VS
 RECOMMENDED OPERATIONAL CURVE
 OH-58A 4N 68-16706



APPENDIX VI. TEST INSTRUMENTATION

For data acquisition, sensitive flight test instrumentation was installed in the test aircraft prior to the initiation of H-V tests. This instrumentation was calibrated, installed, and maintained by USAASTA personnel. The following parameters were recorded on the equipment indicated:

<u>OSCILLOGRAPH</u>	<u>Calibration Range</u>	<u>Location</u>
Rotor blip	N/A	FS 106.0, BL 8.5, WL 89.0
Throttle position	Full close to full open	FS 145.0, BL 9.0, WL 72.0
Rotor rpm	170 to 415 rpm	FS 125.0, BL 0.0, WL 91.0
Torque pressure	Zero to 100 psi	FS 120.5, BL 10.0, WL 65.0
Angle of sideslip	±40 deg	FS -47.5, BL 0.0, WL 27.0
Angle of attack	-14 to +36 deg	FS -44.5, BL 0.0, WL 27.0
Collective position	Zero to 10 in.	FS 71.0, BL 7.5, WL 26.0
Pedal position	Zero to 10 in.	FS 71.0, BL 3.0, WL 65.0
Yaw attitude	±45 deg	FS 155.0, BL 10.5, WL 39.5
Yaw rate	±60 deg/sec	FS 146.0, BL 15.5, WL 37.5
Yaw angular acceleration	±100 deg/sec ²	FS 143.5, BL 0.0, WL 37.5
Lateral cyclic position	Zero to 10 in.	FS 71.0, BL 7.5, WL 26.0
Roll attitude	±45 deg	FS 146.0, BL 10.0, WL 38.5
Roll rate	±60 deg/sec	FS 142.5, BL 16.5, WL 37.5
Roll angular acceleration	±100 deg/sec ²	FS 147.0, BL 0.0, WL 41.5
Longitudinal cyclic position	Zero to 12 in.	FS 71.0, BL 7.5, WL 26.0
Pitch attitude	±45 deg	FS 146.0, BL 10.0, WL 33.5
Pitch rate	±50 deg/sec	FS 146.0, BL 17.5, WL 37.5
Pitch angular acceleration	-60 to 42 deg/sec ²	FS 152.0, BL 3.0, WL 41.5
CG normal acceleration	-0.5 to +2.0g's	FS 118.0, BL 0.0, WL 50.0
Skid touchdown switches (4)	on/off	Front and rear, both skids

PILOT AND ENGINEER PANEL

Boom airspeed (ship system)	Zero to 200 kt	FS -40.0, BL 0.0, WL 27.0
Boom attitude (ship system)	Zero to 11,000 ft	FS -40.0, BL 0.0, WL 27.0
Free air temperature	-20 to +50°C	FS 45.0, BL 0.0, WL 68.0
Rotor rpm	250 to 400 rpm	FS 125.0, BL 0.0, WL 91.0
Fuel used	Zero to 100 gal.	FS 158.0, BL 11.0, WL 82.0
Oscillograph number	N/A	N/A

FAIRCHILD FLIGHT ANALYZER

Vertical distance
Horizontal distance
Time

PHOTOTHEODOLITE RECORDER

Vertical distance
Horizontal distance
Time